Computer-based tools for supporting forest management. The experience and the expertise world-wide

by Borges, J.G.**,** Nordström E.M.,Garcia-Gonzalo, J., Hujala T.
and Trasobares, A. (Eds.)

Report of Cost Action FP 0804 Forest Management Decision Support Systems (FORSYS)

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Preface

Computer-based tools for supporting forest management. The experience and the expertise world-wide answers a call from both the research and the professional communities for a synthesis of current knowledge about the use of computerized tools in forest management planning. According to the aims of the Forest Management Decision Support Systems (FORSYS) (http://fp0804.emu.ee/) this synthesis is a critical success factor to develop a comprehensive quality reference for forest management decision support systems.

The emphasis of the book is on identifying and assessing the support provided by computerized tools to enhance forest management planning in real-world contexts. The book thus identifies the management planning problems that prevail world-wide to discuss the architecture and the components of the tools used to address them. Of importance is the report of architecture approaches, models and methods, knowledge management and participatory planning techniques used to address specific management planning problems. We think that this synthesis may provide effective support to research and outreach activities that focus on the development of forest management decision support systems. It may contribute further to support forest managers when defining the requirements for a tool that best meets their needs.

The first chapter of the book provides an introduction to the use of decision support systems in the forest sector and lays out the FORSYS framework for reporting the experience and expertise acquired in each country. Emphasis is on the FORSYS ontology to facilitate the sharing of experiences needed to characterize and evaluate the use of computerized tools when addressing forest management planning problems. The twenty six country reports share a structure designed to underline a problem-centric focus. Specifically, they all start with the identification of the management planning problems that are prevalent in the country and they move on to the characterization and assessment of the computerized tools used to address them.

The reports were led by researchers with background and expertise in areas that range from ecological modeling to forest modeling, management planning and information and communication technology development. They benefited from the input provided by forest practitioners and by organizations that are responsible for developing and implementing forest management plans. A conclusions chapter highlights the success of bringing together such a wide range of disciplines and perspectives.

This book benefited from voluntary contributions by 94 authors and from the involvement of several forest stakeholders from twenty six countries in Europe, North and South America, Africa and Asia over a three-year period. We, the chair of FORSYS and the editorial committee of the publication, acknowledge and thank for the valuable contributions from all authors, editors, stakeholders and FORSYS actors involved in this project.

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Contents

1 Computerized decision support tools to address forest management planning problems: history and approach for assessing the state of art world-wide

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1.1 Introduction

1.1.1 Why decision support tools in forestry?

At the Association of European Operational Research Societies conference in Helsinki in 1992, Andrés Weintraub, Professor at the University of Chile, concluded that operations research methods had already been successfully applied in forestry. Indeed, simulation and optimization algorithms have been included in software to guide forest managers since the 1960s, and now at least 100 computerized decision support systems (DSS), with various levels of sophistication, have been developed and are being widely used in numerous countries. There are several reasons for the popularity and abundance of these systems. Most importantly, forest management is highly complex. Forestry has multiple social, ecological and economic aspects, since forests not only produce timber but also provide a wide range of other products and services. As physical and social conditions vary enormously around the world it is hardly surprising that diverse systems have been designed and adapted to address forest management problems associated with varying local management systems and socio-ecological conditions. Furthermore, forest managers' decisions can affect large geographical areas for a long time. Actions today determine the decision space for decades to come, and treatments in one part of a forest may affect what is done in other parts, now or in the future. Thus, they must be carefully implemented after considering numerous factors simultaneously; a task that is greatly facilitated by an appropriate DSS.

In addition, forest management is becoming more complex, partly because of increasing awareness of the need for sustainability (Hahn and Knoke 2010), hence the needs for advanced forest DSS are also likely to increase. Sustainability was initially linked solely to timber production, in what was often termed "sustained yield forestry". However, in the 1960s increased attention was directed towards the multiple services supplied by forests, hence "multiple use forestry" strategies emerged. However, the development and implementation of the strategies were regarded as matters for experts. Consequently, use of the DSS developed at the time required high expertise, until awareness arose of the need for participation by local communities and other stakeholders. Since the Rio World Summit in 1992, participatory decision-making has been seen as a key element for the sustainable use of resources, now generally termed Sustainable Forest Management (SFM). Parallel to environmental legislation and increased public involvement in decisions concerning the use of forest resources, the work of forest experts and the expectations towards their work have become more complex and diverse (Tipple and Wellman 1991; Tindall et al. 2010). The involvement of stakeholders in the process has thus profound influence on forest DSS development and use. There can be little doubt that forest policy makers and managers will increasingly rely on DSS to balance the diverse and increasing demands placed on forest ecosystems – *inter alia* delivering renewable raw materials, sustaining biodiversity,

promoting human health, protecting drinking water resources, and providing buffers to resist natural hazards – while at the same time addressing climate change uncertainty.
The purpose of this publication is to describe, as comprehensively as possible (given space and time limitations), modern DSS used in forestry, and the kind of management problems they are intended to address. To this end there are chapters from 18 European countries and 8 countries in North America, Asia and Africa, each analyzing the problems associated with forestry and the DSS used in attempts to tackle them. Even though the main focus of the publication is "full" DSS, other computerized tools are also considered due to the lack of DSS for all the prominent planning problems. A concluding chapter summarizes the relation between management problems and available DSS, indicating areas that are well covered and problems that warrant further attention in DSS development.

This introductory chapter will continue by describing what is meant by a DSS. The concept could be, and has been, used to refer to almost anything that could aid decision-makers, but here it is used more restrictively, within the framework of its use in literature associated with forest DSS. Finally, the way that the work on the individual country reports was conducted is presented, including the definition of the dimensions defining the forest management problem types.

1.1.2 What is a DSS?

In a computer science context, a DSS is often defined as a model-based software system that contains four components: (i) a language system (LS) that enables users to communicate with and use the DSS (ii) a presentation system (PS) for displaying its outputs (iii) a knowledge system (KS) for storing all the input information and (iv) a problem processing system (PPS) (Burstein and Holsapple 2008). Users of the system can be decision-makers, developers or anyone that adds to or taps the knowledge system (or data models). The relationship between them is illustrated in Figure 1.

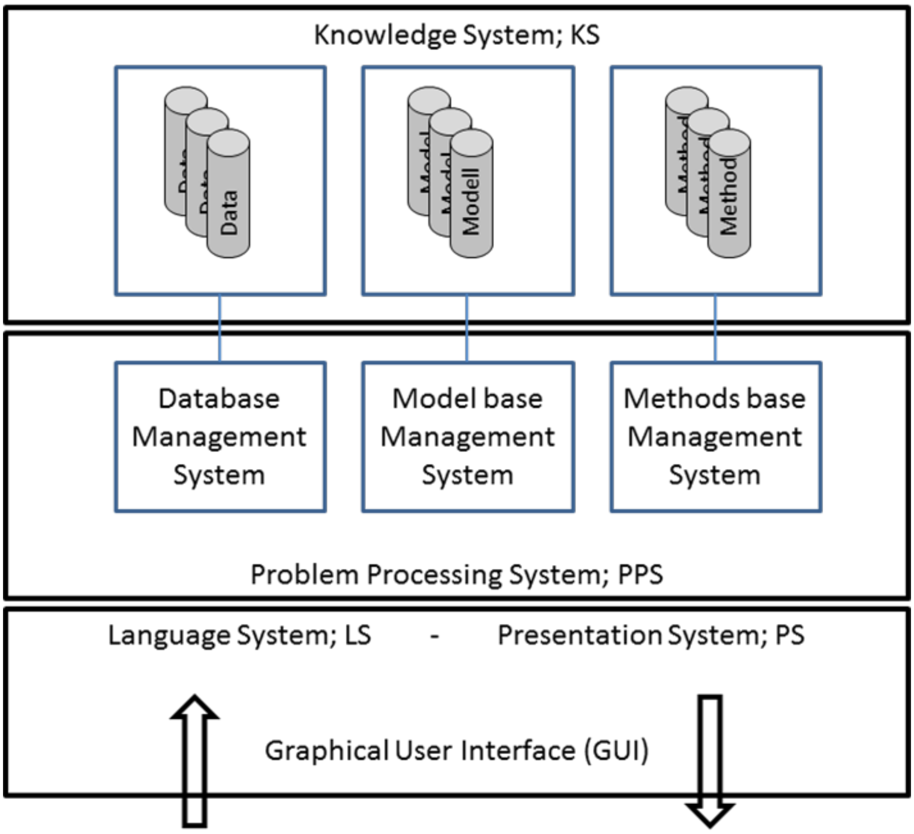

Figure 1. Schematic diagram of the main components of a DSS.

Three of the main components (the LS, PS and KS) are representative systems: the "communicative" system (LS) consists of all messages to the DSS from the user; the presentation system (PS) consists of all messages from the DSS to the user; and the knowledge system (KS) consists of all knowledge that is collected in the form of data or models held in the DSS. The knowledge system is sub-divided into three components here: one that holds data (e.g. data on the forest concerned); one that holds models (e.g. models for predicting growth and yield); and one that holds methods (e.g. for calculating key statistics or a solver for optimizing a problem). The integrative part of the DSS is the problem processing system (PPS). The task of the PPS is, simply, to solve the problems the user has specified. In doing so the PPS must receive information coming from the LS, integrate the data, models and methods, and communicate the result to the PS.

1.2 Reviews of methods and tools

Abundant literature describes components of the KS, and these are of course the subjects of specialized publications devoted to data, models and methods, respectively (some of which specifically consider forest DSS). Notably, the (rapidly evolving) remote sensing field, with special relevance for obtaining detailed forest data, has been presented by Packalén et al. (2008), while methods for assessing landscape attributes have been reviewed by Kätsch (2008). Various categorizations and descriptions of forest growth and yield models have been presented. Gratzer et al. (2004) focus on models describing the spatio-temporal development of forests, whereas Peng and Wen (2006) and Pretzsch et al. (2008) employ a more general classification scheme. Pretzsch et al. (2008) also provide a few examples of computer applications. Fontes et al. (2010) discuss empirical, process-based and hybrid growth and yield models and assess 25 computer programs with process-based models in use in Europe. Some of the software presented by Pretzsch et al. (2008) and Fontes et al. (2010) qualify as DSS in the sense of the term used here, although the focus is on software that integrate various kinds of knowledge components.

Classical (exact) optimization methods (linear programming, dynamic programming etc.) with reference to their use in DSS have been reviewed by Garcia (1990). Heuristic (probability-based) methods came to the fore in the 1990s, particularly as attempts to address spatial problems became prevalent. Sessions et al. (2007) provide a short introduction of heuristic methods related to different planning problems. Bettinger and Kim (2008) review heuristic approaches for spatial (endogenous) optimization. Baskent and Keles (2005) and Hof and Haight (2007) review applications of both exact and heuristic methods for optimizing spatial problems. Another class of methods is represented by those that handle multiple criteria. Mendoza and Martins (2006), Diaz-Balteiro and Romero (2007), Diaz-Balteiro and Romero (2008), and Ananda and Herath (2009) review methods for multiple criteria decision analysis (MCDA) and studies involving such methods. Martins and Borges (2007) review methods that address collaborative planning and they discuss tools for integrating participatory planning.

Several reviews of forest DSS were presented in the 2000s. For example, seven were presented in Issue 1 (Volume 49) of Computers and Electronics in Agriculture (2005), and four were reviewed by Reynolds and Schmoldt (2006). The most comprehensive analysis of forest DSS to date has been provided by Johnson et al. (2007), who characterized 32 systems according to the decision-making factors they consider (biodiversity indicators supported, forest disturbances, silviculture etc.) and includes 15 in-depth studies of successes and failures of DSS applications. Johnson et al. (2007) also cite reviews of DSS capabilities to assist with National Forest plans (Schuster et al. 1993), ecosystem management (Mowrer 1997, Rauscher 1999), biodiversity in county-level planning (Johnson and Lachman 2001). Reynolds et al. (2008) review 10 systems.

Several general conclusions can be drawn from the literature of forest DSS development and use. Firstly, they are likely to become increasingly important as they can furnish tailored forest management solutions; standardized silviculture is not desirable as it reduces diversity and cannot be adapted to meet changing needs as policies evolve (Gadow et al. 2008). Adaptive management of multi-purpose forestry not only requires sophisticated systems for large-scale analyses but also capabilities for iterative on-demand, on-site and ad hoc analyses together with stakeholders. Secondly, social aspects are increasing in importance (Johnson, Gordon et al. 2007; Reynolds et al. 2008), encouraging the application of MCDA, group decision-making, participation and more internet-based applications (Reynolds and Schmoldt 2006). Thirdly, it is anticipated that there will be increasing needs for sophisticated DSS capable of meeting demands for systematic and transparent analysis associated with increases in both social complexity (increases in numbers of players, and both the intricacy and contentiousness of their relationships) and informational complexity (the degree to which available data and relationships must be structured and organized) (Johnson et al. 2007). Fourthly, as a response to these needs there also appears to be a trend towards more comprehensive, general-purpose systems supplanting more single-purpose systems (Rauscher et al. 2005; Reynolds et al. 2008). Fifthly, as a consequence of the increased scope of the systems it is suggested that it might be more appropriate for them to host modular programs capable of running either separately or interactively, rather than a single, massive integrated application (Reynolds and Schmoldt 2006). This line of development points out the significance of model and algorithm libraries and transferable metadata, which raises the future requirements of knowledge management within forestry DSS to a new, “intercontextual” and “intersystemic” level. Sixthly, despite the increasing complexity of the systems, they must be adapted to the needs and competences of their target users and be transparent in order to avoid the “Black box” syndrome (Johnson et al. 2007; Reynolds et al. 2008). Hence, adaptive design cycles, in which systems are used, tested and adjusted in successive iterations (Rauscher et al. 2005), may be valuable.

1.3 Forest problem dimensions

As outlined above, substantial experience has been gained in the development and use of forest DSS, and various facets of currently available systems have been widely reviewed. However, some aspects that have not been thoroughly addressed previously are considered in more detail here. Most importantly, as also mentioned above, the forest DSS are not so much in focus as the capacities of DSS in relation to the problems they are intended to resolve. The country reports begin with descriptions of forest management problems and then link existing DSS to the problems, thereby indicating applications for which forest DSS appear to be useful, gaps in DSS capabilities, and potential areas of know-how transfers. Hopefully, this approach should facilitate better understanding of the properties of DSS, their strengths and their shortcomings. Further, the scope of forest DSS that are covered in the literature cited above is rather limited or biased. Apart from the analysis by Johnson et al. (2007), only 19 unique systems have been considered, and even Johnson et al. (2007) only consider systems applied in North America. Taking that into account and considering that the website of the FORSYS project alone hosts about 60 systems (http://fp0804.emu.ee/wiki/index.php/Main_Page), mostly of European origin, extensive fields of DSS application remain to be described and analyzed.

Due to the diverse backgrounds of the participants of this project it was imperative to establish a common nomenclature for characterizing the problem dimensions. After a lengthy process the definitions in Table 1 were laid down (here slightly edited). There are of course innumerable ways of characterizing a planning problem. The general principles applied here were that the dimensions should be: (i) comprehensive, i.e. cover all planning situations of interest (ii) comprehensible, i.e. fairly easy to identify, using terms that are reasonably well established in the literature for describing planning situations (iii) able to relate to some characterization of DSS and (iv) easy to compare among regions and forest owner categories. The last two of these principles warrant further comment. Regarding principle (iii), an assessment of the extent to which a certain dimension actually could meaningfully be related to existing DSS was made. The literature in the area also gave guidance. An implication of principle (iv) was that the dimensions considered would be rather abstract and not content-specific (e.g. not defined in terms of the managed species or in terms of a specific objective like avoiding wind-throw and avalanches or promoting aesthetic values). A further motivation for applying this level of abstraction is also the potential flexibility of DSS, e.g. from the perspective of a particular DSS the ability to deal with neighbourhood relationships may be the critical issue, whereas it masters the analysis of risks of fire, wind-throw and avalanche just as well.

Temporal scale: The division of the planning process into a hierarchy consisting of what are often called strategic, tactical and operational planning levels is well established in most forestry communities. However, the term “strategic” (in particular) may have other connotations than those intended here (Cea and Jofre 2000; Hoogstra and Schanz 2008). Therefore, the more neutral time terms long, medium, and short are used. The use of time scales, rather than the strategic, tactical and operational trio could also facilitate the classification of planning problems for smaller private forest owners since the trio has developed in corporate settings. To the extent that the terms strategic, tactical and operational are used in the book, they have the same meaning as long-term, medium- and short-term planning. Still, you will find the terms strategic, tactical and operational in the definitions applied here agree well with those provided by, for instance, Gunn (2007), Church (2007) and Epstein (2007), respectively.

Spatial context: As is evident from the studies cited above, spatial aspects are frequently addressed in forest planning. Spatial phenomena can be characterized in diverse ways regarding the distribution of the objects concerned, their shape, connectivity, and their geometry (e.g. line or polygon). The decision here was to have as few categories as possible (three). One indicates that location is unimportant. A typical problem of this type is the standard harvest scheduling problem (see e.g. Ware and Clutter (1971) for an early example). The other two categories indicate spatial significance: one indicating that neighbouring stands are in some way affected by actions in another stand, and the other indicating no such connection, i.e. when considering actions in a given stand there is no need to know what is done in neighbouring stands. Examples of the former type of problem relate for instance to wind-throw problems, where actions in one stand affect the risk of wind-throw in neighbouring stands (Meilby et al. 2001; Forsell et al. 2011). An example of the latter type of problem is the typical zoning problem, where constraints are set for stand treatments within zones or for the zones *per se* but where actions in one stand do not affect the behaviour of other stands (Nalli et al. 1996; Nordstrom et al. 2011) .

It should be noted that these distinctions are different from those applied in the Spatial Decision Support Knowledge Portal (SDS; www.spatial.redlands.edu/sds/), where the categories None, Neighbourhood and Global are used. Global refers to general landscape structures, e.g., numbers of patches, patch size distributions or ecological networks, whereas Neighbourhood is characterized by local interaction. This means that our category Spatial with no neighborhood interrelations falls under None according to SDS. Furthermore, it is a matter of interpretation whether our category Spatial with neighbourhood interrelations covers either the Global and Neighbourhood SDS categories, or only Neighbourhood. There is a certain degree of vagueness in our term neighbourhood that one should be aware of when considering the results.

Spatial scale: The implicit focus of the entire project is on forest management and support tools that help decision-makers in that endeavour. The scope of the FORSYS COST Action has been formulated as dealing with any “…forest management planning problem /that/ involves the definition of the timing and location of forest management options in a unit of forest land over a planning horizon, in order to approximate or optimize management objectives…”. From that perspective, the forest level is of primary interest. However, for some forest owners, the forest decomposes into a few stands, or problems are approached on a stand-by-stand basis. In some countries, due to the ownership structure, the stand level may be very important compared to forest-level planning. In order to describe this kind of management problem the stand level must also be represented. More problematic is the regional/national level. The objective of this publication is not to cover problems and systems pertaining to the sphere of forest policy. However, in some countries forest policy is virtually synonymous with forest management. We would thus ignore some interesting cases if this level was excluded.

Decision-making dimension: As described above, SFM refers to forestry undertaken with considerations of its effects on different stakeholders and future generations. Thus, there are generally numerous participants, but their level of participation may vary substantially, and SFM can be exercised even if there is essentially only one active decision-maker, provided his/her decisions are governed by appropriate certification schemes, laws and regulations. It is not unanimously defined when a single-decision-maker planning problem actually becomes a multiple-decision-makers problem; is it sufficient to acquire information from stakeholders or does it require collegial group decision-making? In this book, two categories of decision-making were applied: One or more decision-makers (for all classes of multiple-stakeholder forestry, including SFM) and Single-owner (for cases where a single owner makes decisions largely autonomously, although it should be noted that the decisions of even single owners may be heavily constrained by regulations). Indeed, an interesting aspect of the association between problems and DSS is, of course, to what extent the DSS are adapted to multi-stakeholder situations.

Objectives dimension: The most common objective cited in the forest economics literature is to maximize the net present value of the forest, as generally operationalized by the Faustmann formula. For some owners of small forest holdings this could be a valid, single objective. However, for larger forest holdings, or holdings in more complex social settings, different kinds of values must be balanced. In this book, such situations are classified as multi-objective problems. One could also note that multiple objectives could also refer to different aspects of one item, such as the financial value and harvest profile over time of timber production (Hallefjord et al. 1986). In the DSS this might technically be handled as a single objective problem, for instance by expressing all goods and services in one commensurate kind.

Goods and services dimension: The goods and services, market and non-market categories are of interest from several viewpoints; notably they indicate the kind of forestry being pursued, its purposes, and the consequent requirements for any DSS used. If the primary target is to secure fresh water a different DSS will probably be required (or different modules of the same DSS) than if the main goal is to optimize timber production in plantation forestry. The Goods and services dimension may or may not have implications for the Objectives dimension as discussed above.

One aspect that is not found in Table 1 is that of risk and uncertainty. It was excluded as a problem-defining dimension because, basically, no problems in forestry are completely free of uncertainty. Thus, attempting to categorize uncertainty would involve rather subjective assessments of the degrees of uncertainty regarding future developments in pertinent variables.

Table 1. Definition of problem dimensions

Temporal scale

- **Long-term (strategic) management planning.** Planning horizon extending over more than 10 years.
- **Medium-term (tactical) management planning.** Planning horizon extending from two to 10 years.
- **Short-term (operational) management planning.** Planning horizon extending over one year or less, typically including planning periods of one month or less.

Spatial context

- **Spatial with neighbourhood interrelations.** The interactions of decisions made for neighbouring stands (or other areal units) are of importance, i.e. a decision made for one stand may i) constrain decisions for neighbouring stands or ii) influence the outcome of decisions made for neighbouring stands.
- **Spatial with no neighbourhood interrelations.** Locations of forest operations are of importance, but it is assumed that a decision made for one stand does not constrain decisions for neighbouring stands or influence the outcome of decisions made for neighbouring stands.
- **Non-spatial.** Stands may be aggregated into strata or analysis units without considering their mutual locations. There is no concern with locational specificity or neighbourhood interrelations.

Spatial scale

- **Stand level**. Focused on units with homogeneous ecological, physiographic and development features.
- **Forest level.** Focused on forest landscapes with several stands managed for (a) common purpose(s).
- **Regional/national level.** Focused on sets of landscapes that may all be managed for different objectives.

Decision-making dimension

- **A single decision-maker** makes the decision on his/her own, e.g. the forest owner.
- **One or more decision-makers** have the power to decide. In addition, there can be other parties (stakeholders) with no formal decision-making power that are influenced or may influence the decision.

Objectives dimension

- **Single**. The management planning problem addresses one and **only** one objective.
- **Multiple**. The management planning problem addresses two or more objectives, any pairs of which could be conflicting, complementary or neutral with respect to **each other**.

Goods and services dimension

- **Market wood products.** The management planning problem addresses the supply of wood products that are traded in the market (roundwood, pulpwood, biomass…)
- **Market non-wood products.** The management planning problem addresses the supply of non-wood products that are traded in the market (fruits, cork…)
- **Market services.** The management planning problem addresses the supply of services that may be traded in the market (recreation, hunting, fishing…)
- **Non-market services.** The management planning problem addresses the supply of services that are typically not traded in the market (public goods, aesthetic values, water, biodiversity…)

1.4 Data for the country report chapters

The sources for the country reports vary considerably between countries (Table 2). Almost all country reports are based on consultations with developers and users (China, Germany, Russia, and USA are exceptions). To some extent this reflects the size of the country; to cover, for instance, China or USA requires methods other than for Switzerland. However, this does not necessarily mean that such contacts have not been made, only that they have not been explicitly stated in the report. In almost all cases authors refer to their own experience (and for the exceptions – Greece, Ireland, Italy, Morocco, the Netherlands and South Africa – this does not exclude such experience, only that it is not explicitly stated). In a few cases, special questionnaires have been prepared for the reports, notably in Brazil, Germany, and Portugal. Additionally, a few countries (Austria, Russia and South Africa) have referred to questionnaires without stating their exact numbers. It could be noted that sometimes it is difficult to draw a clear line between consultations and questionnaires (Denmark is such an example). All reports contain references to various documents. The account in Table 2 is not necessarily complete; where not already stated, one could for most countries add "other written material".

Table 2. Data sources used for the country report chapters.

Country	Consultation with developers [a)]	Consulta-tion with users [a) b)]	Questio-nnaire [c)]	Documents [d)]
Austria	x (a)	x (a)	x (various organizations)	x (wiki, reports, journals)
Brazil	x (a)	x (a)	x (22)	x (technical and scientific references)
Canada	x (a)	x (a)		x (internet sources, reports, journals)
Chile	x (a)	x (a)		x (articles, websites)
China				x (laws and regulations, reports)
Denmark		x (interviews)		x (Danish and international journals)
Estonia	x (a)	x (a)		x (laws, regulations, technical documents)
Finland	x (a)	x (a)		x (scientific papers, plan documents, wiki)

Country	Consultation with developers [a]	Consulta-tion with users [a) b)]	Questio-nnaire [c]	Documents [d]
Germany			x (36)	x (scientific papers, reports)
Great Britain	x (a)	x (a)		x (scientific papers, reports)
Greece	x			x (scientific papers, reports, proceedings)
Hungary	x (a)	x (a)		x (legal cases, other written material)
Ireland	x	x		x (scientific papers, reports, conference proceedings)
Italy	x	x		x (articles, reports, dissertations)
Morocco	x			x (user guides, test cases, other written material)
Netherlands		x (5)		x (reports, articles, plans)
Norway	x (a)	x (a)		x (scientific papers, internet)
Portugal	x (a)	x (a)	x (24)	x (peer and non-peer reviewed publications)
Russia			x (various organizatio ns)	x (scientific and technical publications, internet, laws and regulations)
Slovenia	x (a)	x (a)		x (articles, reports)
South Africa		x	x (to users)	x (STSM, other written material)
Spain	x (a)	x (a)		X (text books, forest plans, manuals, web pages, other written material)
Sweden	x (a)	x (a)		x (scientific papers, reports)
Switzerland	x (a)	x (a)		x (articles, proceedings, reports)
Turkey	x (a)	x (a)		x (articles, reports)
USA				x (literature, internet, past surveys)

[a)] x = consultation is stated; (a) = includes also authors as developers or users.
[b)] Number in brackets designates number of contact, if given.
[c)] Specifically prepared for this book, otherwise referred to Documents. Number in brackets designates number of responses, if given.
[d)] wiki refers to the FORSYS wiki on forest DSS (http://fp0804.emu.ee/wiki/index.php/Main_Page); STSM refers to short term scientific missions conducted within FORSYS.

It is to be expected that the quality of the database for the reports varies between countries. Some countries have used peer reviewed journals for decades to document experiences whereas others, for different reasons, have had limited access to international publication. Some of the material consists of reports that, if it was not for the insights of the authors, would otherwise be difficult to access. The very broad as well as deep exposition of problems and tools presented here relies ultimately on the unique group of experts that is gathered around this publication.

1.5 The publication process

The work was initiated in early 2010. A publication with country reports was identified as a powerful tool for transferring know-how between the countries involved in the FORSYS COST Action. Material on the appropriate format was circulated, and during the steering group meeting in April 2010 it was decided to issue country report templates, together with explanations and instructions. At the same meeting a special task committee (STC) consisting of Antoni Trasobares (Spain), Jordi Garcia-Gonzalo (Portugal), Teppo Hujala (Finland) and Eva-Maria Nordström (Sweden), was established with Jose Borges (Portugal) as Coordinator. One of the first actions of the STC was to disseminate a form to guide presentations of preliminary country reports at the next meeting in November in Brussels 2010. During that meeting about 20 short presentations on problems and DSS were delivered and final revisions were made to the templates and instructions. From that point on, the work followed the set procedures. The STC was heavily involved in the work from the beginning. The members distributed responsibility for maintaining close contact with representatives of the participating countries among themselves to ensure there were well-defined channels of communication with the authors of each report. The STC reviewed the country reports and compiled feedback for authors twice, during two-day meetings in spring and autumn 2011. Most country reports underwent several rounds of revision to ensure that they all followed the same format.

This volume rests on the contribution of more than 100 authors and the dedicated work of the STC. It is without doubt the most comprehensive account of forest planning problems and forest DSS ever published.

References

Ananda, J. and G. Herath (2009). A critical review of multi-criteria decision making methods with special reference to forest management and planning. Ecological Economics **68**(10): 2535-2548.

Baskent, E. Z. and S. Keles (2005). Spatial forest planning: A review. Ecological Modelling **188**(2-4): 145-173.

Bettinger, P. and Y.-H. Kim (2008). Spatial Optimisation – Computational Methods. In: K. v. Gadow, Pukkala, T. (eds). Designing Green Landscapes. Dordrecht, Springer. **15:** 111-135.

Burstein, F. and C. W. Holsapple (2008). Handbook on decision support systems 1. Berlin ; London, Springer.

Cea, C. and A. Jofre (2000). Linking strategic and tactical forestry planning decisions. Annals of Operations Research **95**: 131-158.

Church, R. (2007). Tactical-level forest management models. In: Handbook of Operations Research in Natural Resources : International Series in Operations Research & Management Science.

Diaz-Balteiro, L. and C. Romero (2007). Multiple Criteria Decision-Making in Forest Planning: Recent Results and Current Challenges. In: C. R. A. Weintraub, T. Bjørndal, R. Epstein (eds) Handbook of Operations Research in Natural Resources. New York, Springer**:** 472-488.

Diaz-Balteiro, L. and C. Romero (2008). Making forestry decisions with multiple criteria: A review and an assessment. Forest Ecology and Management **255**(8-9): 3222-3241.

Epstein, R. (2007). Harvest operational models in forestry. In: Handbook of Operations Research in Natural Resources : International Series in Operations Research & Management Science.

Fontes, L., J. D. Bontemps, et al. (2010). Models for supporting forest management in a changing environment. Forest Systems **19**: 8-29.

Forsell, N., P. Wikstrom, et al. (2011). Management of the risk of wind damage in forestry: a graph-based Markov decision process approach. Annals of Operations Research **190**(1): 57-74.

Gadow, K. v., T. Nuutinen, et al. (2008). Adaptive Design of Forested Landscapes. In: K. v. Gadow, Pukkala, T. (eds) Designing Green Landscapes. Dordrecht, Springer. **15:** 3-31.

Garcia, O. (1990). Linear programming and related approaches in forest planning. New Zealand Journal of Forestry Science **20**(3): 307-331.

Gratzer, G., C. Canham, et al. (2004). Spatio-temporal development of forests - current trends in field methods and models. Oikos **107**(1): 3-15.

Gunn, E. (2007). Models for strategic forest management. In: Handbook of Operations Research in Natural Resources : International Series in Operations Research & Management Science.

Hahn, W. A. and T. Knoke (2010). Sustainable development and sustainable forestry: analogies, differences, and the role of flexibility. European Journal of Forest Research **129**(5): 787-801.

Hallefjord, A., K. Jornsten, et al. (1986). A Long-Range Forestry Planning Problem with Multiple Objectives. European Journal of Operational Research **26**(1): 123-133.

Hof, J. and R. Haigh (2007). Optimization of Forest Wildlife Objectives. In: C. R. A. Weintraub, T. Bjørndal, R. Epstein (eds) Handbook of Operations Research in Natural Resources. New York, Springer**:** 404-418.

Hoogstra, M. A. and H. Schanz (2008). The future orientation of foresters: An exploratory research among Dutch foresters into the prerequisite for strategic planning in forestry. Forest Policy and Economics **10**(4): 220-229.

Johnson, K. N., S. Gordon, et al. (2007). Conserving creatures of the forest: A guide to decision making and decision models for forest biodiversity. Corvallis, OR, Oregon State University, College of Forestry.

Kätsch, C. (2008). Assessing Landscape Attributes. In: K. v. Gadow, Pukkala, T. (eds) Designing Green Landscapes. Dordrecht, Springer. **15:** 79-108.

Martins, H. and J. G. Borges (2007). Addressing collaborative planning methods and tools in forest management. Forest Ecology and Management **248**(1-2): 107-118.

Meilby, H., N. Strange, et al. (2001). Optimal spatial harvest planning under risk of windthrow. Forest Ecology and Management **149**(1-3): 15-31.

Mendoza, G. A. and H. Martins (2006). Multi-criteria decision analysis in natural resource management: A critical review of methods and new modelling paradigms. Forest Ecology and Management **230**(1-3): 1-22.

Nalli, A., T. Nuutinen, et al. (1996). Site-specific constraints in integrated forest planning. Scandinavian Journal of Forest Research **11**(1): 85-96.

Nordstrom, E. M., L. O. Eriksson, et al. (2011). Multiple Criteria Decision Analysis with Consideration to Place-specific Values in Participatory Forest Planning. Silva Fennica **45**(2): 253-265.

Packalén, P., M. Maltamo, et al. (2008). Detailed Assessment Using Remote Sensing Techniques In: K. v. Gadow, Pukkala, T. (eds) Designing Green Landscapes. Dordrecht, Springer. **15:** 53-77.

Peng, C. H. and X. Z. Wen (2006). Forest simulation models. Computer Applications in Sustainable Forest Management: Including Perspectives on Collaboration and Integration. Dordrecht, Springer. **11:** 101-125.

Pretzsch, H., R. Grote, et al. (2008). Models for forest ecosystem management: A European perspective. Annals of Botany **101**(8): 1065-1087.

Rauscher, H. M., K. Reynolds, et al. (2005). Decision-support systems for forest management. Computers and Electronics in Agriculture **49**(1): 1-5.

Reynolds, K. and D. Schmoldt (2006). Computer-aided decision making. Computer Applications in Sustainable Forest Management. Dordrecht, Springer. **11:** 143-169.

Reynolds, K. M., M. Twery, et al. (2008). Decision Support Systems in Forest Management. In: F. Burstein and C. W. Holsapple (eds) Handbook on decision support systems 2. Berlin, Springer.

Sessions, J., P. S. Bettinger, et al. (2007). Heuristics in Forest Planning. In: C. R. A. Weintraub, T. Bjørndal, R. Epstein (eds) Handbook of Operations Research in Natural Resources. New York, Springer**:** 431-448.

Tindall, D. B., H. W. Harshaw, et al. (2010). Understanding the social bases of satisfaction with public participation in forest management decision-making in British Columbia. Forestry Chronicle **86**(6): 709-722.

Tipple, T. J. and J. D. Wellman (1991). Kaufman,Herbert Forest Ranger 30 Years Later - from Simplicity and Homogeneity to Complexity and Diversity. Public Administration Review **51**(5): 421-428.

Ware, G. O. and J. L. Clutter (1971). Mathematical Programming System for Management of Industrial Forests. Forest Science **17**(4): 428-&.

2 Design and use of computer-based tools supporting forest planning and decision making in Austria

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2.1 Introduction

2.1.1 Socio-economic and ecological environment

Austria is a predominantly alpine Central European country with an area size of 83,871 km² and a forest cover of 47.6%. According to the Austrian Forest Inventory 2007/ 2009 the forest cover has a total area of 3.92 million ha (BMLFUW 2010). Austria is situated in the Central European climatic zone (moderate, humid), however, the eastern part and the eastern foothills of the Alps are more continental Pannonian climate (hot, dry). The main tree species is Norway Spruce (*Picea abies* L. K.) with a total share of 61.2% (growing stock in productive forests). According to the Austrian Forest Inventory, the share of broadleaved trees has increased in recent years, within these beech and hardwoods such as maple, ash or hornbeam play a major role. The forest ownership is 53% small private forests (<200 ha), 32% private estates (>200 ha) and 15% federal forests. At present, Austria's forest resource is underutilized because of economic, social and technical reasons. The current annual harvest is around 18-20 million m³, while the total increment is estimated at 31 million m³ per year. The mean stand volume is around 300 m³/ha in commercial forests whereas the mean annual increment is 9 m³/ha. The forestry sector's contribution to gross domestic product growth was about 2.1% in 2003 according to the most recent calculations (€ 4.8 billions). Therefore, 0.4% was accounted for by forest management, 0.9% by wood processing and 0.8% by paper and cardboard production and processing. Some two-thirds of all Austrian citizens live in rural regions, and forests as a major renewable resource play an important role in this context. From a nature conservation point of view slightly more than one million hectares of forest are identified as protected forests in accordance with nature conservation law and in natural forest reserves.

The Austrian Forest Act (amended BGBl.I Nr. 55/2007) attributes five functions to forests:

(1) productive function (i.e., sustainable timber production)
(2) protective function (i.e., protection against erosion and natural hazards

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(3) welfare function (i.e., the protection of environmental goods like drinking water)
(4) recreational function (use for recreation) and
(5) habitat function (protection of forests as a habitat for living organisms.

The overall principles of the Act are: i) the preservation of forest area ii) the preservation of the productivity of forest sites and their functions and (iii) the preservation of yields for future generations (sustainability). Accordingly, forest sites must not be destroyed, degraded or damaged and any clearings have to be reforested. The forest may not be used for any other purpose than for forest culture. More importantly, protected forests have to be treated without impairment of the protective functions. If the preservation of a protective function or water procurement is demanded, forests are formally banned by the authority. For such a ban, forest management prescriptions have to be prescribed and forest owners have a right to apply for subsidies for implementing forest measures and to ask for compensation from the beneficiaries of the forest. Timber production is described as the main use of Austrian forests. At the same time, this use is under the constraint of sustainable management. For this purpose, immature stands (as a rule no younger than 60 years) must not be felled. Stricter forest management regulations are in force on a provincial level in the mountainous parts of Austria. For instance, clear cuts exceeding 0.5 ha have to be approved by the authority with special supervision for felling in protected forests. As regards social aspects, everybody has the right of access to any forest for recreational purposes during daytime, no matter if it is private or public property.

2.1.2 Forest management problems

In the following, an overview is given on prevalent problem types in Austrian forest management, and how these relate to the key problem types of FORSYS. Furthermore, information is provided on who is involved in the respective planning processes as well as on the relevance of computer-based decision support tools.

2.1.3 Selecting options for forest conversion

Since the 19th century, extensive areas of natural broadleaved and mixed forests in warm and partly dry lowlands have been transformed into conifer plantations either dominated by Norway spruce (*Picea abies* (L.) Karst.) due to its superior productivity and wood quality or to pine forests (*Pinus sylvestris* (L.)). Substantial areas of these secondary coniferous forests are close to their ecophysiological limits and are particularly vulnerable. In warmer and eventually drier future climates, an increased frequency of drought periods and generally an increasing inter-annual variability in climate biotic and abiotic risks for these forests is expected (Lindner et al. 2010). Furthermore, multiple rotations of Norway spruce may lead to soil compaction and increased soil acidification, which in turn may affect nutrient cycling depending on site conditions. To improve crop reliability and to reduce economical and ecological risks, the conversion of pure Norway spruce and pine stands into mixed-species stands, which are better adapted to the specific site conditions, is often recommended (Spiecker et al. 2004). In debating the likely impacts of global climate change and possible adaptation strategies, much emphasis has been placed on secondary conifer forests. The development of sound stand conversion programmes is currently one of the key issues in silvicultural research and forest management planning. Risk rating current stands, support in selecting appropriate species mixtures as well as the treatment of current stands are major issues calling for science-based knowledge and decision support.

This problem type can be characterized with the following dimensions: strategic (choice of tree species) and tactical, spatial with no neighbourhood interrelations, stand level, single decision-maker, multiple, market wood products, non-market services.

2.1.4 Managing mountain forests

In mountain forests, various ecosystem services have to be met such as producing timber, protecting infrastructure and settlements from natural hazards like avalanches, mud flow and torrents, preventing fragile mountain sites from soil erosion, and providing sustained yield of high quality water resources. Silvicultural treatment plans for such multi-purpose mountain forests need to be tailored to stand and site conditions, and prioritized management objectives. In this context, close-to-nature forestry with single stem and group selection systems attempt to balance these often conflicting objectives. However, standard approaches applying silvicultural and forest engineering measures independently are not sufficient. Particularly challenging is the treatment of mature stands scheduled for regeneration. Decision-making about harvesting and natural regeneration of mountain forests with cable yarding systems requires therefore the consideration of several key issues: (a) meeting minimum economic constraints of harvesting operations (b) considering mid- to long-term effects of damages to the residual stand and to advance regeneration (c) providing suitable conditions for establishment of natural regeneration (d) controlling the mechanical stability of the stand (e) utilizing the growth potential of the stand. Additionally, results from the Austrian Forest Inventory and of recent game damage monitoring have revealed severe impacts of game on forest regeneration (BMLFUW 2010). More than two-thirds of all Austrian forests are browsed beyond the capacities of natural regeneration.

This problem type can be characterized with the following dimensions: tactical, spatial with neighbourhood interrelations, stand level, more than one decision-maker, multiple, market wood products, non-market services.

2.1.5 Utilization of timber resources

Timber production is the main use of Austrian forests. The current harvest is around 18-20 million m³, while the total increment is estimated at 31 million m³ per year. At present, Austria's forest resource is underutilized because of economic, social and technical reasons. As 53% of the forest ownership is small private forests (<200 ha) mostly comprising a low level of technical equipment and silvicultural know-how, the possibilities for wood mobilization are limited. Therefore, substantial efforts are made to identify strategies for increased utilization of timber. On the other hand, logistics related to timber harvesting, logging and transport have been improved in the last decades, e.g. with innovations in real-time spatial localization (using mobile phones, GPS, web technologies) and optimization procedures. In addition, the analysis and design of wood-based value chains has raised increased scrutiny, i.e. the sequence from forestry production, to harvest and transport, and industrial processing and trade. This issue comprises the sustainability impact assessment of forest wood chains (Wolfslehner et al. 2011), flexible supply chains and logistics (Bajric et al. 2010), and smart use of small-diameter hardwood in Austria (Huber at al. 2010). From time to time, storm, snow and other weather-related disasters with their subsequent mass propagation of forest pests cause quite significant, but usually regionally limited, economic damage and a huge amount of salvaged timber. In recent years, storm and bark beetle damage has been particularly severe. The year 2003 saw one of the highest levels of wood loss due to bark beetle in Austria since records started more than 50 years ago. In this context, huge amounts of timber needed to be processed from the forest to sawmills risking reduced timber quality and imbalances on the timber market.

This problem type can be characterized with the following dimensions: short to mid-term, spatial, regional/national level, more than one decision-maker, multiple, market wood products.

2.1.6 Objectives

This report aims to provide an overview of the design and use of computer-based tools supporting forest planning and decision making in Austria. In detail we are focusing on:

(1) An inventory of decision support tools in forest management planning, with a focus on the key problem types listed
(2) a description of the key features regarding architecture, development, use of models, methods and knowledge management techniques
(3) lessons learned on the use of computer-based decision support tools so far

2.2 Materials and methods

Information on the use of forest Decision Support Systems (DSS), models and methods used in forest DSS, knowledge management (KM) techniques applied and participatory approaches utilized is mostly related to universities and research institutions in Austria. In addition, computer-based decision support tools have been identified by a survey among ministries, local forest authorities and forest owner associations. With a set of structured and open questions it was possible to identify the use of existing computer-based decision support tools within the organizations contacted, relevant contact persons and the way in which these tools are used in forest management planning problems. Some of the material presented here has been already introduced to the FORSYS Wiki (http://fp0804.emu.ee/wiki/index.php/Main_Page). The following institutions can be named as relevant for developing and applying computer-based tools in forest management in Austria.

At the Institute of Silviculture, Department of Forest and Soil Sciences at the University of Natural Resources and Life Sciences, strong emphasis is set on the development and application of DSS in natural resource management. The Know-Center is a nationally funded application-oriented research centre primarily concerned with knowledge management and knowledge technologies. As a knowledge technology provider, a number of techniques and tools developed at the Know-Center can suit forestry decision support systems, but have not been applied to this domain yet. The Knowledge Management Institute at Graz University of Technology is concerned with the technical aspects of knowledge management and with web-based mechanisms for knowledge sharing and transfer. The Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) is a multidisciplinary research and training institution of the Federal Government of Austria. Applications developed at BFW support knowledge transfer and provide practical advice to forest owners.

2.3 Results

2.3.1 DSS related to forest conversion

ClimChalp: A web-based DSS tool for silvicultural planning and decision-making in low-elevation secondary Norway spruce forests was developed to help forestry extension staff to explore adaptation options for silviculture in secondary Norway spruce forests in Austria (Vacik et al. 2010). ClimChalp has a strong focus on the question of suitable stand treatment programmes for currently existing Norway spruce stands at low elevation sites naturally supporting mixed broadleaved forest types given a particular set of management objectives (represented by a set of indicators focusing on timber production, ecophysiological tree suitability, timber yield, harvesting and silvicultural costs, carbon sequestration, biodiversity and groundwater recharge). The tool has three main components: the information base, the DSS generator and a graphical user interface (GUI) which is particularly designed to support the consultation process of the forestry extension services for small-scale private landowners by reducing the necessary user input to a minimum. Stand treatment programmes over 100 years for initial stand types had been designed and were simulated with the forest ecosystem model PICUS under current climate and four transient regionalized climate change scenarios.

Figure 1. Climchalp - supporting the management of Norway Spruce Forests

The hybrid approach of PICUS v1.42, henceforward referred to as PICUS, aims to bring together the abilities of a 3D gap model (Lexer and Hönninger 2001) in simulating structural diverse forest stands on an individual basis with process-based estimates of stand level primary productivity. In general, PICUS offers a detailed projection of stand dynamics under the simulated management and climate conditions, including individual-tree information on diameter and height. This core concept forms the nucleus of a modular simulation framework integrating a process-based soil module, a management module (Seidl et al. 2005) as well as a thermo-energetic process module of Norway spruce bark beetle infestation (Seidl et al. 2007). PICUS is sensitive to changes in temperature, precipitation, radiation and vapour pressure deficit. Previous analyses found a realistic response to the climatic gradients in the complex terrain of the European Alps, both in terms of species dynamics (Lexer and Hönninger 2001; Didion et al. 2009) and productivity (Seidl et al. 2005).

The user of ClimChalp is supported in comparing decision alternatives by means of multi-criteria analysis and a combined approach of visualized and verbal qualitative ratings. ClimChalp was designed to support the members of the forestry extension staff in Lower Austria. Currently the applicability and use of the tool is explored by a small number of experts within the local authority in order to give feedback for further development and a broader use within the organisation.

DSD: The decision support system DSD v1.1 (Decision Support Dobrova) was developed for the analysis and selection of silvicultural treatment alternatives for Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) karst.) stands in southern Austria (Lexer et al. 2005). The tool is particularly designed to support the forest resource management

Figure 2. DSD supporting management of pine forests in Carinthia

consultation process with forest landowners in the course of the management of secondary coniferous forests. In close cooperation with the local forest authorities, a generic model of the consultation process had been developed (Vacik et al. 2004a). DSD v1.1 supports a planning process which covers the phases of decision-making: (i) identification of current states regarding site and stand conditions (ii) identification of owners' expectations and preferences regarding a set of objectives (iii) selection and evaluation of management alternatives. The stand treatment programmes for representative stand types were designed to support a variety of future target species mixtures. The growth and yield simulator MOSES (Hasenauer 2000) was used to simulate these stand treatment programmes over a period of 30 years; the model output was combined with expert knowledge and economic parameters and used to inform the indicator system. MOSES is a distance-dependent tree model which is well suited to studying the effects of various silvicultural treatments over short- to mid-term planning periods (Hasenauer 2000). DSD was designed to support the members of the local forest authority in Carinthia. After exploring the applicability of the tool, it was introduced in the local forest administration to be used by a small number of forest management planners from 2003 onwards. Currently a revision of the tool is planned in order to adapt the decision space to the demands raised by the users during recent years.

Wolschart: Wolschart was designed in response to a heavy snow breakage disturbance which affected almost 100% of the Wolschart property. There were two main objectives: (1) assigning each stand to a treatment category (immediately clear cut and replant, salvage and continue with business as usual management, salvage and underplant with broadleaves), and (2) proposing suitable species mixtures. Based on an intensive literature review, a rule base was constructed to evaluate each stand based on a stand inventory. To assess species suitability, a static model was developed based on the concept of the fundamental niche (Steiner and Lexer 1998) which linked key site factors to species requirements as derived from the literature. A multi-criteria decision-making methodology was employed to evaluate a set of silvicultural alternatives for the management of the damaged Norway spruce stands with regard to the objectives of the private forest owner (Lexer 2000). The forest growth model MOSES was employed to project stand growth according to the assumptions of a decision alternative. The combined use of these tools to support decision-making is described in Lexer et al. (2000). Wolschart was designed for research purposes only to support the forest owner in exploring the silvicultural treatment options.

2.3.2 DSS related to the management of mountain forests

CONES: The CONES project ('COmputergestützte PlaNung von Nutzung Eingriffen im Seilgelände') aimed at the development and application of a spatial decision support system (SDSS) based on ArcGIS to assist the forester on site in combining silvicultural and harvest operations in a concurrent engineering approach (Vacik et al. 2004b). The process of decision-making about harvesting and natural regeneration of forest stands in steep terrain with a cable yarding system considers three sub-processes to optimize the overall utility of a forest operation: (i) What is the best silvicultural strategy? (e.g., type and intensity of entry) (ii) Which is the best suitable timber harvesting system? (iii) What is the optimal location of the skyline trails? CONES supports the decision-making process by utilizing a forest model (PROGNAUS), damage models for residual stands and advance regeneration and multi-criteria analysis techniques in evaluating different options (Vacik et al. 2006a). The stand treatment programmes are designed and are simulated with the forest ecosystem model PROGNAUS. The distance-independent individual-tree growth model PROGNAUS supplies tree species specific, direct estimates of diameter and height increment, mortality, competition, stand density. In addition, the simulator contains various auxiliary models for the prognosis of stem damage, log size and log quality assortments (Ledermann 2004). CONES was developed for the Austrian Federal Forests Organisation (ÖBF AG) to support a concurrent engineering between silvicultural and forest harvesting operations. After a long period of testing the forest managers evaluated the SDSS as too complex to be used in daily management, this did not allow any further improvement.

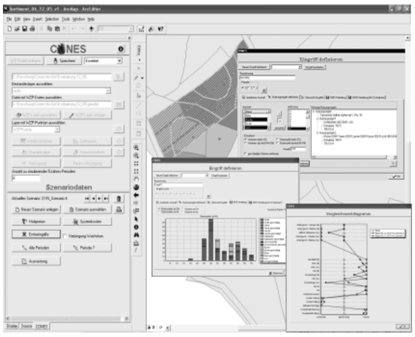

Figure 3. CONES – supporting regeneration planning at the ÖBF AG

Wildalpen / KATER : A prototype spatial decision support system (SDSS) for regeneration planning in the protected forests of Vienna was developed for selecting the best silvicultural treatment option for stands scheduled for natural regeneration (Vacik and Lexer 2001). The decision problem is factored into decisions on the time to begin the regeneration process, the choice of the future species composition and the selection of the regeneration method. A geographical information system and a database management system were used for the implementation of the core components of the SDSS. A decision model allowed the determination of stands scheduled for natural regeneration by using a model for the potential crown defoliation of Norway spruce and stand information data. A model for assessment of site suitability of tree species determines site specific species mixtures. The identification of management objectives at the stand level for evaluation of management practices which best meet these forest-level goals was achieved by MapModels (Riedl et al. 2000). An additive multiple-attribute utility model was used to find the best combination of growing stock objectives and regeneration methods which simultaneously maximizes the expected utility and satisfies all constraints of the forest decision-maker. The KATER project proceeded with the development of decision support tools for the management of the protected forests of the City of Vienna (Fleck and Vacik 2006) and came up with knowledge management techniques to support decision-making in protected forests as well (Magagna et al., 2006). City of Vienna water resource managers make use of the knowledge base developed during the KATER project for making their management decisions in emergency situations. The SDSS prototype was used for research

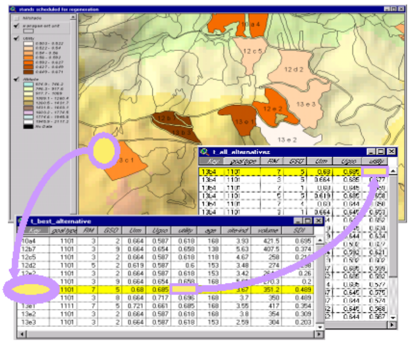

Figure 4. Wildalpen Prototype – Protected Forests, Vienna

purposes only and not further developed, the expert system based on the knowledge base developed is still under consideration by the local administration.

Figure 5. ISDW Web application "Initiative Schutz durch Wald"

ISDW: If the preservation of a protective function or a requirement for water procurement is needed, forests are banned by the forest authority in Austria. For such a ban, forest management prescriptions have to be prescribed and forest owners have a right to compensation from the beneficiaries of the forest. The Initiative ISDW (Initiative Schutz durch Wald) is supporting this process by providing computer-based tools to assess the present and future protection function by estimating the effects of specific management options by means of an Expert System (BMLFUW 2004). Regional management plans are used to define detailed management prescriptions at local level, using GIS, database management systems and web-based wizards. Regional forest managers all over Austria use the tool for the analysis of the current and future protection efficiency of protected forests and to develop management plans for specific projects. Training for the data investigations in the field and the application of the ISDW tool has been provided by the Ministry of Agriculture, Forestry, Environment and Water Management for interested users recently.

2.3.3 Decision support tools related to timber harvest and transport

Several computer-based tools have been developed during recent years in order to support the short-term planning of timber harvesting and the optimization of logistics and transport.

Real-time spatial optimization: This prototype SDSS seeks to optimize the Wood Supply Chain (WSC) in real-time using Geographical Information Science and Technology (GIS&T) coupled with combinatorial optimization methods (Scholz 2010). The system answers the question, to whom timber should be sold – and transported thereafter – to generate the highest profit, with consideration of transportation costs as well as the needs of all stakeholders. The results are detailed schedules for each truck, indicating the timber pick-up and delivery locations ordered in a temporal sequence, which forms a tour. To generate a basis for optimizing the WSC, a spatio-temporal database is created which serves as central data platform for all stakeholders of the WSC, where data can be accessed by standardized spatial and non-spatial web services. For the purpose of obtaining real-time solutions the position of each truck is tracked using Location-based Services utilizing a Service Oriented Architecture (Scholz et al. 2008). Optimizing the WSC relies on the mathematical definition of the problem as a Vehicle Routing Problem with Pickup and Delivery and Time Windows in terms of a Mixed Integer Program, which is solved with a heuristic optimization methodology. The algorithm used in this approach is Adaptive Large Neighbourhood Search (ALNS) (Ropke and Pisinger 2006) that is enriched by the spatial domain and thus called spatial ALNS (Scholz and Bartelme 2010). The results of a first test study in the context of a research project show

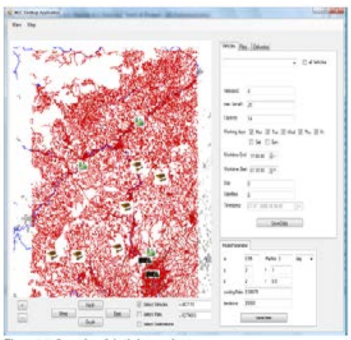

Figure 6. Optimizing the Wood Supply Chain

that optimization increases the profit generated in comparison to an algorithm that behaves in a similar manner to human logistics planning (Scholz 2010).

WoodLogistics: This fully operational supply chain management system is intended to increase the transparency of the WSC and currently focuses on the province of Styria (Holzcluster 2011). WoodLogistics is a project that is pursued by the forest industry - Holzcluster Steiermark GmbH with a number of industry partners - supported by Graz University of Technology and the University of Life Sciences, Vienna. A central database is continuously (24/7) accessible by all stakeholders of the WSC, which allows an intelligent planning of the processes overcoming institutional borders (e.g. timber production or timber haulage). In addition, participants are able to schedule and monitor timber delivery to sawmills on a daily basis. Hence, this tool enables the dispatcher to ‘order’ additional truckloads or to stop further timber delivery to a certain sawmill in case of over delivery. In order to enhance the transparency of logistic operations, the stakeholders have the opportunity to use an accounting tool for haulage costs or the possibility of using a controlling tool for dispatching costs, which both use a map interface.

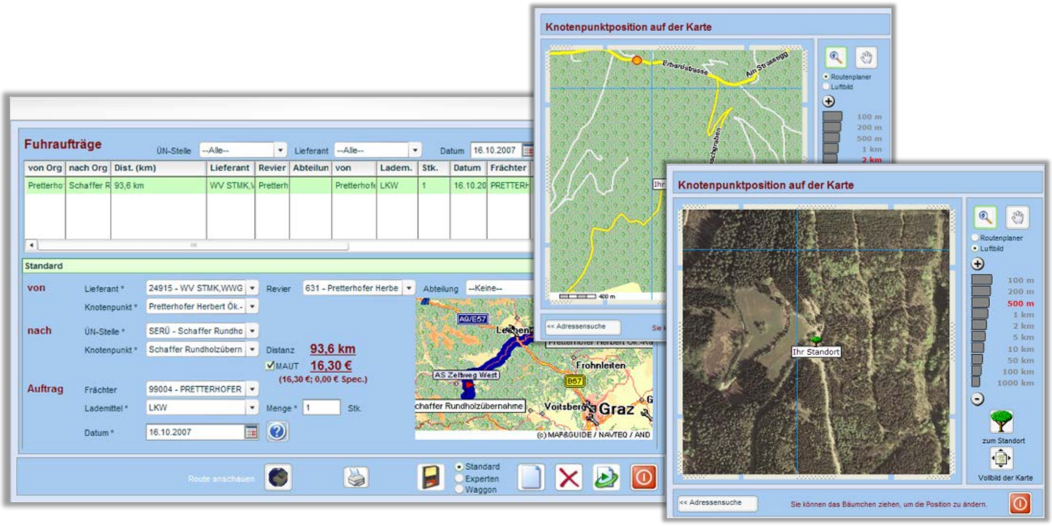

Figure 7. WoodLogistics supporting the Wood Supply Chain in Styria (Holzcluster 2011)

WWG Manager: The WWG Manager is a system for collecting, managing and visualizing WSC data in near-real time, especially developed for the Forest Association in Carinthia (Geochronix 2011). The system consists of a central database, a central management application for managing and visualizing as well as several mobile devices with applications for visualizing and collecting WSC-related data. The mobile devices follow the principle of Location-based Services, and thus are able to collect and display information in relation to the present location. The central management application enables the managers of the Forest Association Carinthia to visualize timber ready for haulage in a map interface that is based on Google Earth. Hence, the allocation of trucks to certain routes or timber piles to be picked up is supported by a GIS. An invoicing and accounting system is integrated as well as a notification service that keeps members of the Forest Association informed about the status of their


Figure 8. WWG Manager for supporting the WSC (Geochronix 2011)

timber.

Figure 9. TimberControl and Smartphone for Forest Mobile monitoring timber flow (FMM 2011)

TimberControl: The company Forest Mapping Management (FMM) released a complete suite of GIS-based tools for forest management for forest enterprises (FMM 2011). The tools follow a web-based approach and thus require an internet connection for 24/7 availability. Two modules offer the possibility to manage and monitor timber flow starting with the harvesting process and ending with timber haulage. Based on a proprietary GPS-based tracer installed on machines, any forest enterprise is able to visualize the position of forest machines and trucks in real-time. Additionally, timber piles can be managed with a map interface and their haulage can be managed using the system at hand. The application Forestmobile offers the possibility to collect data – e.g. on timber piles – as well as the functionality to display and manage information in relation to the current position on a mobile device for any participant of the WSC. Thus, a constant monitoring of the timber utilization and haulage processes is possible.

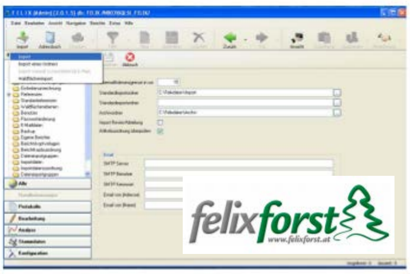

Figure 10. FelixForst supporting selling of timber

FelixForst: FelixForst supports the selling of timber assortments of forest owners and associations. It offers the possibility to handle contracts and invoices in a digital manner. FelixForst was developed by the forest owner association in Austria and is offered as licensed product to its members. Problems along the WSC can be identified and the timber is being formed out according to the customer's needs.

Figure 11. Praxisplan Waldwirtschaft supporting forest planning

Praxisplan Waldwirtschaft: With the 'Praxisplan' tool, forest owners are able to make a forest plan for their forest property. Without any detailed knowledge about forest resources, the tool allows the prediction of the annual cut and the likely harvesting costs related to the human and technical infrastructure available. GIS maps enable the display of the forest plan for a total of 10 years. The tool is offered without license costs by the forest consultant services of the chambers of agriculture in Styria. Training for interested forest owners is currently scheduled. Forest consultants currently use the tool to get an overview of forest resources independent from owner properties. The extension GEOKONTAKT supports communication between forest owners, hauling companies and sawmills along the WSC.

ToSIA (Tool for Sustainability Impact Assessment of Forest Wood chains) has been developed within the FP6 Integrated project 'EFORWOOD' for assessing the sustainability impacts of Forest-Wood-Chains (FWCs). FWCs are defined as chains of production processes (e.g. harvesting–transport–industrial processing) which are linked with products (e.g. a timber frame house). Sustainability is determined by analyzing environmental, economic, and social sustainability indicators for all the production processes along the FWC (Päivinen et al. 2010). Multi-criteria analysis (MCA) is implemented as a separate software tool that is linked to ToSIA via a data interface. It facilitates the selection of indicators, their specification for a specific decision problem via thresholds and weighting of indicators with regard to their importance for a sustainability impact analysis. The analysis part provides relative sustainability impact ratings (i.e., an aggregated dimensionless index representing the relative preferences for a set of alternatives) for individual segments of the forestry wood chain (i.e., forestry, transport, industrial production, trade) or for the entire chain. Sensitivity analysis informs about the effects of changing the weighting on the overall rating. Uncertainty analysis allows a judgment of the impact on the assessment result arising from uncertain input data. The MCA tool has been developed by the Austrian research group at BOKU, testing prototypes in Baden-Württemberg, Germany (Wolfslehner et al. 2011). The ToSIA approach is currently used in Austria to analyze the smart material use of small diameter hardwood.

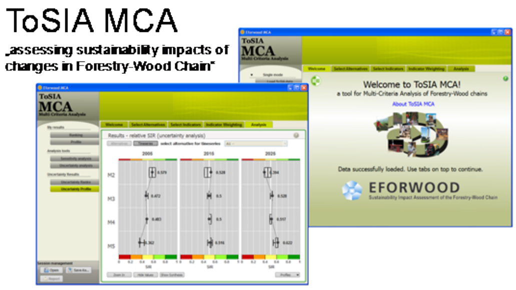

Figure 12. ToSIA - Tool for Sustainability Impact Assessment of Forest Wood chains

2.3.4 Categorization of computer-based tools

Regarding forest management problems in Austria, several computer-based tools were identified which are addressing to some extent these problems, which are linked to the key decision problems of FORSYS.

Table 1. Categorization of computer-based tools developed and/or applied in Austria according to problem types described

Problem type	DSS/Tool	Models and methods	KM techniques	Participatory planning
strategic (choice of tree species) and tactical, spatial with no neighbourhood interrelations, stand level, single decision-maker, multiple, market wood products, non-market services.	ClimChalp	PICUS, PBS, MAUT	DBMS, WebGIS	preference elicitation; prioritization of management strategies
	DSD	MOSES, AHP, MAUT, niche model	DBMS	preference elicitation; prioritization of management strategies
	Wolschart	AHP, MAUT, niche model	DBMS, GIS	prioritization of management objectives
tactical, spatial with	CONES	Prognaus,	DBMS, GIS	prioritization of

neighbourhood interrelations, stand level, more than one decision-maker, multiple, market wood products, non-market services.		Damage Models, BPS, MCA		management strategies between forest engineer and manager
	Wildalpen/ KATER II	AHP, MAUT	DBMS, GIS, Ontology	Preference elicitation; prioritization of management strategies
	ISDW		Expert System DBMS, WebGIS	Justification of subsidies
short to mid-term, spatial, regional/national level, more than one decision-maker, multiple, market wood products.	Real-time spatial optimization	Combinat-orial optimization (heuristics)	Spatio-temporal DBMS	prioritization of transport strategies
	Wood Logistics		DBMS, GIS	prioritization of transport strategies
	WWG Manager		DBMS, GIS	prioritization of transport strategies
	Timber Control		DBMS, GIS	prioritization of management strategies, accounting and marketing
	FelixForst		DBMS	prioritization of assortments, accounting and marketing
	Praxisplan Waldwirt-schaft, Geokontakt		DBMS, GIS	design of alternatives prioritization of management strategies, communication
	Tosia	Promethee, AHP, Scoring	DBMS	prioritization of management and transport strategies

2.4 Discussion and conclusions

Regarding the prevalent problem types described, several computerized decision support tools have been developed in Austria. In the context of the impacts of global climate change and possible adaptation strategies, much emphasis has been placed on the management of secondary conifer forests. This is partly reflected in the development of tools supporting these activities and related to stand conversion as well. DSS specifically devoted to management of mountain forests are rare.

Concerning the architecture of forestry DSS, there is a noticeable shift from desktop DSS towards a modularized architecture with mobile and static clients or with web interfaces. Thus, DSS (or relevant parts of them) have to be designed in such a way that they are executable on a mobile device. In order to support a seamless communication of such heterogeneous systems, standardized (web) services are of interest, which lead to generic Service Oriented Architectures (SOAs). Such concepts are realized in DSS for timber utilization. In addition, as contemporary mobile devices detect their own position with Global Navigation Satellite Systems (GNSS) this information can be incorporated in the decision-making process. Location-based services may be useful for providing “mobile” decision support, and for the evaluation and calibration of decision support models at hand. The activities of FHP Austria to support the WSC with common data protocols and reports (FHPDAT) are in that context relevant as well.

In analyzing the development and use of KM tools related to the identified forest management problems it was not possible to link the tools to a specific problem type because of their universality and generality. KM techniques cover a broad range of different topics for the creation, consumption, analysis, presentation and sharing of knowledge (Lindstaedt et al. 2002). Since forest decision support systems rely on managing knowledge, nearly every KM technique can be considered as important. Creation and elicitation of knowledge can be considered as the very first step in knowledge management, with the goal to create a common understanding of a particular domain. Several KM techniques, such as 'expert interviews' or 'expertise profiling' support this step. Expertise profiling supports employees when searching for an expert within their organization. The objective is to create and provide a profile of skills, experiences and knowledge of all experts within an organization or a domain. Expert interviews directly aim to externalise knowledge from experts and make it available for later use. KATER II (Karst Water Research Programme) has been one example related to both techniques. Kater II is a EU Interreg IIIB CADSES project with the goal of developing a decision support system for the Karst regions in Austria, Italy and Slovenia. It combines different stakeholder interests from tourism, agriculture and water pollution control. Knowledge which has been identified through profiling was organised and structured, preferably by using information technology. In this context MindMaps were considered as a simple form of knowledge maps allowing the organisation of concepts hierarchically.

However, human-centred capture approaches like Knowledge Maps or simple text-based documentation conflict with the needs of information systems for more formal representations of knowledge. Ontologies, understood in computer science as the formalisation of a conceptualisation (Gruber 1993), focus on making knowledge explicit through using formal, logical theories. Creating such ontologies becomes labour intensive and hence requires either collaboration among experts or support through data mining techniques. The IDIOM (Information Diffusion Across Interactive Online Media, www.idiom.at) Project provides data mining techniques and creates ontologies through analysing textual information contained in online media. The IDIOM Project has been a research project on acquiring, managing and applying knowledge to monitor climate change reports in media (Scharl et al. 2008). The web portal aggregates, filters and visualizes environmental web content from 150 Anglo-American news media sites and creates a formal representation of the underlying knowledge by using ontologies (Weichselbraun et al. 2008).

However besides visualizing knowledge, understanding and supporting users becomes even more crucial. Especially in narrow domains, accessing knowledge depends strongly on the skill and expertise of the user themselves, and, clearly, the ease of access. Knowledge sharing has become a key issue in knowledge management. This is clearly shown by the advancement of the web (i.e. web 2.0) as a new media to connect different communities with each other for sharing expert knowledge and best practices. Two projects, namely COCOON and waldwissen.net, demonstrate the importance of easy and contextualized access to knowledge.

At the University of Natural Resources and Life Sciences, Vienna, students learn to cross-link the ecological, socio-economic and technical knowledge of maintaining, regenerating, tending and utilizing forests in a sustainable way. The principle of blended learning, a combination of online phases and face-to-face meetings is applied. Within COCOON, a content management system and an authoring tool was developed (Vacik et al. 2006b). Besides the content information COCOON includes interactive features, search engines, questionnaires, a glossary and communication tools (discussion forum, chat). The authoring tool supports content processing by various editors, which makes the use of any HTML-editor non-essential for authors to transfer learning material to hypertext.

Recognizing the growing importance of the internet for knowledge sharing, the Austrian Forest Research Center (BFW), jointly with three other research institutes from Freiburg, Freising and Birmensdorf, has established the information platform 'waldwissen.net' which offers specially processed information for forest practice. This goes from research articles to guidebooks and technical notes to the review of books and database CDs. As well as this information platform, a series of online forums have been established for supporting specific forest management planning problems. In addition, several online platforms support forest management planning:

- www.herkunftsberatung.at is used for selecting appropriate provenances for afforestation
- www.borkenkaefer.at is used for the online monitoring of the outbreak of bark beetle populations in selected traps
- www.wildeinflussmonitoring.at is supporting the documentation of damage by game and its comparative analysis between provinces
- www.waldinventur.at allows the in-depth analysis of the results of the Austrian national forest inventory
- bfw.ac.at/ws/sdis.schadenstypen supports the identification of forest diseases and pathogens by means of standardized criteria.

Besides the information platforms, many forest practitioners and forest planners make use of the web-GIS tools offered by the nine provinces in Austria (e.g. SAGIS, TIRIS, DORIS). These web tools allow the regional administration to display and communicate relevant environmental information about forest resources. Restricted access is offered for the documentation of forest owner specific information, public access mostly allows the display of various land cover and land use maps (e.g. forest types, forest roads, forest functions, conservation areas, topographic maps).

Knowledge Management is strongly related to DBMS – spatial, spatio-temporal or non-spatial – which is one way of structuring and storing knowledge. Interdisciplinary science 'forces' researchers to exchange knowledge about objects and their behaviour. Due to the fact that different disciplines do seldom share a common 'view of the earth', every research area has its own semantics, which makes it hard to identify the tools and techniques relevant for a specific problem domain. Thus, exchanging knowledge stored in databases becomes a critical issue, not from a syntactic but from a semantic viewpoint. Incorporating a semantic-ontological view in knowledge representation and management would enhance interdisciplinary collaboration and communication. A number of techniques and tools developed at the Know-Center can suit forestry decision support systems, but have not been applied to that domain yet. In particular techniques such as semantic technologies, search and visualisation techniques as well as technology-enhanced learning solutions developed within the APOSDLE project (www.aposdle.tugraz.at) could be applied to forestry decision support systems.

It can be stated that participatory elements are still weakly represented in forest management planning in Austria. In summary, the proposed tools are mainly designed for supporting single forest owners/managers/decision-makers. On the other hand, in participatory forest policy-relevant issues such as the Austrian National Forest Programme the modes of participation (workshops, group work etc.) are still mostly conventional without using operations research methods or computer-based tools. Initially, there is progress towards model-supported stakeholder involvement and MCA relating to a form of collegial vulnerability assessment with a team from the Austrian Federal Forests (Lexer and Seidl 2009), and the designed facilities for the group ToSIA-MCA to be further developed and applied for a 'real-life' participatory evaluation of sustainability impacts of forest-wood chains. Other MCA-based approaches e.g. by SERI (http://seri.at) are from outside the forestry domain but provide relevant projects such as ARTEMIS (sustainability impact assessment energy production, http://seri.at/projects/completed-projects/artemis/) or Optima Lobau (Weiglhofer et al. 2006). However, a sound emphasis on participatory elements is a constraint to inter- and trans-disciplinary needs to combine natural science (e.g., ecosystem modeling), social sciences (e.g., policy and stakeholder analysis), and decision analysis (e.g., MCA) to not reduce participatory planning in the context of DSS to a purely technical exercise (Wolfslehner and Seidl 2010).

References

Bajric F., Vuillermoz M., Usenius A., Heikkilä A., Winking A., Wilhelmsson L., Jodlowski K., Fillbrandt T., Opferkuch M., Wolfslehner B., Lexer M.J. and Huber P. 2010. FlexWood - Industrial requirements, gaps and improvement needs. Flexwood Deliverable 3.1, EU-FP7.

BMLFUW, 2004. Initiative Schutz durch Wald – ISDW, http://www.isdw.at/filemanager/download/29461/, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wien, Austria.

BMLFUW, 2010. Ergebnisse der Österreichischen Waldinventur (ÖWI 2007-2009), Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft, (BFW), Bundesamt für Wald, http://bfw.ac.at/rz/wi.home, Vienna, Austria.

Didion M., Kupferschmid A.D., Lexer M.J., Rammer W., Seidl R., Bugmann H. 2009. Potentials and limitations of using large-scale forest inventory data for evaluating forest succession models. Ecol Model 220:133–147.

Fleck W. and Vacik H. 2006. A Decision Support Tool for selecting Harvesting Systems in the Protection Forests. In: Wiener Wasser Werke, MA 31, Kater 2006, International Conference "All about karst & water" - Decision Making in a Sensitive Environment, 9.10 – 11.10.2006, Vienna, Austria; Proceedings on DVD, 169-173.

FMM GmbH 2011. FMM und Forst. http://www.fmm.at/de/Forst.html, Austria.

Geochronix Software GmbH 2011. Der WWG Manager im Waldverband Kärnten. http://geochronix.at/en/forest/wwgmanager, Austria.

Gruber T. 1993. A Translation Approach to Portable Ontology Specifications, Knowledge Acquisition, 5(2), 199-220, 1993.

Hasenauer, H. 2000. Die simultanen Eigenschaften von Waldwachstumsmodellen. Paul Parey, Berlin, 131 p.
Holzcluster 2011. Was ist Woodlogistics? http://www.woodlogistics.org, Holzcluster Steiermark GmbH, Austria.

Huber H., Pleschberger H., Wolfslehner B., Teischinger A. and Hansmann Chr. 2010. Superior processing of small diameter hardwood. In: Teischinger A. et al. (eds.). Processing technologies for the forest and biobased products industries, PTF BPI 2010, Salzburg University of Applied Sciences.

Ledermann T. 2004. PROGNAUS – ein Waldwachstumsmodell zur Fortschreibung von Inventurdaten, Austria, http://www.waldwissen.net/technik/inventur/bfw_prognaus/bfw_Prognaus_2004.pdf

Lexer M.J. 2000. Ein multi-attributives Nutzenmodell zur Unterstützung der waldbaulichen Planung dargestellt am Beispiel sekundärer Fichtenwälder. Forstwissenschaftliches Centralblatt 119: 377-394.

Lexer M.J., Vacik H., Hönninger K. and Unegg F. 2000. Implementing a Decision Support System for Silvicultural Decision Making in Low-Elevation Norway Spruce Forests. In: Klimo, E., Hager, H., Kulhavy, J. (eds.). Spruce Monocultures in Central Europe - Problems and Prospects. EFI Proceedings, No. 33, 119-134.

Lexer M.J. and Hönninger K. 2001. A modified 3D-patch model for spatially explicit simulation of vegetation composition in heterogeneous landscapes. Forest Ecology and Management 144: 43-65.

Lexer M.J., Vacik H., Palmetzhofer D. and Oitzinger G. 2005. A decision support tool to improve forestry extension services for small private landowners in southern Austria. Computers and Electronics in Agriculture 49, 1: 81-102.

Lexer M.J. and Seidl R. 2009. Addressing biodiversity in a stakeholder-driven climate change vulnerability assessment of forest management. Forest Ecology and Management 258: 158-167.

Lindner M., Maroschek M., Netherer S., Kremer A., Barbati A., Garcia-Gonzalo J., Seidl R., Delzon S., Corona P., Kolstrom M., Lexer M.J. and Marchetti M. 2010. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. Forest Ecology and Management 259: 698-709.

Lindstaedt S., Strohmaier M., Rollett H., Hrastnik J., Bruhnsen K., Droschl G. and Gerold M. 2002. KMap: Providing Orientation for Practitioners when Introducing Knowledge Management, Proceedings of the 4th International Conference on Practical Aspects of Knowledge Management (PAKM 2002), Springer Verlag, Vienna - Austria, 2002.

Magagna B., Köck R., Kollarits St., Hochbichler E. 2006. The Role of Ontologies within KATER II Project: Formalisation of the Hydrotype Concept. In: Wiener Wasser Werke, MA 31 (Eds.), Kater 2006: International Conference “All about karst & water" - Decision Making in a Sensitive Environment, Vienna, Austria; Proceedings, p. 39-50.

Päivinen R., Lindner M., Rosén K. and Lexer M.J. 2011. A concept for assessing sustainability impacts of forestry-wood chains. European Journal of Forest Research, in press, DOI: 10.1007/s10342-010-0446-4

Riedl L., Vacik H. and Kalasek R. 2000. MapModels: A new approach for spatial decision support in silvicultural decision making. Computers and Electronics in Agriculture 27(3): 407-412.

Ropke S. and Pisinger D. 2006. An adaptive large neighbourhood search heuristic for the pickup and delivery problem with time windows. Transportation Science 40: 455-472.

Scharl A., Stern H. and Weichselbraun A. 2008. Annotating and Visualizing Location Data in Geospatial Web Applications, 17th International World Wide Web Conference (WWW-2008), 1st International Workshop on Location and the Web. Beijing, China: Association for Computing Machinery (ACM). 65-68.

Scholz J. 2010. Real-time spatial optimization. Ph.D. thesis, Graz University of Technology.

Scholz J., Bartelme N., Prüller R. and Strauss C. 2008. Optimizing the Wood Supply Chain: Concept and Methods, International Journal of Spatial Data Infrastructures Research, Vol. 3, Special Issue GI-Days, Münster, 2007, pp. 95-117.

Scholz J. and Bartelme N. 2010. Spatial-enabled Adaptive Large Neighbourhood Search for Optimizing the Wood Supply Chain, Proceedings of GIScience 2010, Zurich, Switzerland. http://www.giscience2010.org/pdfs/paper_122.pdf (last accessed: 21.01.11).

Seidl R., Lexer M.J., Jäger D. and Hönninger K. 2005. Evaluating the accuracy and generality of a hybrid patch model. Tree Physiology 25(7): 939-951.

Seidl R., Baier P., Rammer W., Schopf A. and Lexer M.J. 2007. Modelling tree mortality by bark beetle infestation in Norway spruce forests. ECOL MODEL, 206: 383-399.

Spiecker H., Hansen J., Klimo E., Skovsgaard J.P., Sterba H., v. Teuffel, K. (eds.) 2004. Norway spruce conversion – options and consequences, European Forest Institut Research Report 18, Leiden, Netherlands, p 269.

Steiner C. and Lexer M.J. 1998. Ein klimasensitives statisches Modell zur Beurteilung der Baumarteneignung. Forstarchiv 69: 92-103.

Vacik H., Lexer M.J. 2001. Application of a spatial decision support system in managing the protection forests of Vienna for sustained yield of water resources.. For. Ecol. Manage., 143, 1-3, 65-76

Vacik H., Lexer M.J. and Englisch M. 2004a. Einsatz des Decision Support Systems DSD v1.1 zur Unterstützung der forstlichen Beratung im Landesforstdienst. Forstarchiv 75 (5): 1-11.

Vacik H., Lexer M.J., Palmetzhofer D., Stampfer K. and Limbeck-Linienau B. 2004b. Anwendung der Entscheidungshilfe CONES zur Planung von Verjüngungseingriffen im Gebirgswald. In: Strobl et al. [Hrsg.] , Angewandte Geoinformatik 2004, Beiträge zum 16. AGIT-Symposium Salzburg, Wichmann Verlag (Heidelberg), 715-723.

Vacik H., Lexer M.J. and Wolfslehner B. 2006a. Application of a Spatial Decision Support System for Regeneration Planning in Water Protection Forests. In: Wiener Wasser Werke, MA 31 (Eds.), Kater 2006: International Conference "All about karst & water" - Decision Making in a Sensitive Environment, Vienna, Austria; Proceedings, 199-210

Vacik H., Wolfslehner B., Spörk J. and Kortschak E. 2006b. The use of COCOON in teaching silviculture. Computers & Education 47(3): 245-259.

Vacik H., Lexer M.J., Rammer W., Seidl R., Hochbichler E., Strauss M. and Schachinger C. 2010. ClimChAlp - a webbased decision support system to explore adaptation options for silviculture in secondary Norway spruce forests in Austria. In: Falcao, A., Rosset. C (Eds.) , Proceedings of the Workshop on Decision Support Systems in Sustainable Forest Management. Lisbon, http://www.fc.ul.pt/dsfm2010/docs/presentations/paper_15.pdf

Weichselbraun A., Wohlgenannt G., Scharl A., Granitzer M., Neidhart T. and Juffinger A. 2008. Discovery and evaluation of non-taxonomic relations in domain ontologies, International Journal of Metadata, Semantics and Ontologies.

Weigelhofer G., Blaschke A.P., Haidvogl G., Hohensinner S., Reckendorfer W., Reiter K., Schuh B. and Hein T. 2006. Optima Lobau: An interdisciplinary scientific approach evaluating future scenarios in an urban floodplain. 36th International Conference: DANUBE.RIVER.LIFE

Wolfslehner B. and Seidl R. 2010. Harnessing ecosystem models and multi-criteria decision analysis for the support of forest management. Environmental Management 46(6): 850-861.

Wolfslehner B., Brüchert F., Fischbach J., Rammer W., Becker G., Lindner M. and Lexer M.J. 2011. Exploratory multi-criteria analysis in sustainability impact assessment of forest-wood chains – the example of a regional case study in Baden-Württemberg. European Journal of Forest Research, in press. DOI: 10.1007/s10342-011-0499-z.

3 The use of forest decision support systems in Brazil

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3.1 Introduction

At 516 million ha, Brazilian native and planted forested areas occupy 60.7% of Brazil's total territory, making these forests the second largest forested area in the world, after the Russian forests. The country is divided into six ecosystems, depending on the climate and forest cover type: the **Amazon** tropical region with 419.7 million ha (85% forested); the savannah-like **Cerrados** with 203.6 million ha (33% forested); the **Atlantic** tropical forests in the coast with 111.0 million ha (27% forested); the **Caatinga** semi-arid region with 84.5 million ha (56% forested); the **Pampa** grasslands with 17.7 million ha (18.1% forested); and the regularly flooded **Pantanal** with 15.0 million ha (58% forested). More statistics about Brazilian forests can be found at www.florestal.gov.br.

Brazilian forests have been grouped by FAO in six categories: production (planted forests, national forests and state forests: 6.2%); protection of soils and water resources (basically a tenth of the Brazilian territory categorized as a permanent preservation area: 16.5%); biodiversity conservation (protected area in eight different conservation unit categories: 9.7%); social services (used by traditional peoples and protected in three different conservation unit categories: 24.8%); multiple use (legally preserved in a federal and state conservation unit called environmental protected area: 6.0%); and other uses (prevalent use is still undetermined: 36.8%).

According to current data, **public forests** in Brazil cover an area of approximately 290 million ha, including national forests, national parks, biological and ecological reserves etc. These forests are under the direct responsibility of four governmental institutions: the MMA ministry of environment (this forest policy proponent is also empowered to sign forest concessions); the SFB forest service (manager of public forests at the federal level in charge of producing forest goods and services); the IBAMA renewable natural resources and environment institute (environmental licensing and monitoring); and the ICMBio biodiversity institute (manager of all federal conservation units). Supported by public hearings, many processes involving planning, decision-making and destination processes have also been defined with the participation of three councils specially constituted to consider multilateral participation: the CONAMA national environmental council, the CONAFLOR national forests commission, and the CGFLOP public forests management commission. Brazilian experience with concessions in public forests is concentrated in the Amazon, and started just a few years ago. The first forest concession, in the Jamari National Forest, designated in 2007 an area of 96,000 ha to three concession holders allowed to implement reduced impact logging systems (RILS) described in sustainable management of tropical forest (SMTF) plans; the second concession (Saracá-Taquera National Forest) was signed in 2009, and designated 50,000 ha to two concession holders; and the third forest concession process (Amana National Forest), involving 210,000 ha, is currently in the public hearings phase.

Communal forests represent a special category in Brazil and are used by traditional and indigenous peoples and communities, small landowners (subsistence agriculture) and land reform settlers. The Brazilian constitution guarantees free access to indigenous populations and *quilombolas* (slave descendents living in *quilombos*, areas their ancestors fled to looking for freedom). The 2006 Public Forests Management Law reinforces the rights of local communities living in public forests to exploit free of charge the forest resources available in these lands. Approximately 129 million ha (15% of Brazilian territory) is designated to these communities, including the 98.4 million ha occupied by many different indigenous tribes.

Private forests amount to approximately 99 million ha, according to periodic national census assessments. Fast-growing industrial planted forests play an important role in Brazil´s economy and represent less than 7% of the total land covered with private forests. Harvested products from these plantations are predominantly eucalyptus wood (4.5 million ha), pine wood (1.8 million ha), acacia wood (0.17 million ha) and other species (0.30 million ha).

3.1.1 Prevalent forest management problem types in Brazil

FORSYS problem type categories consider six problem dimensions: temporal scale, spatial context, spatial scale, stakeholder involvement, objectives and outputs. In Brazil, it is important to briefly refer to the current legal framework that directly influences how land owners use their rural properties and implement forest activities.

The Brazilian framework of laws that control environmental licences, land use and forest management is intricate and has been significantly improved over the last two decades. These laws regulate the way land owners use their land, and explicitly predetermine the amount of land that a rural property has to preserve for environmental purposes or to maintain uncultivated protecting soils and water streams (usually referred in Brazil as APPs – Permanent Preservation Areas), or to reserve as a precautionary measure to maintain a constant stock of wood and forest resources (also referred in Brazil as RLs – Legal Reserves).

Basically, the management of forests in Brazil is undertaken either by a group of workers in a private company or by a federal or state team of public officials. The importance of the legal framework becomes clear when Brazilian forest managers consider spatial context and scale dimensions. For example, the spatiality of forest operations in a public or private property is intrinsically constrained by law. Side banks of rivers, water springs, and hill tops must be excluded from production purposes in the property as protected areas (APPs). Depending on the geographical location of the property, native forests have to be maintained as legal reserves (RLs) in 80% (Amazon region) or 20% (other Brazilian regions) of the property area. Clear cutting is not allowed in legal reserves, and in these areas a long-term forest management plan is always required to implement harvest or plantation operations. Conventional agricultural crops, perennial cultivation of coffee, rubber trees, fruit trees, forest plantations like eucalyptus, pine, teak and acacia, and other similar activities are, therefore, constrained to the remaining area.

Consequently, in Brazil, **private forest plantations** are cultivated in patches neighbouring APPs and RLs, which means that neighbourhood interrelations are obligatorily considered when these planted forests are spatially distributed in the property.
Governed by law, the management of forests in legal reserves (public or private RLs) and **public forests** in Brazil has to strictly follow a very comprehensive and detailed set of rules. Harvesting licences in RLs and public forests, and transportation permits for wood produced

in these areas can only be issued by state officials after a long-term strategic plan is approved and an annual short-term operational plan is submitted.

Considering the prevailing legal framework in Brazil, and FORSYS suggested dimensions, four prevalent forest management problem types are reported in this document. The remaining types are not reported either because there are none – as in cases involving single decision-makers and where spatiality is not considered (the current Brazilian legal framework imposes the consideration of spatial constraints when planning land use in all rural properties) – or because there are too many variations, as in the case of stand level and tactical or operational forest management problems where simplified versions of trial and error and simulation techniques are usually applied. The problem types reported in this chapter are numbered B1, B2, B3 and B4 and presented in Table 1. The Brazilian Forest Service produces an annual forest plan at the national/regional level and could be classified as a different type, but their approach to deal with such problems fits the B4 type.

Table 1. Prevalent problem types in Brazil according to FORSYS dimension categories

Dimensions		**Types**			
		B1	**B2**	**B3**	**B4**
Temporal scale	Long-term (strategic)	X	X	X	X
	Medium-term (tactical)				
	Short-term (operational)				
Spatial context	Non-spatial				
	Spatial with neighbourhood interrelations			X	
	Spatial with no neighbourhood interrelations	X	X		X
Spatial Scale	Stand level				
	Forest level	X	X	X	X
	Regional/national level				
Parties involved	Single decision-maker				
	More than one decision-maker/stakeholders	X	X	X	X
Objectives	Single	X			
	Multiple		X	X	X
Goods and services	Market non-wood products				X
	Market wood products	X	X	X	X
	Market services				X
	Non-market services				X

Forest management problem types B1, B2 and B3 are typical among professional teams dealing with **private forest plantations**. Concession managers and public officials in **public forests**, and legal reserve managers dealing with the management of **private forests**, usually face a B4 forest management problem type.

3.2 Material and methods

Two main sources of information were used in this report. The first source of information is represented by the main laws and regulations that rule the management of **public forests**.

The second source of data was the collection of responses from a questionnaire that allowed for a more detailed analysis of all three problem types that characterize the management of **private forest** plantations.

3.2.1 Scope of the study

Most frequently, activities related to forest management occur in Brazil when dealing with private industrial planted forests, natural forests in legal reserves (RLs), concessions in national forests and communal forests. Statistics presented in the introductory section illustrate the relative importance of these forests. Although small in terms of land use, around 4.4% of all Brazilian territory, the management of private industrial planted forests (6.6 million ha), concessions in national forests (0.36 million ha) and communal forests (30.5 million ha) contribute to a significant 4% of the Brazilian annual Growth Domestic Product (GDP). Forest management and planning activities in communal forests are practically irrelevant.

The management of small private forests (for Brazilian standards, with less than 1,000 ha) was not included in the survey. In these cases, forest managers rely basically on simple GIS applications, electronic spreadsheets and tacit knowledge. For the assessment reported here, it is important to emphasize that the sample represents the group of private forest managers with a supposedly higher level of willingness to adopt more complex knowledge management and decision support systems.

3.2.2 Assessed problem types

All four problem types were assessed in this study. The distribution of the sampled group of respondents, considering these four FORSYS problem types, is presented in Table 2. For 15 respondents in the private forests group, the prevalent dimensions of the forest management problem correspond to the B2 category, that is: long-term temporal scale, spatial context with no neighbourhood interrelations and spatial scale at the forest level, involving more than one decision-maker, market wood products and multiple objectives. The only difference for the other six respondents in the private forests group is the existence of only one objective (B1 problem type). And furthermore, among the private forest managers, in only one case the spatial interrelation with neighboring forest stands was considered (B3).

Table 2. Distribution of valid questionnaires among FORSYS problem types

Problem type	Number of responses	Area effectively planted
B1	6	378,974 ha
B2	15	1,012,802 ha
B3	1	94,500 ha
B4	1	356,000 ha

In the case of **public forests**, the problem type was defined in Table 1 as B4, where the considered dimensions are very similar to B2, except that forests are expected to produce multiple goods and services (market wood and non-wood products, and market and non-market services).

3.2.3 Methodology

Interviews and consultation of the regulatory norms and laws provided most of the needed information to characterize knowledge management tools and phases implemented by managers dealing with public forests, especially forest concessions. Basically, these managers do not use sophisticated knowledge management tools and decision support systems. In fact, and invariably, all planning and management phases in these cases are supported by basic geographical information systems applications, electronic spreadsheets and tacit knowledge.

The planning and management of planted industrial forests, on the other hand, has increasingly relied on more sophisticated and improved management techniques. An accurate assessment to produce the results expected in this report required the development and application of a structured questionnaire. The survey was applied to a group of 22 forest managers representing the private industrial forest sector.

The questionnaire was made available to 30 different companies, and the final number of valid responses amounted to 22. These responses represent 21% of the total area planted with industrial forests in Brazil, or more specifically 1.48 million ha in a universe of 6.77 million ha. The number of responded questionnaires per class of effectively planted forest area is presented in Table 3.

Table 3. Distribution of valid questionnaires among classes of effectively forested area

Class interval	Number of responses	Total area planted
< 50,000 ha	11	172,228 ha
50,000 to 100,000 ha	6	518,684 ha
100,000 to 150,000 ha	2	258,000 ha
150,000 to 200,000 ha	2	325,699 ha
200,000 to 250,000 ha	1	211,665 ha

The assessment was based on a survey with 22 questions organized into two sets. The first set, with 12 questions, tried to characterize the problem in terms of size, format and complexity. The second set, with 10 questions, characterized the use of knowledge management tools, decision support systems and planning phases.

3.3 Results

All prevailing problem types in Brazil refer to situations where more than one decision-maker and stakeholder are involved. The set of FORSYS methods to describe and assess participatory planning was used to address all reported Brazilian forest planning problems. Problem types B1, B2 and B3 are assessed in Table 4 and Table 5. Table 4 summarizes the participatory planning methods qualified by the questionnaires. Table 5 describes how knowledge management techniques are used in Brazil according to their contribution for the identification, analysis and solving of the three prevailing problem types. A description is provided for each phase: intelligence, design and decision-making. Table 6 summarizes the participatory planning method and knowledge management techniques used in Brazil to manage forest concessions in National Forests. The information provided in Table 6 was compiled from interviews and the revision of legal and normative documents discussed with public officials.

Table 4, in the design phase, refers to basic models generated by matrix generators. These are linear programming harvest scheduling Type I and Type II applications that have been developed in Brazil since the 1980s (Rodriguez and Lima 1985; Rodriguez and Moreira 1989), as cooperative research projects. One of the first cooperative projects in Brazil was a partnership between the University of Sao Paulo and IPEF, a Brazilian forest research institute sponsored mainly by private forest companies.

Variations around the first applications in the 1980s have been applied since then to produce all strategic and tactical plans used by most forest managers in charge of large-scale forest plantations in Brazil. An example of a more recent application that generates strategically and tactically integrated plans, also developed in close cooperation with the university as a research project, and effectively applied by many companies was presented by Banhara et al. (2010).

The same Table (4) also refers in the design phase to software that reads data from relational databases that integrate information from different data modules like the register (a catalogue of forest stands and historical series of plantation cycles), forest inventory, GIS and operational data logs. These databases have been developed in Brazil according to relational database principles developed by experts cooperating with research projects in Brazilian and Portuguese universities. Such initiatives have been published in Brazilian forestry journals (Miragaia et al. 1999; Nobre et al. 2003; Nobre et al. 2004; Nobre and Rodriguez 2005).

Several techniques incorporated as standard procedures by forest managers working in the private sector in Brazil have their origins as graduate dissertations and thesis in Brazilian universities. Most of these contributions result in papers published in Portuguese, in Brazilian scientific journals like *Scientia Forestalis*, *Cerne* and *Árvore*, for instance. The consequence is further development and modernization of forest planning techniques in Brazil that usually passes unnoticed internationally. But, the undeniable fact is that the contribution given by many graduate forestry programmes has been significant for the development and modernization of DSS forest management tools and for the management of large-scale industrial forest plantations in Brazil.

Table 4. Summary of results that characterize the forest planning process considering problem types B1, B2 and B3

Problem types		Dimensions	
B1, B2 and B3		Temporal Scale:	Long-term (strategic)
		Spatial Context:	Spatial with no neighbourhood and with neighbourhood interrelation
		Spatial Scale:	Forest level
		Parties involved	More than one DM
		Objectives:	Single/Multiple
		Goods and services:	Market wood products
Phases	**Participants**	**Methods/Tools used (if any)**	
Intelligence	Planners and non-planners from other departments, including board of directors and operational managers	(1) Spreadsheets with production goals per product type. Basically, commercial expectations are informed. (2) Also available resources like budget, machinery, investments resources are informed using spreadsheets. (3) Product expected prices, and market growing expectations and scenarios are defined using spreadsheets. (4) Interviews to clarify cost assumptions. (5) Interviews to clarify main directives and strategies like maximize net present value NPV, or maximize production, or minimize costs, etc. (6) Analysis of previous contracts to generate, for example, assumptions on alternative harvesting and thinning ages. This generates data that will be part of a model. (7) Workshops to validate the strategy. (8) In all cases data are typed into matrix generator software by the planning team.	
	Planning team (experts)	(1) Workshops and training sessions. (2) Prepare requests for goals, prices, assumptions and constraints using spreadsheets. According to 64% of our sample, goals and assumptions come from people from other departments of the company such as the board of directors, and commercial and operational managers.	

		(3) 19% of our sample shows that they create scenarios according to assumptions given in this intelligence phase.
Integration to DSS & Participation type		There is **no digital integration** in this phase; amount of data does not demand specific software. Data is taken as input to the design process. In this phase, we have a participatory process to exchange information. The aim of the participatory process in this phase is to create an environment of cooperation. Whenever possible, the expert team creates a representative model. Parties involved must agree on basic assumptions in this phase.
Design	Planning team (experts)	(1) The expert team creates a basic model in a modeling environment to the Matrix Generator software (Woodstock, Planflor, Optimber, Homemade software). (2) Software that reads data from a relational database (integrated data from the register, inventory, GIS and operational modules) and exports it to Excel spreadsheets and text files that are used as input files by Matrix Generator software. (3) VB Macros that transform data and prepare it as input to the Matrix Generator. (4) C#, SQL-Server and Oracle procedures that read data from the database, process, format and generate the preformatted components of the model (yield tables, stands current situation, prices, costs, etc.) (5) Use of the matrix generator environment to test many scenarios and objectives.
Integration to DSS & Participation type		Digital integration to other tools is intensive, aiming to provide input data that is related to stand information, inventory, costs and maps. The aim of these integrations is also to reduce 'manual data processing'. However, 9% of the respondents declared that they still have intense manual and spreadsheet preparation of data before the matrix generator processing phase. Participation here is focused on data preparation. Parties involved (operational, logistics, controllers, GIS team) participate indirectly. These parties have the responsibility to provide good quality data and they are asked to check them before planning design process starts. In this sense, this phase is characterized as a participatory process due to the fact that the model building phase depends on the previous work of other teams that share the responsibility for accuracy and data quality.
Decision	Planners and	(1) 40% of the survey respondents use graphs and tables generated by the report writer of the matrix

making	non-planners from other departments, including board of directors and operational managers	generator and solver software. These graphs and tables are discussed in workshop, or shared through e-mail in documents named ‘scenario analysis’. (2) 68% of the survey respondents complement their analysis using graphs and dynamic tables built in Excel®
	Planning team (experts)	Calculation and preparation of tables and graphs to compare scenarios using Excel® or the Matrix Generator specific tools.
Integration to DSS & Participation type		The survey showed the existence of three different participatory decision processes: (1) All scenarios are submitted to all parties in a workshop or meeting and the group chooses which scenario is the best depending on company’s strategy. (2) The planning team chooses the best scenarios and presents the advantages of each one in a report or in a meeting. Then, a small group (or the company main stakeholder) chooses the best. (3) The planning team chooses the best according to predefined criteria and validates it in a small group of DM such as the board of directors.

Table 5. A description of how knowledge management tools are used along the planning phases in planted industrial forests in Brazi

Intelligence phase		
The basic KM tools used in this phase are: (i) a set of pre-defined and pre-formatted spreadsheets to contain, organize and share information about goals, prices, objectives and assumptions; and (ii) workshops and interviews to clarify information and share responsibility on goals and objectives. The same set of knowledge management tools is used in this phase, independently from the decision support system used in subsequent phases.		
Design phase		
DSS main component	**Description**	**Use of KM Tools & Techniques**
1 – Simulation systems	DSS based on data analysis and simulations using VB Macros, Delphi, etc.	(1) DBMS MS SQL-Server® modular systems to store and manage stands information (register), inventory and operational data. (2) Agents programmed in Transact-SQL to retrieve data from database sent afterwards to Excel spreadsheets to be analyzed. (3) Excel back to register and inventory modules.
2 – Homemade optimization system	DSS based on optimization techniques. Matrix generator programmed by internal team of experts.	(1) DBMS MS SQL-Server® modular systems to store and manage stands information (register), inventory and operational data. (2) Agents programmed in MS VB Excel to treat information and prepare to be used in a Matrix generator.
3 – *Optimber* and *Planfor*	DSS based on Linear Programming optimization techniques. Matrix Generator programmed and supported by a local software provider.	(1) DBMS MS SQL-Server® and Oracle® modular systems to store and manage stands information (register), inventory and operational data. (2) Excel to manage data from register and inventory modules. (3) Agents programmed in Transact-SQL and in Oracle® language to retrieve data from database sent afterwards to Excel®. From Excel® data is formatted to become part of the model.
4 – *Woodstock* & *Stanley*	DSS based on Mixed integer Programming optimization techniques. Matrix Generator and modeling environment programmed and supported by a Remsoft (global	(1) DBMS MS SQL-Server® and Oracle® modular systems to store and manage stands information (register), inventory and operational data. (2) Agents programmed in Transact-SQL and in Oracle® language to retrieve data from database which is sent afterwards directly to become part of a model.

	software provider).
Decision-making phase	
The basic KM tools used in this phase are: (i) a set of spreadsheets containing graphs and tables, organized in such way that can be used to share information about calculated scenarios; (ii) a set of graphs and tables produced for instance by Woodstock and Stanley analytic environments to share results and explore other scenario calculations; (iii) workshops where the expert team presents scenario results. The same set of knowledge management tools is used in this phase, independently from the decision support system used in previous phases.	

Table 6. Summary of results that characterize the forest planning process considering problem type B4

Problem types		Dimensions	
B4		Temporal Scale:	Long-term (strategic)
		Spatial Context:	Spatial with no neighbourhood and with neighbourhood interrelation
		Spatial Scale:	Forest level
		Parties involved	More than one DM
		Objectives:	Single/Multiple
		Goods and services:	Market non-wood and wood products; and market and non-market services
Phases	**Participants**	**Methods/Tools used (if any)**	
Intelligence	Brazilian Forest Service	Public forests in Brazil are regulated by the Law for the Management of Public Forests, which determines the annual preparation of a document called PAOF (SFB 2010), an acronym in Portuguese for Forests Concession Annual Plan. The PAOF plan is annually prepared and establishes which public forests will become available for concessions in the next year. The document is annually prepared by experts in the Brazilian Forest Service ('SFB'), a branch of the Brazilian Ministry of Environment. A registry of all public forests is maintained by the SFB. Most of these forests are legally bounded to provide protection and sanctuary for biodiversity and communal cultures. Some, like National Forests, are available for sustainable forest management.	
	Planning team (experts)	An expert team in the SFB collects national and regional data using GIS and spreadsheets as the main tools for data compilation and analysis. Meetings involving many representatives from federal and state agencies – in charge of issues related with the environment, transportation infrastructure, energy, agriculture etc – are held to evaluate interactions and common objectives.	

		Many public hearings are held annually to discuss the possibilities of opening certain areas in National Forests for concessions.
Integration to DSS & Participation type		The process does not benefit from systems that integrate data. Participatory processes try to exchange information. Expert teams involved do their best to figure out relevancies and to establish reasonable conditions to filter the overwhelming amount of information that will indicate which areas in National Forests will contribute the most for regional and local development.
Design	Planning team (experts)	A catalogue of data describing all public forests in Brazil maintained by the BFS is filtered to provide a list of forests bounded to provide legal and justifiable concession offers. An expert team in the Brazilian Forest Service relies basically on exploratory tools provided by Excel spreadsheets and GI systems.
Integration to DSS & Participation type		The designing process is manual in terms of processing data collected from several sources, including reports produced in many public hearings and meetings with local communities.
Decision-making	Brazilian Forest Service	No formal DSS is used Basic filtering of the data provided in previous phases constitutes a set of basic rules that are used to identify the list of forests that becomes available for concessions auctions in a specific year. A provisional document is produced and submitted to public hearings again until an agreement is reached. Suggestions collected during the public hearings are integrated in a final version of the document, which is signed by the Minister of Environment and published in July every year.
Integration to DSS & Participation type		Although not supported by modern information technology, the process is reasonably well integrated to participatory process.

3.4 Discussion and conclusions

The regular use of Forest Decision Support Systems in Brazil is still confined to a very small group of users, most of them working exclusively for the pulp and paper industrial sectors. Very few of these systems tend to be complex applications, relying heavily on modern information technologies. In fact, most of them are still struggling to incorporate the full potential of mathematical optimization, multi-objective techniques, expert system support etc.

Results show that there is plenty of space for the development of knowledge management tools and decision support systems in Brazil. The issue of how successfully the developed tools have addressed the Brazilian problem types reported in this chapter has to take into consideration the context in which such solutions have been generated. The vast majority of techniques used by professionals in the area have been developed and extracted from research projects conducted by graduate students, researchers and professors working in universities in Brazil, who also have benefited from working in close collaboration with researchers in other universities outside Brazil. Most of the forest planners currently using DSS tools for the management of large-scale forest plantations in Brazil have either been co-authors or graduate students who developed the data or problem modelling techniques themselves. So, basically, the situation in Brazil can be summarized as an ongoing educational process that, in close cooperation with research activities and graduate programs in the main Brazilian universities, introduces regular and gradual improvements to the DSS forest management tools that have been used to solve all problem types reported in this chapter.

Expert teams using more advanced optimization techniques and working in the industry sector, are more motivated and have better access to more updated information technology. The survey among forest managers of industrial planted forests reveals that the planning process involves collaborative participation. There is involvement of many decision makers in all phases, and there is exchanging of information and sharing of responsibilities.

The whole process of planning and managing public forest concessions, characterized as problem type B4, can immensely benefit from more elaborate decision support systems and from the integration with modern information technologies. The enforcement of the legal framework to professionally manage public forests is still a recent event in Brazil, and some innovative initiatives can be foreseen in the near future.

References

Banhara, J.R., Rodriguez, L.C.E., Seixas, F., Moreira, J.M.M.A.P., Silva, L.M.S., Nobre, S.R. and Cogswell, A. 2010. Agendamento otimizado da colheita de madeira de eucaliptos sob restrições operacionais, espaciais e climáticas. Scientia Forestalis (IPEF) 38: 85-95.

Miragaia, C., Borges, J.G., Rodrigues, F.A. and Rodriguez, L.C.E. 1999. Uma aplicação do sistema in Flor na gestão de dados florestais. Circular Técnica IPEF 190: 1-6.

Nobre, S.R., Rodriguez, L.C.E., Assis, M. L. R. and Amaral, T.M. 2003. Avaliação do uso da tecnologia da informação nos sistemas de administração da produção florestal. In: 8o Congresso Florestal Brasileiro, 2003, São Paulo. Informações Gerais e Trabalhos Voluntários. São Paulo: SBEF e SBS.

Nobre, S.R., Rodriguez, L.C.E., SILVEIRA, L.E.S. and SIMÕES, G.D.O. 2004. Componentes básicos de um modelo relacional de dados para a gestão florestal. Silva Lusitana 12: 103-117.

Nobre, S.R. and Rodriguez, L.C.E. 2005. A relational data model for the generation of large-scale forest scheduling problems. In: Symposium on Systems Analysis in Forest Resources, 2003, Stevenson. PNW General Technical Report. Portland: USDA - Forest Service, 656: 299-306.

Rodriguez, L.C.E. and Lima, A.B.N.P.M., 1985. A utilização da programação linear na determinação de uma estratégia ótima de reforma de um talhão florestal. IPEF. Instituto de Pesquisas e Estudos Florestais, Piracicaba, 31: 47-52.

Rodriguez, L.C.E. and Moreira, R. M. E. 1989. Gerenciamento de florestas de *Eucalyptus* com modelos de programação linear. Série Técnica. Instituto de Pesquisas e Estudos Florestais, Piracicaba, 6: 1-15.

SFB, 2010. Plano Anual de Outorga Florestal – 2011. Serviço Florestal Brasileiro, Brasília, DF 85 p.

4 The development and use of forest management decision support systems in Canada

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4.1 Introduction

Canada is the world's second largest country with an area of 9,984,670 km^2. It is a federation of 10 provinces (Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Nova Scotia, Ontario, Prince Edward Island, Quebec and Saskatchewan) and three territories (Northwest Territories, Nunavut and Yukon Territory).[7] Figure 1 is a map of the provinces and territories of Canada, overlaid with a map of its forest ecozones which are described below.

The largest province is Quebec which covers an area of 1,542,056 km^2 and the smallest is Prince Edward Island (PEI) with an area of only 5,660 km^2. The population of Canada on 1 January 2011 was 34,278,406 (Statistics Canada 2011). The most populated province is Ontario, which had a population of 13,282,444, and the least populated province is Prince Edward Island which had a population of 143,481 at that time. The 1 January 2011 populations of the Northwest Territories, Nunavut and Yukon were 43,554; 33,303 and 34,306 respectively.

There are many different ways of describing and classifying forest land and the National Ecological Framework for Canada (Ecological Stratification Working Group 1996) is often used to classify forest land in Canada. Ecozones are large and very generalized, having roughly the same land features, climate and organisms throughout them (McGill University 2011). Canada has 20 ecozones, 15 of which are terrestrial and five of which are marine. The 11 forest ecozones are shown in Figure 1.[8]

7The primary difference between provinces and territories is that provinces exercise powers that are based on the Constitution Act of 1867, whereas the territories exercise powers delegated to them by the federal government which is commonly referred to as the Government of Canada.

8 See http://canadianbiodiversity.mcgill.ca/english/ecozones/index.htm for a description of the location, climate, geology and geography, flora and fauna, human population and representative photographs of representative locations within each ecozone. The Atlas of Canada, a web-based catalogue of maps of Canada which is maintained by the federal government's Department of Natural Resources Canada (NRCan), includes maps of many social, economic and ecological aspects of Canada's forests (http://atlas.nrcan.gc.ca/auth/english/maps/environment/forest).

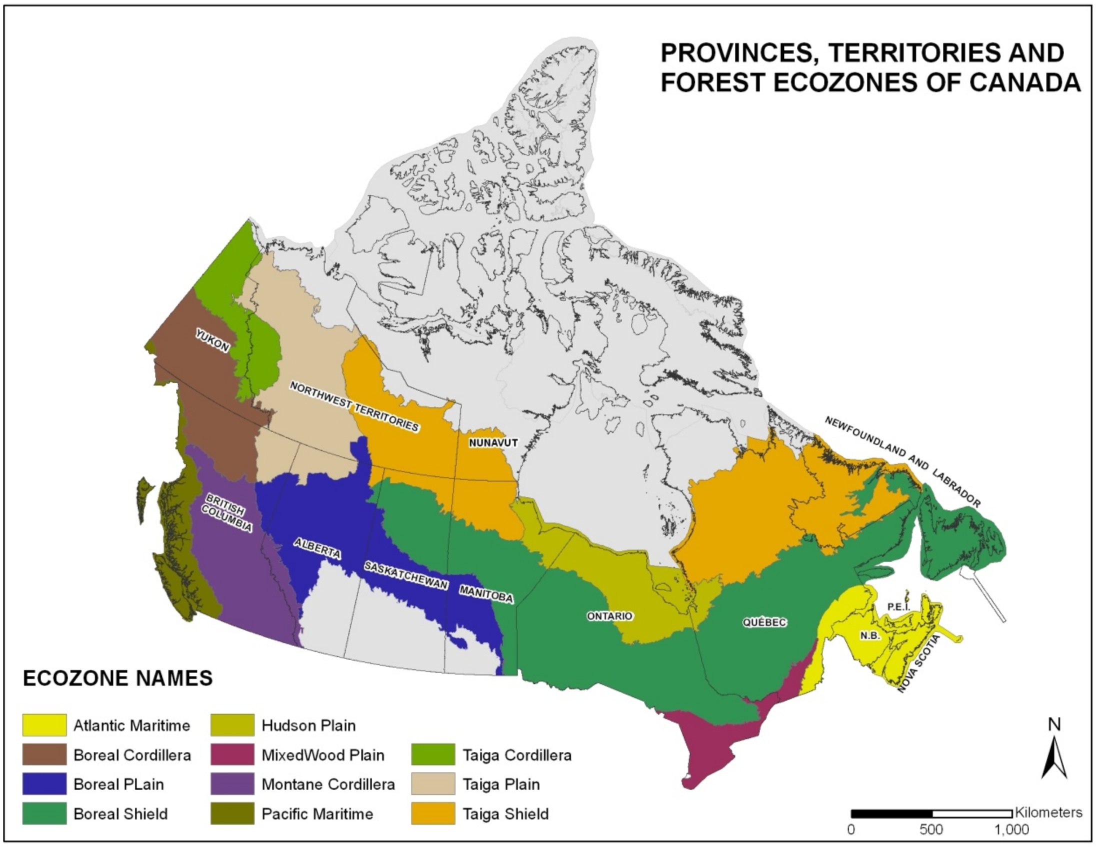

Figure 1. Map of the provinces, territories and forest ecozones of Canada.[9]

Canada has 418 million ha of forested land, of which 244 million ha are classed as being capable of being used for timber production, with approximately 89% publicly owned and 11% privately owned (Rotherham 2003).

In terms of forest harvesting activities, Canada has one of the world's largest forest economies[10]. Total sector revenues are approximately C$57 billion. Total exports are approximately C$26 billion including pulp (C$7.3 billion), paper (C$10.0 billion) ,lumber (C$5.2 billion), panels (C$1.5 billion) and other wood products (C$2.0 billion) . Total direct employment is 237,000 people. Biomass combustion currently contributes to about 6% of Canada's energy requirements[11] and this use is expected to grow.

The federal government, provinces and territories are responsible for the stewardship of the public forest land under their jurisdiction. Each of the provinces and territories is unique with respect to the ecozones in which its forest lies, the bio-geophysical processes that influence the ecological process that shapes them, how they were managed in the past and how they are currently managed. It is therefore not surprising that those governments have developed and implemented forest policies that share many common

9 Prepared by L. Zang by overlaying the Agriculture and Agri-Food Canada (2008) national ecological framework map of the ecozones of Canada on the Natural Resources Canada (2008) map of the administrative boundaries of Canada.

10 The statistics in this paragraph are taken from the Forest Products Association of Canada website www.fpac.ca/index.php/en/industry-by-the-numbers/ where more detailed information is also available.

11 See http://canmetenergy.nrcan.gc.ca/bioenergy-systems/1791 for more details.

features, but vary, to some extent, from jurisdiction to jurisdiction as each level of government implements policies that it feels will best meet the needs of its citizens.

Typically, large forest enterprises have had some form of land tenure on Crown land, a land tenure that implies a right to certain harvests but also often implies responsibility for land management and silviculture. Tenure arrangements are currently under active discussion in many Canadian provinces and are likely to emerge in somewhat different forms from the present. Understanding the true impact of alternative tenure arrangements is a pressing area of concern.

While private landownership represents only 11% of the Canadian total, private land is typically the most productive and most accessible land, producing 19% of the total Canadian harvest (see Rotherham 2003). The extent to which forest land is privately owned varies significantly from province to province, with the smallest provinces (New Brunswick, Nova Scotia and Prince Edward Island) having the highest proportion of private land holdings. However, private landholding is significant across the country. The total amount of productive private forest land in Canada is approximately 25 million ha, larger than the total amount of productive forest land in Finland, for example.

Although most of the public forests of Canada and the land on which they grow are viewed as provincial resources that are administered by the provincial governments, there are some exceptions, the most significant of which is some relatively small parcels of land, notably national parks (which cover a total of approximately 225,000 km^2 or roughly 2.2% of the area of Canada) which remain under the jurisdiction of the federal government[12]. The federal government has passed the jurisdiction of non-national park forest land in the territories over to the territorial governments that administer those forest lands, much like the provinces administer their forest lands. Since Canada is a constitutional monarchy, publicly owned land is commonly referred to as Crown land.

4.1.1 Canadian Council of Forest Ministers (CCFM)

Canadians have long recognized the importance of inter-governmental collaboration and cooperation to meet provincial, territorial, national and global concerns. That sentiment is perhaps best reflected in the existence of the Canadian Council of Forest Ministers (CCFM), which was established in 1985 to serve, in its own words, as "an important forum for the federal, provincial and territorial governments responsible for forests to work cooperatively to address major areas of common interest" and to provide "leadership on national and international issues and sets direction for the stewardship and sustainable management of Canada's forests" (CCFM 2010).

Canadians have a deep commitment to sustainable forest management (SFM). Canada participated in a 1992 multinational seminar on criteria and indicators (C&I) in Montreal which led to the development of what is referred to as the 'Montréal Process' and supported SFM at the 1992 UN Conference on Environment and Development in Rio de Janeiro, Brazil. The CCFM followed up on that commitment by developing its first national C&I framework which was released in 1995 and subsequently refined in 2003. Those C&I are described in CCFM (2003) and their use is described in CCFM (2008). That report describes how those C&I are applied at national, provincial, territorial and local levels. From a forest management planning perspective the C&I have, in the words of the CCFM "been used as the basis for developing local level indicators (LLI) of SFM that are meaningful at a local scale; in turn, the LLI help guide planning, data

12 Note that the provincial and territorial governments have also developed and maintain many parks and protected areas on the forest land under their jurisdiction.

collection, reporting and decision-making to meet provincial regulatory requirements for SFM" and for forest certification purposes.

4.1.2 The role of First Nations in forest management in Canada

Aboriginal peoples inhabited the portion of North America that is now Canada for thousands of years prior to European colonization, but they had virtually no impact on forest management planning until very recently. Some of the First Nation peoples signed treaties with the British Crown and the federal government assumed responsibility for those treaties after the founding of Canada. Others never signed such treaties, and to this day there are First Nation communities that are negotiating with federal and provincial governments to develop agreements that will address, for example, how they will be compensated for land they no longer control and how they will benefit from natural resource development.

In the past, First Nations people were largely ignored when forest management plans were developed and implemented and the construction of forest access roads and harvesting activities often disrupted their hunting, fishing, trapping and other traditional land use activities. Canada's recognition that it treated its First Nations people poorly in the past and that it must right past wrongs is reflected in many ways (see for example, Government of Canada 2011) including the extent to which they must play a significant role in forest management planning and the extent to which forest management must address their needs and aspirations as well as traditional economic concerns.

Two court rulings have played a very important role in clarifying aboriginal rights with respect to forestry and other natural resources. The 1997 Delgamuukw ruling of the Supreme Court of Canada pertains to First Nations in the province of British Columbia that did not sign treaties. One of the most important provisions of that ruling is that it provided First Nations with title to some forest lands and it laid out strict guidelines for consultation with all indigenous peoples in Canada. Another landmark court decision is what is referred to as the Marshall ruling of the Supreme Court, which affirmed gathering rights that are now interpreted by some as the right of First Nations people to harvest timber on their traditional lands.

Those new realities are perhaps best reflected in the CCFM's Criterion 6: Society's Responsibility, which pertains to fair and effective resource management choices and includes indicators designed to serve as measures of the extent to which First Nations people and their aboriginal and treaty rights are respected, and the extent to which they are consulted and their traditional ecological knowledge informs forest management.

4.1.3 Forest certification

Forest certification has been widely adopted within Canada's forest sector in keeping with a commitment to sustainable forest management. In its 2008 Statement on Forest Certification Standards in Canada, the Canadian Council of Forest Ministers stated that "Governments in Canada support third-party forest certification as a tool to demonstrate the rigour of Canada's forest management laws, and to document the country's world-class sustainable forest management record".

All of the members of the Forest Products Association of Canada (FPAC) and many organizations that are not members of FPAC are third-party certified using one or more of:

1) the Canadian Standards Association (CSA) Sustainable Forest Management System (SFM) standard

2) the Forest Stewardship Council (FSC) standard
3) the Sustainable Forestry Initiative (SFI).

As of mid-year 2011, a total of 151,121,853 ha had been so certified (Certification Canada 2011). Canada now has the largest area of third-party certified forest land in the world.

4.1.4 Forest management planning on Crown land in Ontario

As was noted above, most of the forest land in Canada is publicly owned and administered by provincial and territorial governments which refer to the publicly owned land under their jurisdiction as Crown land. The policies and procedures that govern the management of Crown land vary from province to province and territory to territory, based on the form of tenure that provides forest companies with access to the forest resources on that land over extended planning horizons subject to their adherence to the terms and conditions of their tenure agreements.

We chose to focus on the management of Crown land in the province of Ontario to illustrate how one of the 10 provinces and three territories establishes and implements the planning processes that guide the management of the forest land under its jurisdiction. However, every province has in place its own approach. In terms of wood supply estimation, the CCFM, under its National Forestry Database program, compiled a brief description of each province's approach in the Canadian Council of Forest Ministers (2005) report. That report provides a brief outline of the forest conditions and forest sustainability issues that affect wood supply in each province and the decision support tools available. Although the report was issued in 2005, it probably is more representative of the situation about three to four years earlier.

Ontario's approach to forest management planning is described on the Ontario Ministry of Natural Resources' publicly accessible website entitled Forest Management Planning in Ontario (www.mnr.gov.on.ca/en/Business/Forests/2ColumnSubPage/STEL02_163511.html). The province of Ontario covers an area of 1,076,395 km^2, 71 million ha of which is classed as forested land and 90% of the forested land is publicly owned Crown land. Roughly 26 million ha of that Crown land (which is referred to as the Area of the Undertaking (www.mnr.gov.on.ca/en/Business/Forests/1ColumnSubPage/290572.html) (or the AOU)) is managed for the production of timber and other forest resources.

The Crown Forest Sustainability Act (CFSA) and the Environmental Assessment (EA) Act constitute the legislative framework for forest management in Ontario. Ontario's commitment to sustainable forest management is addressed in the CFSA, the purpose of which is "to provide for the sustainability of Crown forests and, in accordance with that objective, to manage Crown forests to meet social, economic and environmental needs of present and future generations" (OMNR 1994).

The EA Act prescribes the processes that govern the formal approval of forest management activities, such as the type of public consultation that must take place during the planning process, the construction of forest access roads, harvesting operations and forest renewal and tending. The administration of the EA Act falls under the jurisdiction of the Minister of the Environment who in effect, oversees the environmental impact of forest management activities that are administered by the Minister of Natural Resources. That oversight is perhaps best reflected in the Class EA approval for forest management activities by which the Ministry of the Environment (MOE) stipulates how the OMNR will carry out and administer forest management in Ontario.

The EA Act allows the MOE to approve "some classes or groups of projects that are carried out routinely and have environmental effects that can be predicted and mitigated, have approval under the EA Act through a Class EA". Forest management on Crown land in Ontario is carried out under what is referred to as Ontario's Forest Management Class Environmental Assessment. The Class EA allows the OMNR to proceed without carrying out a formal environmental assessment of every forest management activity that takes place, on the assumption that all such activities will adhere to the provisions of the Class EA.

The OMNR's Forest Management Planning in Ontario website (www.mnr.gov.on.ca/en/Business/Forests/2ColumnSubPage/STEL02_163511.html) describes how it carries out forest management planning under the terms of the Class EA. The MOE first granted approval of the Class EA for a nine-year period beginning in 1994. That approval was extended in 2003 with Declaration Order MNR-71 (www.downloads.ene.gov.on.ca/files/eaab/mnr71_forest_class_DO.pdf) (which is referred to as the OMNR's Forest Management Class EA Approval) which contains 55 conditions that the OMNR must adhere to when carrying out forest management, including the preparation, review and approval of forest management plans. The OMNR's planning process is described in its Forest Management Planning Manual (www.mnr.gov.on.ca/en/Business/Forests/Publication/MNR_E000215P.html) which is a regulated manual under the CFSA. The OMNR must report to the MOE on the Class EA every five years and Amending Order MNR-71/2 (www.downloads.ene.gov.on.ca/files/eaab/mnr71_2forest_classamend_DO.pdf) is the current version of the Class EA. The Class EA requires the OMNR to "develop and implement guides, policies and scientific studies that provide direction and information to be used in forest management planning and includes reporting requirements".

The OMNR's Forest Management Plans website: (www.mnr.gov.on.ca/en/Business/Forests/2ColumnSubPage/STEL02_163549.html) presents an overview of how forest management is carried out on Crown lands in Ontario. Most of the forest land that is used for timber production in Ontario is partitioned into what are described as management units (MU) that are managed by forest companies under Sustainable Forest License (SFL) agreements. The SFL agreements govern many aspects of the management of the MU (e.g., harvesting and renewal) and require the company to submit a 10-year plan that is to be "prepared in an open and consultative fashion by a Registered Professional Forester with the assistance of a multi-disciplinary planning team and a local citizens' committee, as well as with input from Aboriginal communities, stakeholders and interested members of the public". The planning process calls for the formation of a planning team that must carry out extensive public consultation and allow for a local citizens' committee (LCC) to assist the planning team and the appointment of representatives of the LCC and Aboriginal communities to the planning team.

The 10-year plan is a comprehensive plan that must include both a long-term strategic plan and a short-term operating plan. The planning team is expected to use "long-term model projections" to investigate the potential impact of "different levels of harvest renewal and tending…to predict the short, medium and long-term economic, social and environmental benefits" of the proposed management strategy. The short-term operating components of the plan must describe where forest access roads will be established and where harvesting, renewal and tending will take place for the first two five-year periods of the plan. The OMNR and the forest companies that manage MUs under SFLs make extensive use of computer-based forest management decision support systems (FMDSS) to inform their planning processes.

4.1.5 The use of FMDSS for strategic forest management planning in Ontario

Forest companies that develop plans for their SFL MUs in Ontario must use a strategic forest management planning model that has been approved by the Director of the OMNR's Forests Branch but they are free to supplement their use of one or more of the approved models with models that have not been so approved. Currently, the following models have been approved for forest management planning on Crown land in Ontario:

1) the OMNR's Strategic Forest Management Model (SFMM) (www.aimms.com/references/case-studies/ontario-ministry-of-natural-resources-forestry)
2) Forest Ecosystems Solutions' Forest Simulation and Optimization System (FSOS) (www.forestecosystem.ca/index.html)
3) Spatial Planning Systems' Patchworks™ (www.spatial.ca).

The use of those FMDSS is of course supported and augmented by many other forest management planning tools including forest growth and yield models, forest inventory data and spatial planning database systems that are beyond the scope of this report.

The FORSYS framework classifies forest management planning problems based on their spatial scale, temporal scale, spatial context, objectives, parties involved and goods and services considered. Table 1 describes the four most common categories of planning problems associated with forest management in Canada with respect to the FORSYS attributes.

4.2 Materials and methods

Forest management planning decision support systems (FMDSS) are used throughout the forest management hierarchy from high-level strategic policy development and evaluation initiatives to use of on-board computers to determine optimal bucking patterns. Unfortunately, most use is not well documented in the open literature for many reasons, including: 1) government analysts are not always able to share the results of detailed quantitative analyses of the alternatives they evaluate in the course of developing new policy initiatives 2) private sector companies are understandably reluctant to share the results of such analyses for competitive reasons and 3) the analysts involved seldom have the time or resources to publish their work in the peer reviewed literature. However, most forest land in Canada is publicly owned and all Canadian governments ascribe to the CCFM C&I for SFM which call for extensive public consultation on the development and approval of strategic forest plans for forest management units or what forest management planners commonly call estates. We have therefore chosen to focus our review of the use of FMDSS in Canada on such problems.

Table 1. The four most common types of Canadian forest management planning problems characterized with respect to the FORSYS problem type attributes.

Problem	FORSYS problem type attributes	Comments
Provincial policy analysis	Regional level Strategic Non-spatial Multiple objectives Multiple stakeholders Multiple goods and services	Provincial governments use FMDSS to inform policy development. For example, several provincial governments have recently or are currently exploring the development of new forest tenure systems.
Strategic non-spatial plan for a forest management unit	Forest level Strategic Non-spatial	Forest companies that are granted tenure must periodically (every 5 or 10 years) prepare and submit plans

	Multiple objectives Multiple stakeholders Multiple goods and services	for provincial government approval and/or forest certification purposes over rolling planning horizons.
Strategic spatial plan for a forest management unit	Forest level Strategic Spatial Multiple objectives Multiple stakeholders Multiple goods and services	Some agencies now stipulate that some spatial detail be included in their strategic plans.
Spatial harvest operating plans	Forest level Operational Spatial Multiple objectives Multiple stakeholders Market wood products	Forest companies must develop spatially explicit plans that are linked with or embedded in their strategic plans, that specify when and where they will construct forest access roads and carry out harvesting and silviculture activities during the first few (typically 5 or 10) years of their planning horizon.

Given the size of Canada (9,984,670 km^2), the number of political jurisdictions (the federal government, 10 provinces and three territories), the size of its forests (418 million ha), their biodiversity (11 forested ecozones), ownership (public and private), use (e.g., production of timber and non-timber products and protection) and the many stakeholders (e.g., the public, companies, environmental NGOs and First Nations) that shape how Canada's forests are managed and used, it's not surprising that there is no comprehensive documentation of the development and use of the many FMDSS that are used to help determine how Canada's forests should be managed.

Our primary objective was to provide our readers with an overview of the development and use of forest management decision support systems (FMDSS) in Canada. We had neither the desire nor the ability (see below) to catalogue and describe all of the many FMDSS that have been developed and used in Canada. Our aim was to focus instead, on FMDSS that are widely used on an ongoing basis, the best examples of which are the strategic forest-level planning models that are used by most provincial governments. Our initial intent was to describe only FMDSS that had been implemented, but we very quickly realized that it would not be possible for us to validate the extent to which many FMDSS have been truly implemented so we included in our report, descriptions and discussions of some FMDSS that have or appear to have been used by at least one decision-maker or organization. Our selection of FMDSS to cover in that way was guided primarily by our personal knowledge of what FMDSS have been developed and/or used, what we discovered in the course of preparing this report, and our desire to highlight FMDSS needs that are representative of the breadth and scope of Canada's FMDSS needs.

We used an unstructured multi-faceted approach to compile information on the development and implementation of FMDSS in Canada. Both of us have been involved in many aspects of forest management and the development and use of FMDSS in Canada for more than 30 years. We have carried out research, taught forestry professionals and others, participated in government advisory groups, evaluated research grant proposals, refereed journal manuscripts, attended conferences and seminars focused on FMDSS applications in forestry and studied and contributed to the forest management planning research literature. Given our backgrounds we are reasonably knowledgeable about what FMDSS are used by most Canadian government agencies, but since we are both academics and most companies do not discuss their FMDSS initiatives publicly, we are much less familiar with the development and use of FMDSS by forest companies.

We began by preparing an itemized list of FMDSS developments and uses based on our experience and then enhanced our knowledge by 1) contacting government and forest industry representatives we knew would be familiar with the FMDSS used in their organizations 2) contacting representatives of a small number of consulting companies that we knew were engaged in the development and use of FMDSS in Canada and 3) engaging a research assistant who used internet resources to compile information on the many Canadian government agencies that are responsible for the administration of Crown land. We also made extensive use of internet search engines to find peer-reviewed and other publications that describe the development and/or use of FMDSS in Canada.

4.3 Results

FMDSS are used by many organizations for many purposes in the Canadian forest sector. Since most of the forest land in Canada is publicly owned Crown land that is administered by provincial and territorial governments we decided to begin by describing what FMDSS are used for strategic timber supply analysis. We then describe several FMDSS that have been used in different parts of Canada. Since there are many small companies that provide forest management planning services to both small and large clients, we then provide a brief overview of that sector of the Canadian forest sector, and illustrate how those companies perform by describing one of the many companies in that sector. We then describe the FMDSS that have been developed by FPInnovations, a large forest research organization and two FMDSS developed and used within the academic community.

4.3.1 Use of FMDSS for strategic timber supply analysis on Crown forest land in Canada

FMDSS methods have a long history of use for strategic analysis of timber supply in Canada (Canadian Council of Forest Ministers 2005). A particularly vivid recent example is the report of the New Brunswick Task Force on Forest Diversity and Wood Supply, chaired by Thom Erdle (Erdle and Ward 2008). The task force carried out a quite detailed analysis of diverse strategic alternatives. Part 3 of the report gives a discussion of how analytic techniques were used to shed insight on these alternatives. Although not stated explicitly, much of the analysis was carried out using Woodstock™-based linear programming models. This work forms part of an active public debate, which is still ongoing as New Brunswick continues to develop its forest strategy (see http://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/CrownLandsForests/Erdle/ErdleReport-e.pdf).

Canada's forest land is managed by one federal, 10 provincial and three territorial governments and many companies and individual land owners that are responsible for their privately owned land under a diverse array of policies and procedures using many different decision support systems. We chose not to report on the use of FMDSS by private land owners because it would be very difficult to determine who uses what and because such a small portion of the forested land is managed by such individuals. We provide an overview of the use of FMDSS for tactical and operational planning by forest companies below, keeping in mind that most companies have neither the desire nor the resources to share what they do outside their organizations.

Most of Canada's forest management planning efforts are directed towards strategic planning of the management of Crown land. The federal provincial and territorial governments are ultimately responsible for the stewardship of such land, but much of that land is managed in collaboration with forest companies.

The policies and procedures, the roles of the many players involved and the FMDSS that are used vary across the country and over time. Fortunately, Canada's National Forestry Database Program's Technical Subcommittee on Reporting Wood Supply compiled a comprehensive overview of the policies, procedures and methods that are used to carry out strategic timber supply analysis in each jurisdiction (Canadian Council of Forest Ministers 2005). Table 2 is based on that report which in the words of its authors provides "an overview, by jurisdiction, of the wood supply situation in Canada. It includes the history of wood supply estimation and regulation, the current inventory situation, analysis methods, and issues that influence wood supply determinations." They point out that "across the country there is a high degree of consistency in policies, administrative procedures, and technical approaches in the regulation of harvest levels and forecasting of wood supply on provincial lands. However, there is considerable variability in the details of the ways these policies are applied." Column 2 of Table 2 which shows what FMDSS was used to provide wood supply estimates by province and territory is based on the contents of that report. We encourage interested readers to study CCFM (2005) which addresses the use of FMDSS for timber supply analysis on Crown land in Canada in far more detail than we can provide in this chapter. Please note however, that both CCFM (2005) and Table 2 are national 'snapshots' of what Canadian government agencies used to produce the 2005 timber supply analysis and do not necessarily reflect the current use of FMDSS in Canada, which is better reflected in Table 3 in the Appendix.

Table 2. Summary description of the FMDSS that were used to produce Canada's 2005 national timber supply analysis, excerpted from CCFM (2005).

Jurisdiction	FMDSS used for 2005 wood supply analysis
British Columbia	A variety of models used
Alberta	Woodstock/Stanley™ suite of tools and Patchworks™
Saskatchewan	FORMAN, COMPLAN and Mistik Forest Management Model.
Manitoba	Woodstock/Stanley™ suite of tools and modified version of Von Mantel's method
Ontario	Strategic Forest Management Model (SFMM)
Quebec	SYLVA II simulation model
New Brunswick	Woodstock™ forest-level timber supply model
Nova Scotia	SAWS simulation model to forecast wood supply for an 80 year planning horizon.
Prince Edward Island	Woodstock™ wood supply model
Newfoundland	Woodstock™ wood supply model to compute AAC for each district by owner. Stanley™ use to produce spatial harvest schedules.
Yukon Territory	Woodstock™, Spatial Woodstock™ and Stanley™
Northwest Territories	Woodstock™

4.3.2 An overview of selected FMDSS that are used for forest management planning in Canada

In this section we present a brief overview of five of the FMDSS that are used in Canada. This list is by no means exhaustive but includes the FMDSS that are used on much of Canada's forest land.

4.3.3 Forest Simulation and Optimization System (FSOS)

FSOS, which was developed by Forest Ecosystem Solutions Limited (www.forestecosystem.ca), is a forest planning system that can link strategic, tactical and operational planning levels. It can operate in non-spatial and spatially explicit modes, with the distinct advantage of being able to model tactical harvest units and their sequencing simultaneously within long-term timber-supply projections. It considers not only traditional forest values but it also tracks all forest stands over time and identifies the contribution of those stands to the management unit's social, economic and environmental objectives. It uses meta-heuristics to solve spatially explicit forest management planning problems.

4.3.4 PatchworksTM

Patchworks™ is a spatially explicit FMDSS that was developed and is distributed by Spatial Planning Systems (www.spatial.ca) which is located in Deep River, Ontario. Tom Moore of Spatial Planning Systems describes Patchworks™ as a spatially explicit planning system that uses operational planning-level detail (GIS data) over long strategic planning horizons (typically up to 200 years). It can be used to generate operational level harvest schedules that are economically efficient and fully compliant with long-term sustainability goals. Spatial features that can be addressed using Patchworks™ include opening sizes and adjacencies, residual patch layouts, transportation logistics, road construction scheduling, and roadless area design (e.g. triad management). Patchworks™ uses stochastic meta-heuristics to generate good solutions to large intractable problems. A goal programming formulation is used to allow multiple objectives to be considered simultaneously and to allow the exploration of trade-offs between various spatial and aspatial goals. The Patchworks™ model has graphical user interface 'wizards' that can be used to configure modelling options such as targets, maps, reports and solver options. Advanced users can also use a scripting language that fully exposes the Patchworks™ and Java API. The Patchworks™ system also includes translators to import modelling problems from other aspatial planning models.

Patchworks™ is used across Canada by government agencies, forest companies and consulting firms. Most of the government clients are the analysis departments of natural resource management agencies, where Patchworks™ is used for policy analysis and in support of sustainable development plans. Industrial customers are typically large multinational firms that are managing one or more large forest estates of 500,000 to several million hectares in size.

4.3.5 SELES

The Spatially Explicit Landscape Event Simulator (SELES) is a raster-based simulation modelling environment that can be used to develop cellular automata, natural disturbance, habitat suitability and population models (Fall and Fall 2001). It was originally developed at Simon Fraser University and has been used extensively in British Columbia (BC) to support land-use planning exercises, timber supply projections for allowable annual cut determination, habitat supply projections and with great effect in projecting the population dynamics and provincial forest impacts of the mountain pine beetle. SELES has also been used across Canada and internationally for projects ranging from habitat connectivity, wetland/forest dynamics, sustainable forest management planning, national parks planning, and forest restoration. As a modelling environment, SELES gives the modeller the ability to adopt a modular approach using landscape events developed by others to improve the understanding of the system under examination and the interactions between components of the system.

A generic spatial timber supply model (STSM) captures the traditional components of an FMDSS, namely succession, growth, harvesting and reporting as separate landscape events. While SELES is a freely available compiled program, the STSM and other models built with SELES are generally open-source, and a community of users has developed (www.seles.info) to promote model sharing and collaboration.

4.3.6 Strategic Forest Management Model (SFMM)

Ontario's Strategic Forest Management Model (SFMM) is an aspatial strategic FMDSS that is used extensively for forest management planning in Ontario. SFMM is based on Reed and Errico's (1986) linear programming formulation of the network representation of a forest in which one can readily incorporate estimates of fire losses and other uncertain natural disturbance processes. It is a variant of what Johnson and Scheurman (1977) referred to as model II, and what some now refer to as a model III form of a forest estate linear programming model. Forest stands are aggregated into aspatial analysis units that are relatively homogeneous with respect to cover type, growth and yield and silvicultural regime. Solutions indicate how much of each analysis unit to harvest during each period to maximize some objective (e.g., volume maximization) subject to specified (e.g., harvest flow) constraints. The first version of SFMM was developed by R.G. Davis of the OMNR (Davis 1999) who drew upon and extended his M.Sc.F. thesis research (Davis 1991), which is described in Davis and Martell (1993). The original version of SFMM has since been revised and enhanced many times (see for example, Ontario Ministry of Natural Resources 2007) and is now implemented using the AIMMS modelling language/system (www.aimms.com/references/case-studies/ontario-ministry-of-natural-resources-forestry).

4.3.7 Woodstock™

The Woodstock Optimization System from Remsoft Inc. (www.remsoft.com), is a widely used suite of software for building forest management planning models. Woodstock™ provides the user the ability to model a variety of landscape themes with various development types, and to explore how these evolve under various treatment actions given quite general yield functions. The technical details of the original Woodstock™ were outlined in Walters (1993). Woodstock™ can operate in either a variety of simulation modes or as a linear programming model with quite general objective functions. The original linear programming model used a Model II framework, so that Woodstock™ was primarily an aspatial model. An accompanying package, Stanley™, enabled the users to carry out spatial analysis following initial Woodstock™ runs (Walters et al. 1999). Over time, Woodstock™ has come to include GIS capabilities as part of data management and output display. The introduction of a Model I framework in 2007 enabled levels of spatial resolution as desired by the user. A range of heuristics, mapping, graphing and reporting functions are provided to help with planning and communicating plans. Woodstock™ is not itself a decision support system; it is a modelling system. However, it is a key part of many decision support systems. All of the Canadian Provinces, except PEI, use Woodstock™ as part of their analysis capabilities as do many large commercial companies.

4.3.8 Private Canadian company involvement in forest management planning in Canada

There are many companies involved in the Canadian forest sector, and they range from very small companies that provide forest management consulting services to small private landowners and others to large corporations with operations in both Canada and abroad. Some make little or no use of what most observers consider to be modern computer-based FMDSS, many develop and/or support basic software that supports the administrative needs of companies, while others develop and or use complex FMDSS to address their clients' needs. The Canadian Forests Website (www.canadian-forests.com), which is a private initiative developed by two individuals, one of whom is an editor and another who is a forestry consultant, describes itself as "the foremost website on forests and forestry in Canada. It provides quick access to all the internet sites of the federal and provincial governments, the forest industries, service and supply companies, associations and NGOs, consultants, education and research…and much more." Its list of forest sector companies is by no means complete, but as of 3 October 2011 it listed 166 consulting companies and 34 software development companies that work in the Canadian forest sector.

One example of the many companies listed on the Canadian Forests Website is The Forestry Corp, which describes itself as "a team of natural resource management, information technology and data management professionals" that is based in Edmonton, Alberta. Its services include landscape modelling (e.g., modelling stand and landscape level attribute changes over time) and strategic plan development. It has its own in-house application development expertise and it also supports the use of FMDSS developed by others (e.g., Patchworks™ and Woodstock™).

4.3.9 The use of FMDSS by Canadian forest companies

Since most forest companies do not publicly document their development and use of FMDSS we decided to report on the FMDSS developed and supported by FPInnovations, a non-profit member organization that carries out scientific research and technology transfer for the Canadian forest industry. FPInnovations is one of the largest forest research centres in the world and has four divisions: 1) forest operations 2) wood products 3) pulp and paper and 4) the Canadian wood fibre centre.

Their FPSuite FMDSS is an integrated process control platform for forestry operations which includes four modules which can be used to help improve the efficiency and reduce the costs of many aspects of forest operations. These modules can be used independently, in conjunction with other data streams or all together in an inclusive process control platform. It includes: FPDat, FPCom, FPTrak and FPInterface. FPDat is a hardware/software package that collects and analyzes data on production activities then informs the operator and managers on performance, areas treated, productivity and real-time costs. FPCom provides communication hardware that allows data to be collected from the machines and then provided to the central office. FPTrak provides the capability of tracking the progress of production activities at a given site and conducting analyses on performance, areas treated and wood flow.

FPInterface is the decision support module which provides a GIS-based spatial planning tool together with cost and productivity predictions for harvesting, biomass, road construction and maintenance, trucking and silviculture. Over 35 years of cost and productivity studies by FPInnovations can be used as default data values for decision analysis, or the users can replace them with their own site-specific data. Based on this spatial and productivity data, FPInterface allows the evaluation of alternative schedules of operations and wood flow control. Modules include Operational Planning for sequencing forest activities and crews together with wood flow allocation to mills. The BIOS module produces estimates of biomass recoverable volumes by product type, recovery costs and energy balances. The Value Chain module, based on FPInnovations sawmill optimization software, allows the estimation of costs and income that can be generated from a cut block. The MaxTour module enables the improvement of transport efficiency by calculating how to combine loads to reduce empty trips and optimize backhaul opportunities. The Reforestation module helps calculate the net costs, present and ongoing, of the silvicultural work needed to maintain and improve the productivity of forest stands.

4.3.10 Two FMDSS that were developed and are used within the academic community

Many FMDSS have been developed within the Canadian academic community in response to needs expressed by forest companies and government agencies and/or what academics and their students perceive to be important decision-making problems and FMDSS needs to which they could apply their knowledge and expertise. It would have been very difficult for us to compile a comprehensive list of such FMDSS, but more importantly, it would have been impossible for us to document the extent to which they have actually been implemented and contributed to enhancing forest management practices in Canada. We chose instead to select two FMDSS developed by academics and have been used by others, of which we have been aware for many years. One (FPS-ATLAS) has been used primarily by companies operating in western Canada and the other (SBWDSS), has been used primarily by governments in eastern Canada. Neither is necessarily the best or the most widely used FMDSS that has emerged from academia but both have been well documented in the peer reviewed literature.

Forest Planning Studio (FPS-ATLAS) is a forest-level harvest simulation model that was developed by John Nelson in the Faculty of Forestry at the University of British Columbia. Nelson (personal communication 2011) describes FPS-ATLAS as being spatially explicit with respect to forest stands (polygons) and road networks. It was designed and can be used to schedule harvests according to a range of spatial and temporal objectives including policies that pertain to harvest flow, cut block opening size, riparian buffers, seral stage distributions and patch size distributions. Silviculture systems, rotation ages and stand growth and yield are assigned to each polygon. At each time step, polygons are first ranked according to a cutting priority (e.g., oldest first). Polygons are then harvested from this queue subject to constraints designed to meet forest level objectives (e.g., opening size and seral stage targets). Polygons are harvested until either a constraint becomes binding, the queue is exhausted or the periodic harvest target is met. At this stage the forest is aged to the next time period and the process is repeated. At each time period, the model reports the status of every polygon in the forest estate. These periodic inventories can be quickly displayed with a map viewer to assess harvest patterns and/or exported to other landscape models. Road construction, length of active road, and other indicators of road network activity related to the harvest schedule are also reported. Harvest priorities, constraints and stand and forest-level attributes are stored in a MS Access database. FPS-ATLAS provides an interface for editing the database, a module for simulating harvests plus a suite of reporting modules for growing stock, age classes and landscape metrics.

Although FPS-ATLAS has been primarily used for education and research, it has also been used by forest consultants in the technical analyses of harvest levels used to support annual allowable cut decisions in British Columbia. This includes large scale Timber Supply Areas, Tree Farm Licenses and smaller Community Forest Agreements. The model has also been used in Australia and China to help determine annual allowable cuts and growing stock levels. Research applications of FPS-ATLAS include comprehensive decision support systems for forest management planning (Seely et al. 2004) and analysis of forest road networks (Anderson et al. 2006).

The crisis atmosphere that results from significant natural disturbance can lead to the development of significant decision support systems. A major spruce budworm outbreak in New Brunswick which began in the 1950s, became the impetus for some considerable decision analysis work. The major decision, involving strategies for spraying various forms of insecticide, drew the attention of the International Institute for Applied Systems Analysis (IIASA) (see Holling et al. 1975). Although this work gave some policy insight, actual decision support required the development of the Spruce Budworm Decision Support System (SBWDSS) which was developed by Dave Maclean and his colleagues at the University of New Brunswick. Maclean (personal communication 2011) describes the SBWDSS as being designed to be used for both strategic planning (to infer potential timber supply/harvest level losses associated with alternative forest/budworm management strategies and tactics) and operational budworm insecticide spray planning (determining the highest loss areas and therefore higher priority areas for spraying) purposes. The SBWDSS consists of a Woodstock™-based wood supply model and a simulation model (PROPS) which gives the volume losses under a given spray program. The models are used iteratively and the change in wood supply gives the benefits/losses due to the adoption of a particular spray program. SWBDSS has been used for operational planning purposes in the province of Saskatchewan and for strategic planning purposes in New Brunswick. It has also been used for research purposes, primarily in the province of Quebec. The SBWDSS and its use are described in a number of publications including MacLean et al. (2001) which describes its structure and MacLean et al. (2002) which describes its use for strategic planning purposes in New Brunswick. Dymond et al. (2010) documents how it was used for research purposes in the province of Quebec.

In Nova Scotia, the crisis elicited a different response. Public opinion in Nova Scotia was opposed to spraying and none occurred, with the result that approximately 70% of the softwood volume on Cape Breton Island, the part of Nova Scotia most severely affected, was destroyed. However, even on the mainland, losses as high as 20% of volume occurred. In order to develop a strategy for using intensive silviculture to make up for this lost wood supply, the Nova Scotia Department of Natural Resources developed the Strategic Analysis of Wood Supply (SAWS) Model. This model, the development of which began in the 1980s as a mainframe-based, aspatial, highly aggregated model, focuses on site quality, stocking, diameter and height, using a broad variety of forest growth research in the Department. It continued to develop until about 2005 into a detailed model, with all stands spatially represented in a full GIS implementation and the ability to examine a variety of silvicultural policies (see Canadian Council of Forest Ministers 2005, for a brief description). The development of DSS in response to the crisis of natural disturbance continues. The mountain beetle in British Columbia presents a current example (see Shore and Safranyik 2003). The website at www.for.gov.bc.ca/hre/topics/mpb.htm serves to remind us that not all decision support consists of explicit operations research models. Although some explicit models are to be found there, much of the decision support consists of bringing together a massive amount of knowledge and analysis from a broad variety of disciplines.

4.3.11 Knowledge management

Canadian forest managers utilize a diverse array of knowledge management systems to support their forest management planning processes. Traditional forest resource inventories that have long served the needs of forest management planners are now maintained on digital spatial database platforms. The need to predict forest growth and yield over time is addressed by the development and maintenance of forest growth and yield systems that are supported by field sampling methods that vary from jurisdiction to jurisdiction.

Forest management planning on Crown land in Canada involves many stakeholders including government and company representatives, and it must be carried out in such a way that representatives of local communities, First Nations and non-governmental organizations and others can become involved in meaningful ways. Those participants need to generate and share enormous amounts of data, plans and reports, some of which are confidential to selected groups or individuals, and some of which must be widely available.

Some forest management communities have responded to such needs by developing information portals to facilitate the collection, storage and distribution of such forest management-related knowledge. One such example is the Ontario Ministry of Natural Resources' Forest Information Portal which is used to support the exchange of forest information between the Ministry of Natural Resources (MNR) and the forest industry in Ontario. The OMNR uses it to provide data and information to the forest industry and forest companies in turn use it to submit data and information to the OMNR. Examples of the type of data that is exchanged through the portal include forest inventory, forest values, topographical base features, forest operations reports, harvest volumes, maps and other forest management planning information (see http://forest.lrc.gov.on.ca/fiportal/go).

> Many Canadian provinces have made considerable investment in gathering research knowledge on their forests. Some of this knowledge becomes encoded in software that can be used for decision support purposes. For example, the province of Nova Scotia has maintained a system of 3,250 randomly located inventory permanent sample plots (PSP). Of these, 1,700 have been re-measured every five years since 1965. The remainder were established in 1996. The measurement methods are documented in MacPhee and McGrath (2006). The province also maintains a system of research PSP in managed stands. Data from these plots serve as the basis of research reports in the Department (see www.gov.ns.ca/natr/library/publications/forestry-research.asp#research). This growth research is encoded in a publicly available decision support software, the NS Growth and Yield model (MacPhee and McGrath 2006) which landowners can download to do their own analysis of growth potential of their forest. Many Canadian provinces have models that encapsulate

a large body of research and describe the development of their forests, either in the form of growth and yield models like Nova Scotia, or other forms of yield curves that are incorporated in their strategic management models. The productivity and cost information found in the FPInnovations Interface package, discussed earlier, is yet another example of this phenomenon, albeit from the private sector.

4.4 Discussion and conclusions

Canada was an early leader in the use of Operational Research (OR) methods to develop FMDSS. Paull's (1956) article entitled "Linear programming: A key to optimum newsprint production", that appeared in the January 1956 issue of the Pulp and Paper Magazine of Canada, appears to have been one of, if not the first published descriptions of an application of OR to forestry.

The use of strategic analysis models has become well established in the provincial departments of natural resources. This doesn't mean there is not a need for continued developments. One major issue is finding ways to deal with the uncertainties related to natural disturbance processes. The large areas of forested land in Canada mean that it isn't easy to control or counteract these events. Fire can be very difficult to control because of lack of road access and natural fire barriers. This means that fire events can be large both in terms of area and standing volume impacts. When insect events occur, such as the budworm or mountain pine beetle outbreaks, their effects can be substantial. How to deal with such large events that occur stochastically in the context of forest strategy remains an open question.

Until recently, provincial governments took the view that it was up to them to ensure the sustainability of the resource and up to the companies to deal with corporate strategy and the resulting investments in capacity. However, the importance of linking forest strategy and industry capacity is becoming increasingly clear. In many jurisdictions, the sustainable yields of the current strategies do not correspond to the requirements of the industry capacity either in terms of wood type (species, dimension, quality) or location. This will be exacerbated as changes from traditional products such as newsprint or commodity lumber change the nature of the wood type mix required for a changing industry. Economies of scale tend to favour large plants. Transportation costs require harvesting on locations near plants or different systems of material acquisition and distribution. How do these issues affect how we manage forests? The notion of a constant uniformly distributed supply may be open to question. Since nothing else on the landscape (protected areas, ecodistricts, watersheds) is either constant or uniform, this may raise substantial policy questions?

The CCFM's definition of sustainable forest management calls for the maintenance of the representativeness of forest ecosystems and the species diversity that has characterized Canadian forests. This can make management more complex. For example, although their forests are completely different otherwise, both Nova Scotia (NS) and coastal British Columbia (BC) have forests with a large variety of significant species (six significant softwood species and six significant hardwood species plus a host of minor species in NS; coastal BC has seven major softwood species that make up its old growth forests) and quality types. Most other countries manage only a few major species, and often in a plantation context. What does it mean when the total supply of wood is adequate for industry needs but limited markets exist for certain species/quality types? If we extend this to managing for other criteria for sustainable forest management, how do we model the requirements for "maintaining and enhancing ecosystem condition" for watershed condition among others? In particular, how do we model the effects of tenure and the ability to accept society's responsibility for sustainable management?

We know many government agencies have used FMDSS to assist with the development and evaluation of policy alternatives and we know that some forest companies also carry out their own strategic analyses. Under both certification and SFM commitments, land managers are committed to consult with their stakeholder communities. Often the black box nature of FMDSS tools precludes the public from participating fully in the discussion. However, modern graphical and GIS analysis capabilities facilitate the communication of complex spatial and temporal information. The importance of, and the need to engage the public in, forest management planning is widely accepted across the Canadian forest sector and there is ample evidence, both in legislation and in practice, that most of the organizations engaged in the management of Canadian forest land go to great lengths to actively involve the public in their deliberations. However, beyond the use of internet resources and digital mapping software, it is not clear that FMDSS are being used to enhance public involvement in forest management planning, in spite of the advances in computer hardware, software and graphics capabilities. The opportunities for the general public and NGOs to exploit the advances in FMDSS remain to be realized.

Since the 1970s, there has been a steady increase in tension between forest resource use such as recreation, wildlife habitat and biodiversity and industrial timber production. The advances in FMDSS have given practitioners and decision-makers the ability and opportunity to project the interactions to support sound forest management decision-making. A relatively new but increasingly important forest management issue is forest carbon management, and some of the FMDSS we described above have been used to address this issue. As governments and other players in the forest sector grapple with climate change scenarios, the desire to capitalize both financially and environmentally through efficient carbon management is a new and potentially important use of FMDSS which can portray forest resources and virtualize the sustainable development of the complete forest resource.

We found it very difficult to document the extent to which FMDSS are used by Canadian forest companies and impossible to determine the extent to which it has or has not enhanced forest management within Canada's forest sector. We are well aware that as academics, it would be very difficult for us to access this information, since the interaction between industry and the academic community does not occur to the same extent in Canada that it does in some other countries. However, we do not believe that Canadian forest companies have fully exploited the potential benefits of using computer-based FMDSS to enhance their performance. In countries such as Sweden, Finland, Chile and Brazil, our academic colleagues and some of their industrial partners often participate in international conferences and publish their research and document the implementation of their research in international journals. In response to this concern, the federal government, in cooperation with FPInnovations have launched a series of strategic research networks (see http://forest-foret.nserc-crsng.gc.ca/Index_eng.asp). One of these, the Value Chain Optimization Network (www.reseauvco.ca/en/) was established to develop the tools and approaches that will facilitate greater industry DSS usage.

As we noted above, the Canadian forest community is deeply committed to SFM and the use of the Criteria and Indicators of Sustainable Forest Management (C&I) to provide science-based measures of the extent to which it is being achieved. The development and use of FMDSS can and does impact the C&I. Ultimately, the value of FMDSS should be measured by the extent to which they enhance SFM as measured by these C&I. At present no such assessment is possible. One of our hopes is that those that develop and use FMDSS will accept our challenge to document not only their FMDSS development and use but also, the measures that demonstrate the extent to which they contribute to enhancing SFM.

References

Agriculture and Agri-Food Canada, 2008. A National Ecological Framework for Canada – Ecozones. Map of the ecozones of Canada. Ottawa, Canada. http://sis.agr.gc.ca/cansis/nsdb/ecostrat/gis_data.html

Anderson, A., Nelson, J. and D'Eon, R. 2006. Determining optimal road class and road deactivation strategies using dynamic programming. Canadian Journal of Forest Research. 36: 1509-1518.

Canadian Council of Forest Ministers (CCFM), 2003. Defining Sustainable Forest Management In Canada: Criteria and Indicators. Ottawa, Canada, http://www.ccfm.org/pdf/CI_Booklet_e.pdf

Canadian Council of Forest Ministers (CCFM), 2005. Wood supply in Canada, 2005 report [electronic resource]. Electronic monograph in PDF format. Ottawa, Canada, http://dsp-psd.pwgsc.gc.ca/Collection/Fo4-5-2005E.pdf

Canadian Council of Forest Ministers (CCFM), 2008. Measuring our progress: Putting sustainable forest management into practice across Canada and beyond. Ottawa, Canada, http://www.ccfm.org/pdf/CCFM_Measuring_our_progress.pdf

Canadian Council of Forest Ministers (CCFM), 2010. Marking Canada's Progress in Sustainable Forest Management. Ottawa, Canada. http://www.ccfm.org/pdf/MarkingCanadasProgressInSFM_EN.pdf

Certification Canada, 2011. Certification Status Report. Canada-wide – SFM – Mid-year 2011. Ottawa, Canada, http://www.certificationcanada.org/english/status_intentions/status.php.

Davis, R.G. and Martell, D.L. 1993. A decision support system that links short-term silvicultural operating plans with long-term forest-level strategic plans. Canadian Journal of Forest Research 23:1078-1095.

Davis, R.G. 1991. A decision support system to help forest managers design and implement silvicultural strategies. M.Sc.F. Thesis. Faculty of Forestry, University of Toronto., Toronto. 183 p.

Davis, R.G. 1999. Strategic Forest Management Model Version 1.6: user guide. Ontario Ministry of Natural Resources. Sault Ste. Marie, Ontario. Queen's Printer for Ontario, Toronto. 223 p.

Dymond, C., Neilson, E., Stinson, G., Porter, K., MacLean, D.A., Gray, D., Campagna, M. and Kurz, W. 2010. Future spruce budworm outbreak may create a carbon source in eastern Canadian forests. Ecosystems. 13: 917- 931.

Ecological Stratification Working Group, 1996. A National Ecological Framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull. Report and national map at 1:7500 000 scale.

Erdle, T and Ward, C. 2008. Management Alternatives for New Brunswick's Public Forest: A report of the New Brunswick Task Force on Forest Diversity and Wood Supply. Fredericton, Canada, http://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/CrownLandsForests/Erdle/ErdleReport-e.pdf

Fall, A. and Fall, J. 2001. A domain-specific language for models of landscape dynamics. Ecological Modelling. 141:1-18.

Holling, C.C., Dantzig, G.B., Baskerville, C., Jones, D.D. and Clark, W.C. 1975. A case study of forest ecosystem pest management. Vienna, Austria, http://www.iiasa.ac.at/Admin/PUB/Documents/WP-75-060.pdf

Government of Canada, 2011. First Nations in Canada. Department of Aboriginal Affairs and Northern Development Canada. Accessed December 1, 2011.
http://www.aadnc-aandc.gc.ca/eng/1307460755710

Johnson, K.N. and Scheurman, H.L. 1977. Techniques for prescribing optimal timber harvest and investment under different objectives - Discussion and synthesis. Forest Science, Monograph 18. Society of American Foresters, Bethesda. 31 p.

Kloss, D. 2002. Strategic Forest Management Model, Version 2.0 user guide. Ont. Min. Nat. Resour., For. Manage. Br., For. Manage. Plan. Sect., Toronto, ON. 264 p.

MacLean, D.A., Erdle, T.A., MacKinnon, W.E., Porter, K.B., Beaton, K.P., Cormier, G., Morehouse, S. and Budd, M. 2001. The Spruce Budworm Decision Support System: Forest protection planning to sustain long-term wood supplies. Canadian Journal of Forest Research. 31:1742 - 1757.

MacLean, D.A., Beaton, K.P., Porter, K.B., MacKinnon, W.E. and Budd, M.G. 2002. Potential wood supply losses to spruce budworm in New Brunswick estimated using the Spruce Budworm Decision Support System. The Forestry Chronicle. 78:739-750.

McGill University, 2011. Canada's ecozones. Montreal, Canada, http://canadianbiodiversity.mcgill.ca/english/ecozones/index.htm

MacPhee, B. and McGrath, T. 2006. Nova Scotia Growth and Yield Model Version 2. Timber Management Group, Forest Management Planning Section, Forestry Division, Department of Natural Resources, Nova Scotia Government, Nova Scotia, Canada. http://www.gov.ns.ca/natr/library/forestry/reports/REPORT79.pdf

Natural Resources Canada, 2008. Atlas of Canada 1,000,000 National Frameworks Data, Administrative Boundaries. Natural Resources Canada, Earth Sciences Sector, The Atlas of Canada, 2008. Ottawa, Canada, http://www.geogratis.gc.ca/geogratis/en/option/select.do?id=1260C840-E898-DD4D-30DA-C7550BFFE0FE

Ontario Ministry of Natural Resources (OMNR), 1994. Crown Forest Sustainability Act, 1994. S.O. 1994, Chapter 25.

Ontario Ministry of Natural Resources (OMNR), 2007. Strategic Forest Management Model - Software Version 3.2. Queen's Printer for Ontario, Toronto.

Paull, A.E. 1956. Linear programming: A key to optimum newsprint production. Pulp and Paper Magazine of Canada. 57: 85-90.

Reed, W.J. and Errico, D. 1986. Optimal harvest scheduling at the forest level in the presence of the risk of fire. Canadian Journal of Forest Research. 16: 266-276.

Rotherham, T. 2003. Canada's privately owned forest lands: Their management and economic importance. The Forestry Chronicle. 79: 106-109.

Seely, B., Nelson, J., Wells, R., Peter, B., Meitner, M., Anderson, A., Harshaw, H., Sheppard, S., Bunnell, F., Kimmins, K. and Harrison, D. 2004. The application of a hierarchical decision-support system to evaluate multi-objective forest management strategies: A case study in northeastern British Columbia, Canada. Forest Ecology and Management. 199: 283-305.

Shore, T.L. and Safranyik, L. 2003. Mountain Pine Beetle Management and Decision Support. In: Shore, T.L., Brooks, J.E. and Stone, J.E. (eds.). Mountain Pine Beetle Symposium: Challenges and Solutions. Pp. 97-105.

Statistics Canada, 2011. Canada's population estimates: Quarterly demographic estimates. Ottawa, Canada, http://www.statcan.gc.ca/daily-quotidien/110622/t110622a2-eng.htm

Walters, K. 1993. Design and development of a generalized forest management modeling system: Woodstock. Fredericton, Canada, http://www.remsoft.com/docs/library/chile.pdf

Walters, K., Feunekes, U., Cogswell, A. and Cox, E. 1999. A forest planning system for solving spatial harvest scheduling problems. Fredericton, Canada, http://www.remsoft.com/docs/library/cors.pdf

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Appendix

Table 3. Selective list of some of the forest management decision support systems that are currently used in Canada.

FMDSS	**Description/use**	**Further Information**	**Some of the places where it is known to be used**
CBM-CFS3	Operational-scale carbon budget model of the Canadian forest sector	http://cfs.nrcan.gc.ca/pages/94	MB
COMPLAN	Spatial tactical and operational planning	www.srd.alberta.ca/LandsForests/ForestManagement/ForestManagementPlans/documents/CanadianForestProducts/RTSA_Appendix_3.pdf	AB
FSSam	Forest Service spatial analysis model	British Columbia Ministry of Forests, Lands and Natural Resource Operations www.gov.bc.ca/for/	BC
FPS-Atlas	Forest Planning Studio forest-level harvest simulation model	www.forestry.ubc.ca/atlas-simfor/atlas/about.html	BC
FSOS	Forest Simulation and Optimization System	www.forestecosystem.ca	BC
LEAPII	Landscape Pattern Analysis Package II	www.mnr.gov.on.ca	ON
NDPEGTool	Natural Disturbance Pattern Emulation Tool	www.mnr.gov.on.ca	ON
OWHAM	Ontario Wildlife Habitat Analysis Model	www.mnr.gov.on.ca	ON
OMA2	Ontario Marten Analyst	www.mnr.gov.on.ca	ON
Patch	Spatial analysis of landscape patches	www.mnr.gov.on.ca	ON

FMDSS	Description/use	Further Information	Some of the places where it is known to be used
Analyst			
Patchworks	Spatial Strategic forest management planning	www.spatial.ca	BC, AB, SK, MB, ON, QB
SAWS	Strategic Analysis of Wood Supply Analyze silvicultural policy	Nova Scotia Department of Natural Resources. Use is being phased out	NS
SEIM	Socio-Economic Impact Model	www.mnr.gov.on.ca	ON
SELES	Spatially Explicit Landscape Event Simulator	www.seles.info/index.php/Main_Page	BC
SFMM	Strategic forest management planning	www.mnr.gov.on.ca	ON
Silvacom suite	Forest management planning	www.silvacom.com	SK
SIMFOR	Project general trends in selected indicators of forest structure and function through space and time	www.forestry.ubc.ca/simfor/	BC
TSM	Forest management planning	www.tesera.com	AB
Woodstock Optimization System	Forest management planning	www.remsoft.com	BC, AB, SK, MB, ON, QB, NB, NS, NF, NWT, YK

5 The Design and Use of Forest Decision Support Systems in Chile

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5.1 Introduction

Chile has 15.9 million ha of forest (about a fifth of the total land area), with forests accounting for 84.9% (13.6 million ha) and forest plantations amounting to 15.1% (2.3 million ha). Approximately one third of the native forests, 14.1 million ha, are in protected areas of the country.

Industrial wood consumption has increased more than nine times over the past 33 years, from 4 million m^3 in 1975 to more than 39 million m^3 at present. Forest plantations account for 98% of this supply, with native forests providing only 2% of the industrial timber harvesting. Approximately 35% of industrial wood production is processed by the sawmilling sector, while 39% is destined for pulp mills. The rest of the production is primarily used for chip production (13%) and wood panels, both structural and non-structural (8%).

The Radiata Pine has been the preferred species for planting in Chile. It currently covers more than 63% of the planted area. There is, however, growing interest in a species of more rapid development, such as the eucalyptus. The production of eucalyptus wood is predicted to increase from the 12 million m^3 of today to a harvest of approximately 14.8 million m^3 by the year 2025. Native forests contribute only very marginally to the supply of the wood industry since their main use is for firewood.

The majority of the plantations in Chile are private property. Large companies (holding more than 5,000 ha of plantings) represent about 64% of the total of the forest plantations, with the rest in the hands of medium and small-sized companies. About 30% of the native forests are state-owned and lie in protected wild areas. The rest is in private hands belonging mainly to medium-sized or small holdings. About half of the native forests in private hands fall in the category of legal protection whose function is to protect fragile soils and waterways, and there can be no production interventions on these lands.

The level of Chilean production of logs, cellulose, and panels places Chile in sixth place in the world, although far from forested countries such as the United States, Russia, Canada, Sweden, and Finland. 67% of plantations have certificates (PEFC, FSC) accrediting their sustainable management of forest resources, which makes Chile one of the nations of the world with the highest proportion of certified production forests.

Chile's forestry industry has experienced dynamic growth during the past 30 years. With approximately 40 million m^3 production from plantations in the year 2010, and expectations to increase this figure to over 47 million m^3 by 2025, Chile is poised to be a significant global supplier of forest products. The Chilean forestry sector is among the major contributors to GDP and exportation, placed after mining but above the sectors of fish, fruit, wine and other important items.
In 2009, the export of forest products was recorded at $4,162,000 US dollars, a figure which indicates that the forestry sector is the second generator of currency in the country. It should be noted that the rate of average annual growth of forest exports between 2000 and 2009 amounted to 5.8%, including the economic crisis of the last year of that decade, and, considered without the crisis, grew to 10.7% between

the years 1999 and 2008, which is explained primarily by the expansion of the capacity to produce cellulose.

The growing trajectories in forest production were made possible by the high rates of forestation in the past, which grew until the year 2005 when they reverted lower (by nearly 50,000 to 25,000 ha per year). The activity indicators point to a growth of 1.9% per annum in the 1980s, 1.4% in the 1990s, and 0.4% in the most recent decade. The growth of the Chilean forestry industry in the last three decades has been dependent upon the development of external markets. Since 1990, the export value of forest products has increased significantly to reach $4,162,000 US dollars in 2009, equivalent to 8% of the country's total exports. The value of forest product exports peaked in 2008 at $5,452,000 US dollars due to high world prices for remanufacturing, panels and veneer, paper and cardboard, pulpwood and cellulose, and then declined due to the global economic crisis.

The Chilean forest industry produces a wide range of wood products, mainly from pine and eucalyptus plantations. Its backbone is composed of important forestry companies, cellulose, sawlogs and panels, etc. These products are capital and technology-intensive, and have developed capabilities to compete successfully in demanding international markets. Around them, and forming part of their added value, a wide range of suppliers and services has developed.

The timber sector is characterized by the existence of a great number of small sawmills, many owners, and an ample spatial distribution. However, there is a high concentration of production capacity in a few companies that have the technology and the scale to compete abroad. Among them are the sawmills Aserraderos Arauco S.A., CMPC Maderas S.A., and Masisa.

The fibreboard and panel industry has experienced significant growth over the last decade. Plants have been modernized, facilities have been expanded, and new investments have been made in this sector, particularly in panels of plywood. The main producers are Masisa, Panels Arauco, CMPC Wood, and Louisiana Pacific.

The pulp and paper industries are well developed and produce chemical and mechanical pulp, paper for newspapers, and other papers (printing, facial, corrugated and cartons). The production of cellulose is concentrated in two large companies: Celulosa Arauco, with a production of 2.8 million tons/year, and CMPC, with 2.5 million tons/year.

In addition to these primary processors there is an established base of secondary manufacturers who produce a wide range of value-added products. Some of these products include: moldings, doors, windows, various remanufactures, parts and pieces of furniture, finished furniture, and a large variety of wood products.

It is pertinent to note that developed forestry countries manage export levels well above ours per m^3 harvested. The generation of value, measured in export earnings for timber harvested (US $/$m^3$) for the year 2007 is 112 in Chile, 163 in Canada, 272 in Sweden and 331 in Finland. These differences are explained by the value-added products of these countries.

A process of internationalization, carried out with other Latin American countries was started by Chilean forestry companies in the 1990s. The Arauco Group has a large investment portfolio in Argentina, Brazil, and Uruguay. CMPC Holding, meanwhile, has invested heavily in its tissue business in Argentina, Mexico, Brazil, Peru, Uruguay, Colombia and Ecuador. In Argentina it also has a plant for wood and paper bags. In Brazil, its investment is in forests, and CMPC also has a pulp and paper mill. The company Masisa has a presence in different Latin American countries. In Argentina, Venezuela and Brazil it has forests and panel plants, while in Mexico, Colombia, Ecuador and Peru, the company has panel plants.

In spite of the economic crisis, the process of internationalization has not slowed. It continued as CMPC, during 2009, acquired forests and cellulose and paper plants from Fibria located in Guaiba, Brazil, which was the largest international investment in history by a national company, and Arauco, together with Stora Enso, bought the forests of the Spanish paper mill, Ence, in Uruguay.

Chilean forestry policy is implemented by several institutions. The main public institution is the National Forestry Corporation (CONAF) whose role is to encourage growth and development of the productive forestry activities of protecting and conserving forests and the forest environment. The Forest Institute (INFOR) aims to develop the forestry industry by providing statistical and analytical resources, industrial activities, products and markets. The National Environment Commission (CONAMA) is responsible for environmental issues, ensuring harmonization between development and environmental conservation. The Chilean Corporation of Wood (CORMA) is the leading association that represents the private sector of the forest managers. There are also other significant associations, such as MUCECH (smallholders), PYMEMD (small sawmills) and Asim (a secondary industry).

Forests, at a global level, have been the focus of public concern for many years, and of the NGOs dedicated to the issues. The main reason is that a large part of animal and plant life is related to the existence of forests and woods, and that the population growth and the alternative use of land in agriculture, for livestock, infrastructure, and cities has created a decrease in the global forest area. This global trend has been declining over the years to a steady state, although in some regions there still exists some growth or declining imbalances.

In a cooperative effort, the larger Chilean forest companies have developed decision support systems (DSS) with the main objective of maximizing the efficiency of their long-term decisions as well as the operational ones. The DSS on short-term planning have been pioneering work, giving the Chilean companies leadership in this field at the international level.

Table 1. Classification of forest management planning problems in Chile according to the FORSYS dimensions.

ID	Spatial scale	Temporal scale	Spatial context	Objectives	Parties involved	Goods and services
1	Stand level	Strategic	Spatial with no neighbourhood interrelations	Single objective	Single decision-maker	Market wood products
2	Stand level	Tactical	Spatial with neighbourhood interrelations	Single objective	Single decision-maker	Market wood products
3	Stand level	Operational	Spatial with neighbourhood interrelations	Single objective	Single decision-maker	Market wood products
4	Stand level	Operational	Spatial with neighbourhood interrelations	Single objective	Single decision-maker	Market wood products
5	Stand level	Operational	Spatial with no neighbourhood interrelations	Single objective	Single decision-maker	Market wood products
6	Forest level	Strategic	Spatial with no neighbourhood interrelations	Single objective	Single decision-maker	Market wood products
7	Forest level	Tactical	Spatial with no neighbourhood interrelations	Single objective	Single decision-maker	Market wood products
8	Stand level	Operational	Spatial with no neighbourhood interrelations	Single objective	Single decision-maker	Market wood products
9	Forest level	Operational	Spatial with no neighbourhood interrelations	Single objective	Single decision-maker	Market wood products

5.2 Materials and methods

To prepare the material, we worked with one high-level executive in the industry, Claudio Parada, who is a co-author of this article. Our group at the University of Chile has been working for 20 years with the main forest firms in Chile. These firms include the two main ones, Forestal Arauco and Mininco, which cover about two-thirds of the total production in Chile. Claudio Parada has been one of the counterparts in this project. We have developed different models that have been implemented in the industry as described.

The methodology used to develop the study was as follows:

- Interviews with the developers of the applications in major forestry companies in the country
- Interviews with the planners in major forestry companies in the country
- Authors’ experience in forest planning
- Website review of forestry organizations in the country (Corma, Infor)
- Review of scientific research on forest planning tools in use in the country
- Web search

5.3 Results

The first system designed to support the decision-making that was used in the industry was a growth simulator called 'Radiata', initially developed in 1989. The system predicted the amount of timber that would be obtained in the long-run, depending on the type of forest land and other forest variables. The system was widely used in academia, especially in the Department of Industrial Engineering at the University of Chile, as well as in the Department of Forestry of the University, to develop theoretical cutting work in the area of operations research.

At the beginning of the 1990s, forestry companies were associated in a consortium to develop a new version of the Radiata system, which would be based on actual growth data contributed by the consortium companies. This project was of major significance in its time, and was a milestone in the capability to cooperate within the industry.

This system enabled the acquisition of relevant knowledge of the Chilean industry's ability to predict how the forests in the future would grow, and would be the basis for many planning efforts and optimizations that would be undertaken in the future. It would especially support the development of optimization models for long-term planning. The maintenance and updating of this simulator is currently rooted in each company.

5.3.1 Development of optimization systems

In the mid-1970s, operations research developed strongly, especially in the departments of industrial engineering of Chile's main universities, such as the University of Chile, the Pontifical Catholic University, and the Universities of Santiago and Concepcion. This discipline also became very strong in departments of forest engineering, especially at the University of Chile and Austral University. This trend has consolidated from that time until today - operations research is an important part of the curriculum in almost all Chilean forestry engineering programmes.

In the middle of the 1970s, a high level of integration occurred between the Department of Industrial Engineering at the University of Chile and departments of forest engineering at several universities at the level of operations research. The development of operations research in Chile has been very strong academically, but significant applications in industry did not appear until the late 1980s.

5.3.2 Optimization of logistics and forest operations

In 1988, forestry companies were facing an explosive growth in their activity. They were vertically integrated companies, from the forests to the cellulose mills and sawmills. The strategy of the industry as a whole was to position the country as a producer of long-fibre of high quality, and low cost, making it a strong competitor of the New Zealand industry.

Chilean firms proposed a competitive strategy, where efficiency and productivity were central to grow and make profits in the long term. In this context, several threats appeared: Chile had a very weak infrastructure, especially in public roads and ports; the increase in the scale of the operations presented concrete threats of congestion and low productivity that threatened the viability of the industry and its development strategy (by way of example, the Arauco Group was building an industrial complex that required 40 trucks per hour to operate continuously).

In this context, the forest industry, coordinated by the Chile Foundation, developed what could be the first DSS widely used in this industry: a system for optimizing the daily dispatch of the trucks, known as ASICAM. This tool is built on a simulation model with deterministic rules optimizing heuristics, is built on a PC platform, and schedules hundreds of trucks in less than five minutes. The truck fleet and the inventory at the forest is communicated manually. The schedule for the truck fleet is available on the internet or intranet.

The system began operating in 1989 and enabled the optimization of the use of trucks, which represented 45% of the total cost of production. The system is very successful in improving efficiency by about 20%. It is implemented by all Chilean companies of average size and up, and has been exported to the leading companies in Brazil, Argentina, Uruguay, Venezuela and South Africa. In the latter country, the Mondi Forest Company won the South African Logistics Award in 1996 for improvements obtained with ASICAM. The system was developed by a team of researchers of the Department of Industrial Engineering at the University of Chile.

At the beginning of the 1990s, the Chilean forestry industry embarked on an effort to digitize their forest heritage using aerial photographs and Geographic Information Systems (GIS). This development opened the possibility of developing optimization tools that use GIS for supporting decisions with a high spatial component. Thus, in 1991, the team at the University of Chile began the development of Planex, a graphical tool that is powered by GIS to optimize decisions on road design and location of harvesting machinery, strongly supporting planning essential to the harvest. This tool began to be used in 1995, and has been very successful. Chilean industry pioneered this development, possibly motivated by the difficult geography that its homeland presents with many hills and topological accidents. Planex is widely used in Chile and other South American countries. Planex is also unique in its field; according to our records there is no other product of similar characteristics used in forestry enterprises.

These developments in the optimization of decisions in the area of logistics and forest operations, including the planning systems for the short-term that are described in the next section, have given Chilean companies leadership at the international level which was very marked in the late 1990s. Many of these efforts were exported or were adapted to be used in companies, particularly in Brazil and the rest of South America. Possibly the high level of vertical integration of Brazilian companies, as well as their focus on volume and efficiency as a development strategy (like the Chilean companies), led to the high interest in developing this type of tool.

In 1998 the Chilean forestry companies, together with the team at the University of Chile, won the prestigious Franz Edelman Award, given annually by the US Institute for Research Operations and Management Science (INFORMS) for the best application in this discipline, for their development of pioneering applications in the field of logistics and short-term planning in the Chilean forestry industry. The recipient of this award is considered to have the world's highest distinction in decision-making system applications.

5.3.3 Optimization of short-term planning

Thirty years ago, short-term planning was hardly studied in the academic arena. Developments were focused on issues of long-term planning, motivated primarily by the sustainability of this activity, a subject of major importance at that time in the northern hemisphere. Medium-term issues had also been addressed, but not the topics of short-term planning, where the horizon is a few months or a maximum of one year.

The results obtained in optimizing logistics showed the advantages of operations research for the forestry industry, and company managers were motivated to develop new innovations using such tools and technologies. In 1989, the industry requested that the same team at the University of Chile develop a system to optimize short-term planning, which consisted basically of optimizing decisions for the one-year horizon that exists for intervention, such as cutting trees and giving each product a destination. At that time, companies had developed simulation systems that predicted in great detail the products each stand would deliver, according to the schedule of logging used. These systems defined hundreds or thousands of products in great detail and allowed the cost estimation of thousands of schemes for logging in each stand. Certainly an optimization system was appropriate for addressing this problem.

As a result of this development, a system appeared in 1990 known as OPTICORT, which has operated mainly in the Arauco group. This system works with a high level of detail with regard to products and schemes of logging fed by the logging simulators. This system has been a pioneer of its type, and the first to operate intensively in forest product companies according to our records.

Towards the end of the 1990s, Austral University, along with CMPC, developed a system to address the problem of defining optimal movements of forest harvesting machinery, in conjunction with forest intervention decisions for old growth, cutting trees and the optimal allocation of products to various clients. This system, known as Optilog, incorporates the costs of the transfer of harvesting equipment with a temporal network of equipment movement, and composes a combination system of high complexity used intensively by CMPC to define the work plans of the various machines in the forest, and to specify customer orders of products.

CMPC uses the Maxben system, developed by former Austral University academics, to optimize the allocation of the volumes produced in forest work for customer orders in the short term, in periods that are not more than two to three days' duration.

We would like to emphasize that the effect between information systems and systems of optimization is closely related. In this case, the harvest simulators allowed sustaining system planning in the short term. In the case of Planex, GIS enabled the optimization of land financing decisions.

Table 2 presents details of operational or short-term systems.

Table 2. Details of short-term systems.

ID	Problem Type	Computerized Tools/DSS	Models and Methods
9	- Operational (short-term transportation) - Spatial with no neighbourhood interrelations - Forest level - Single decision-maker - Single objective - Market wood products	DSS Name: ASICAM	Heuristic based on simulation.

ID	Problem Type	Computerized Tools/DSS	Models and Methods
5	- Operational (short-term harvesting) - Spatial with neighbourhood interrelations - Stand level - Single decision-maker - Single objective - Market wood products	DSS Name: OPTICORT	Linear programming
3	- Operational (short-term) - Spatial with neighbourhood interrelations - Stand level - Single decision-maker - Single objective - Market wood products	DSS Name: OPTILOG Application made 'to measure' by Austral University and developed in an integrated platform based on the programming language Delphi on a Paradox database. The implementation is highly oriented to give a dynamic service to a non-expert user, in a procedure that allows: recovering the information from the database; configuring the parameters of the particular instance, for example, planning the horizon of planning and temporal resolution; validating the consistency of all the information incorporated; activating the restrictions on use from a predefined set of restrictions; generating the mathematical model in a matrix format; and requesting the resolution of the model to a module of optimization. Once the problem is solved, the optimal solution is loaded to the application, and predefined reports that have been requested by users of the planning are generated. The model implements a network of feasible movements of harvest teams between properties, and that allows decisions about the specific work plans of the different machines in the operation of the different stands in accordance with the timing of harvests.	Mixed integer – linear programming
4	- Operational (short-term) - Spatial with neighbourhood interrelations - Stand level - Single decision-maker - Single objective - Market wood products	DSS Name: PLANEX Application implemented by the University of Chile and developed in a graphical ESRI ArcGIS platform. The application is oriented to the operation of an expert user who, according to the topology of the land, plantations and existing roads and the definition of the available harvesting equipment, identifies a design of harvesting and roads with minimal operating cost.	Heuristic
8	- Operational (short-term) - Spatial with no neighbourhood interrelations - Stand level - Single decision-maker - Single objective - Market wood products	DSS Name: Maxben 4.1	Linear programming

5.3.4 Optimization of medium-term planning

Medium-term planning in forestry is usually a horizon of five years, with quarterly or annual periods. These systems make decisions about harvesting the stands in each of the next five years, including decisions about the ways to enable these operations and their associated costs.

The first such system used widely in the Chilean industry was the MPCOS system, developed by academics at Austral University in the mid-1990s. The system is in use in both the Arauco Group and CMPC. It has also been exported to a company in Colombia. Chilean forestry companies use the system annually to perform their medium-term planning, as well as for specific analysis related to unexpected situations of variation in the availability of stands for harvest.

The mathematical model is based on linear/mixed integer programming. The objective function maximizes the net present value of the existing plantations plus future plantations. The temporal resolution of the system is seasonal (winter and summer). The planning horizon is 18 years, and the linear decision variables consider the surface to harvest of each stand in each season.

The model considers the implementation of a network of roads for access to the stands. Integer decision variables consider construction of different roads in one season following the logic of road construction and activated to allow the harvest of the associated stands. The spatial resolution of the model considers the creation of short units corresponding to forest management units that group surfaces of adjacent stands according to criteria of species, forest management, and planting year.

The structure of the timber flow considers as sources the units cut and intermediate buffers (summer and winter storages), and as destinations the cellulose plants, sawmills and ports that the company supplies.

A new development of this kind appeared recently, made by a former Austral University academic and used in Masisa.

Table 3 presents details of tactical, or medium-term, planning systems.

Table 3. Details of medium-term systems.

ID	Problem Type	Computerized Tools/DSS	Models and Methods
2	- Tactical (medium-term) - Spatial with neighbourhood interrelations - Stand level - Single decision-maker - Single objective - Market wood products	DSS Name: MPCOS Application made 'to measure' by Austral University and developed in an integrated platform based on the programming language Delphi on a Paradox database. The implementation is highly oriented to give a dynamic service to a non-expert user, in a procedure that allows: recovering the information from the database; configuring the parameters of the particular instance, for example, planning the horizon of planning and temporal resolution; validating the consistency of all the information incorporated; activating the restrictions on use from a predefined set of restrictions; generating the mathematical model in a matrix format; and requesting the resolution of the model to a module of optimization. Once the problem is solved, the optimal solution is loaded to the application and predefined reports that have been requested by users of the planning are generated. The model implements a network of relations between access roads and stands that permit entering by activating the necessary roads for the harvesting of the stands at different time periods.	Mixed integer – linear programming
7	- Tactical (medium-term) - Spatial with no neighbourhood interrelations - Forest level - Single decision-maker - Single objective - Market wood products.	DSS Name: HPS 2.5	Linear programming

5.3.5 Optimization of long-term planning

As we mentioned at the beginning, the first efforts to produce a model of long-term planning were carried out at the beginning of the 1990s by the group at Austral University. The system, known as Austral, has been widely used by the Arauco Group and CMPC; these companies have even internalized its maintenance and development.

Forest companies use the Austral system annually to perform their strategic planning, in addition to performing targeted analysis of national variation, installation of industrial centres, and analysis of price variation, amongst others.

The system considers a planning horizon of at least the longest stage of crop rotation and longer periods of two to three years. As for the spatial representation, the model must represent the geographic areas that, having the same characteristics of productivity, allow adequate resolution of the transportation costs to the different markets and industrial plants, as well as the volumetric yield of each species. The timber growth simulator, RADIATA, provides the data for this system.

The basic restrictions consider the options of total availability of plantation surfaces, satisfaction with levels of wood offers of different species, and final inventories of forests.

There are also other developments in this line; one led by a former academic at the University of Chile who developed a system that was used in Forestry Bio-Bio and was exported to Aracruz Cellulose. Recently, Masisa has adopted a system of this type made by a former academic at Austral University.

Table 4 presents details of strategic, or long-term, planning systems.

Table 4. Details of long-term systems.

ID	Problem Type	Computerized Tools/DSS	Models and Methods
1	- Strategic (long-term) - Spatial with no neighbourhood interrelations - Stand level - Single decision-maker - Single objective - Market wood products	DSS Name: AUSTRAL Application 'made to measure' for customers, integrates tools of income and validation of information with the processing of the model and reporting of results. This implementation is intended for use by a non-expert user given the scarcity of this profile of professionals in the country.	Linear programming
6	-Strategic (long-term) -Spatial with no neighbourhood interrelations -Forest level -Single decision-maker -Single objective -Market wood products	DSS Name: FMS 2.5	Linear programming

5.4 Discussion and conclusions

Operations research has been very important in the Chilean forestry industry, mainly in solving operational problems and company planning.

At the operational level, the Chilean developments were pioneering internationally, with broad recognition from both companies in other countries, as well as from academia, where this work has been widely recognized and rewarded.

The technological counterpart has been provided by universities, mainly the Department of Industrial Engineering at the University of Chile, and the School of Forestry Engineering at Austral University. These developments have led to research in most Chilean universities that have some contact with the forest industry.

Possibly the high level of development and the size of the Chilean forest companies has led and motivated this activity. Also, the level of the disciplines of operations research and forest engineering in Chilean universities has enabled us to meet this challenge successfully.

Innovations in information systems have motivated many of these developments. We have several examples that confirm this hypothesis: the system of forest growth, the long-term planning systems, timber growth simulators, and the short-term planning systems; the forest GIS systems and those for the optimization of the financing of lands. The future will see that communication technologies are opening up new possibilities in the area of logistics and forest operations.

Without a doubt, the scientific/technological capacity that Chile had at that time, along with the forestry companies' capacity for innovation, made possible a virtuous cycle that has given a competitive advantage to the industry.

The forest industry has added operations research (OR) tools to improve their management and decision-making procedures. The discipline of OR is widely taught at forestry schools throughout the country. Even though these practices can be seen as a knowledge management (KM) method to capture and enrich the learning activities in a company, the discipline of KM is not well known in this industry and no connection has been made between DSS and KM in methodological or theoretical terms. Regarding participatory planning (PP), we observe the same phenomena. Even though many concepts associated with PP are embedded in these experiences, the PP discipline is not known in this industry, and no formal connection has been made between DSS and PP.

References

Alonso-Ayuso A., Escudero, L., Guignard, M., Quinteros M. and Weintraub, A. 2011. Forestry Management under Uncertainty. Annals of Operations Research, Vol. 190 Issue 1.

Andalaft N., Andalaft P., Guignard M., Magendzo A., Wainer A. and Weintraub A. 200.3 A Problem of Forest Harvesting and Road Building Solved Through Model Strengthening and Lagrangean Relaxation. Operations Research, Vol51 Issue 4, pp.613-628.

Díaz Legües, A., Ferland, J., Ribeiro, C., Vera, J. and Weintraub, A. 2007. A Tabu Search Approach for Solving a Difficult Forest Harvesting Machine Location Problem. European Journal of Operational Research, 179(3), 788-805.

Epstein, R., Morales, R., Serón, J. and Weintraub, A. 1999. Use of OR Systems in the Chilean Forest Industries. Interfaces, Vol.29 Issue 1, pp.7-29.

Epstein R., Nieto E., Weintraub A., Chevalier P. and Gabarro J. 1999. A System for the Design of Short Term Harvesting Strategy. European Journal of Operations Research, Vol.119 Issue 2, pp.427-439.

Epstein, R., Weintraub, A., Sapunar, P., Nieto, E., Sessions, J., Sessions, F., Bustamante, F. and Musante, H. 2006. A combinatorial heuristic approach for solving real-size machinery location and road design problems in forestry planning. Annals of Operations Research, 54(6), 1017-1027.

Epstein, R., Karlsson, J., Ronnqvist, M. and Weintraub, A. 2007. Harvest Operational Models in Forestry. In Weintraub, A., Epstein, R. (et al.) (eds.). Handbook of Operations Research in Natural Resources. 1st Ed, Springer, New York, 365-377.

FAOSTAT-Montes, 2010. Food and Agriculture Organization of the United Nations. http://faostat.fao.org

Goycoolea, M., Murray, A. and Weintraub, A. 2004. Incorporating Average and Maximum Area Restrictions in Harvest Scheduling Models. Canadian Journal of Forest Research, 34(2), 456-464.

Goycoolea, M., Murray, A., Barahona, F., Epstein, R. and Weintraub, A. 2005. Harvest Scheduling Subject to Maximum Area Restrictions: Exploring Exact Approaches. Operations Research, 53(3), 490-500.

Instituto Forestal, 2009. Anuario Forestal. Boletín Estadístico 125.

Mosquera, J., Mordecai, I., Henig and Weintraub, A. 2009. Design of Insurance Contracts using Stochastic Programming in Forestry Planning. Annals of Operations Research, 1572-9338.

Murray, A. and Weintraub, A. 2006. Review of Combinatorial Problems Induced by Spatial Forest Harvesting Planning. Discrete Applied Mathematics, 154(5), 867-879.

Romero, C. and Weintraub, A. 2006. Operations research models and the management of agricultural and forestry resources: A review and comparison. Interfaces, 36(5), 446-457.

Weintraub, A., Jones, G., Magendzo, A., Meacham, M. and Kirby, M. 1994. A Heuristic System to Solve Mixed Integer Forest Planning Models. Operations Research, Vol.42 Issue6, pp.1010-1024.

Weintraub, A. and Bruce, B. 1996. New Issues in Forest Management from an Operations Research Perspective. Interfaces, Vol.26 Issue 5, pp.9-25.

Weintraub, A., Epstein, R., Morales R., Serón, J. and Traverso, P. 1996. A Truck Scheduling System Improves Efficiency in the Forest Industries. Interfaces, Vol.26 Issue 4, pp.1-11.

Weintraub, A., Vielma, J.P., Murray, A. and Ryan D. 2007. Improving computational capabilities for addressing volume constraints in forest harvest scheduling problems. European Journal of Operational Research, 176(2), 1246-1264.

Weintraub, A. 2007. Integer Programming in Forestry. Annals of Operations Research, 149(1), 209-216.

6 The design and use of forest management decision support systems in China

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6.1 Introduction

According to the most recent statistics from the Seventh National Survey on Forest Resources (State Forestry Administration P.R.China 2011), forests cover 195.45 million ha in China. This places China fifth in the world after Russia, Brazil, Canada and the United States in terms of forest area. Nearly half of the country's forest land is located in the northeast (Inner Mongolia, Heilongjiang, and Jilin provinces) and southwest (Sichuan and Yunnan provinces) (Figure 1). The remainder is heavily concentrated in the south central and southeastern parts of the country.

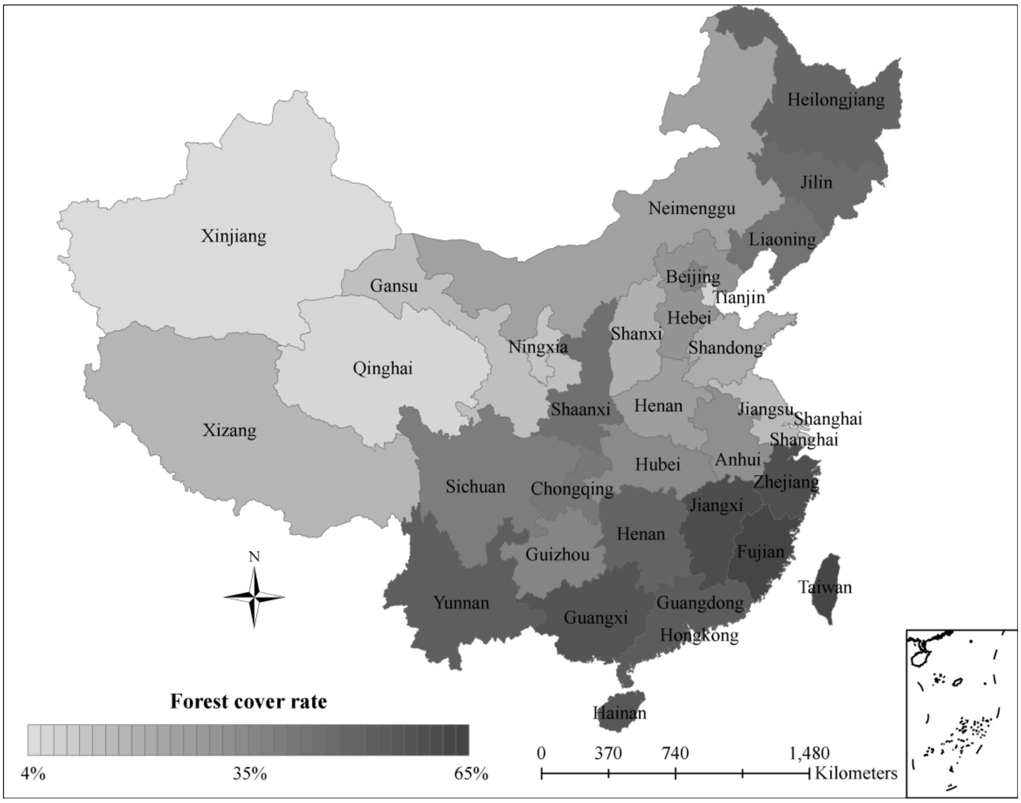

Figure 1. Forest resource distribution of China
Source: SFA, 2011

China's forests suffered from excessive logging in the second half of the 20th century. As a result of this tumultuous history, the country's forests are dominated by younger age classes. As of 2008, young and middle-age forests accounted for 71.1% of standing forests and 74.4% of timber forests (SFA 2011). The logging area of young and middle forests accounts for 78.5% of the total logging area of standing forests, contributing to a diminishing reserve resource (SFA 2011).

Land in contemporary China is either state- or collective-owned. Collective owners include townships, administrative villages and village household groups. Ownership rights for trees or forest resources, however, differ from those with respect to land, reflecting a gradual separation of land use rights from those of land ownership. Four categories of tree tenure have evolved: state-owned, collective-owned, private-owned and mixed ownership by shareholders (Liu 2001). The latter two categories reflect the practice that whoever plants the tree owns it, with associated rights to income earned from the sale of timber or forest products. On an overall basis, therefore, two broad forest ownership classes exist – state-owned forests and non-state forests, which include collective-, private-, and joint-owned trees or forests.

Table 1. Forest ownership in China

Ownership	**Area (1,000 ha)**	**% of national total**
State-owned	71,435.8	39.38
Collective	51,769.9	28.54
Private	58,175.2	32.08

Source: SFA, 2011

For state forests, institutions such as state logging enterprises, state forest farms and nature reserve agencies take responsibility for management and logging operations. In contrast, local communities or households within communities manage non-state forests.

6.1.1 Prevalent forest management problem types in China

FORSYS problem type categories include six problem dimensions: temporal scale, spatial context, spatial scale, stakeholder involvement, objectives and outputs. In China, it is important to briefly describe the current Classification-Based Forest Management (CFM) system that directly guides how forest managers use properties and implement forest activities.

In the year 2000, China's central government accelerated the development of a classification scheme for the nation's forests – Classification-Based Forest Management (CFM). The final version of CFM was completed in 2003, and was implemented at the provincial level over the next few years with the aid of subsidies from central government. CFM aims at a balance of the multiple services of forest resources based on their differences in composition, structure, landscape context, and geographical location. The design of CFM rests on the principles of landscape integrity, forest diversity, forest services, and regional sustainable development (He and CC 2005). It seeks to strengthen integrated forest management based on national-level forestry regulations, local socio-economic and natural conditions, and forest-level ecological properties (Liang 2001).

At the broadest level (I), CFM divides all forest land in China into one of two basic classes: *Ecological welfare forests (EWF)* and *Commodity forests (CoF)*. The former are further subdivided into two categories

(Level II): a) Special Use forests– with seven such uses identified (Level III), including: natural reserve; environmental protection; scenic; historical site; seed; experimental and defense; and b) Shelterbelt forests, the other level-II category of EWF lands, which serve seven key functions (Level III): water source, road and riverbank protection; soil-water conservation; wind/sand and farmland/rangeland shelterbelts; and other protective forests. The second broad (Level I) class of forests in China is that of *Commodity forest (CoF)* lands. These are subdivided into three categories (Level II): a) Timber forests, which may be ordinary timber or two types of fiber forests (Level III)); Fuel forests; and Economic forests, which include four categories of non-timber forest products (Level III) – orchards, medicinal herbs, oil, and chemical materials.

The wide array of forest uses embodied in the CFM framework poses significant challenges for forest managers facing decisions regarding the allocation of resources among multiple objectives and, at times, competing forest uses. The kinds of challenges they face may be characterized by the set of problem types depicted in Table 2.

Table 2. Prevalent problem types in China according to FORSYS categories

Dimensions		**Types**	
		E	**C**
Temporal scale	Long-term (strategic)	X	X
	Medium-term (tactical)		X
	Short-term (operational)		
Spatial context	Non-spatial		
	Spatial with neighbourhood interrelations		
	Spatial with no neighbourhood interrelations	X	X
Spatial Scale	Stand level		X
	Forest level	X	X
	Regional/national level		
Parties involved	Single decision-maker		
	More than one decision-maker/stakeholders	X	X
Objectives	Single		X
	Multiple	X	
Goods and services	Market non-wood products		X
	Market wood products	X	X
	Market services		
	Non-market services	X	X

E: Key forest management problem types for EWF lands

C: Key forest management problem types for CoF lands

Different timescales serve to define different modes of decisions, from operational choices for current management to strategic decisions charting out long-term courses of action. Such choices affect actions affecting forests at different levels of scale, from individual stands, and local forests to national forest resources. Decisions may focus on single or multiple objectives involving wood or non-wood products and market or non-market services.

6.2 Material and methods

This review of computer-based methods for decision support of forest management in China relies on two more readily accessible sources of information on the current status of such methods in management decision-making. The first consists of the major laws and regulations that govern the management of forests in China.

The second source of data emanates from a detailed search of computer-based methods employed in forest management that have been made available online by their source institutions or organizations. The information about forest management planning processes in China and computerized tools to support them is available from several institutional sites, technical reports and national and international research publications.

6.3 Results

All problem types in China identified in this report involve situations in which more than one decision-maker is involved. With this in mind, in addressing these problems, this report utilizes the set of FORSYS methods recommended to assess participatory planning in addressing forest management problem types in China. An outline of the methods and/or tools employed in each of the three phases of participatory planning – intelligence, design and decision-making may be found in Table 3. Figures 2-4 describe how knowledge management tools are designed in China according to their contribution for the identification, analysis and solving of the two prevailing problem types.

Table 3. Summary of steps that characterize the forest planning process		
Process	**Participants**	**Methods/Tools used**
	Planners and managers	(9) Production goals. (10) Law and regulations for forest management of non-private forests. (11) Inventory of available forest resource and its distribution. (12) Stand information and maps. (13) In all cases data are incorporated within software by experts.
	Experts	(4) Prepare requests for goals, data, and information. (5) Investigate and complete the data, models and information that are needed but which planner does not have.
Integration to DSS & Participation type		Database is created by experts to store all information. Database serves as input to the design process.
Design	Experts	(6) According to the management goals, experts decide the software types (GIS-based, expert system (ES) or integrated one) to be used in addressing management problems. (7) When the type(s) of computer tool(s) is/are selected, experts write the software. (8) Data is transformed and prepared as input to the software. C#, SQL-Server and Oracle procedures that read data from the database, process, and format and generate the preformatted components of the models are utilized. Models are integrated into the software. (9) Goals are input to the software, and results are generated as output.
Integration to DSS &		Digital integration to other tools is intensive, in order to provide input data that is related to stand information, inventory, and maps. Participation here is focused on data preparation and selection of tools.

Participation type		
Decision making	Planners and managers	(3) Discuss the results generated by software programs. (4) Review adequacy of results and any additional demands for software applications.
	Experts	(1) Transform the results into tables and graphs. (2) Modify the software.
Integration to DSS & Participation type		There are three (see section 3.1) different participatory decision processes: (4) All results are submitted to planners and managers who then choose which scenario is the best. (5) Experts choose the best results and present the advantages of each to the planners.

6.3.1 The design of forest management decision support systems (FMDSS)

6.3.2 GIS-based FMDSS

Geographic information systems play a very important role in forest decision support systems. They can provide decision makers with a variety of options in making different kinds of spatial and non-spatial evaluations. GIS-based multi-objective decision-making support systems in forest management continue to proliferate rapidly. Land use planning processes that incorporate the linear combination of geographic information systems are also making valuable contributions towards enhancing the capabilities of forest managers. The typical design of a GIS-supported FMDSS is presented in Figure 2.

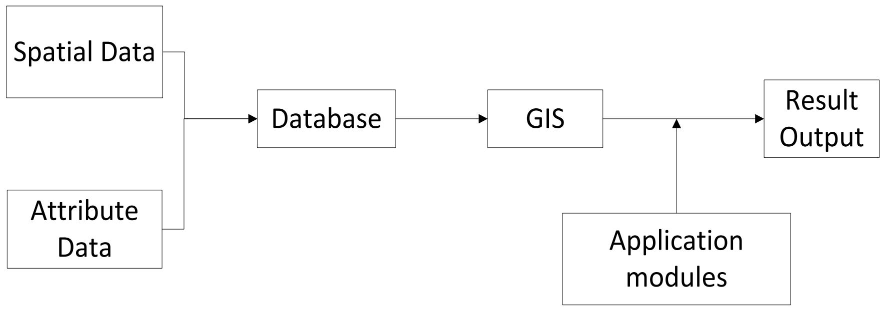

Figure 2. Designs of GIS-based FMDSS

(1) Create database: including spatial data (digitized maps) and attribute data (stand information, inventory data).
(2) GIS based software read the data from the database.
(3) Integrate application modules into the software.
(4) Resultant output.

6.3.3 Knowledge-based FMDSS

A Forest Resources and Environment Network decision support system adopts an internet-based three-level structure as the operating mode – user / webserver / database server.

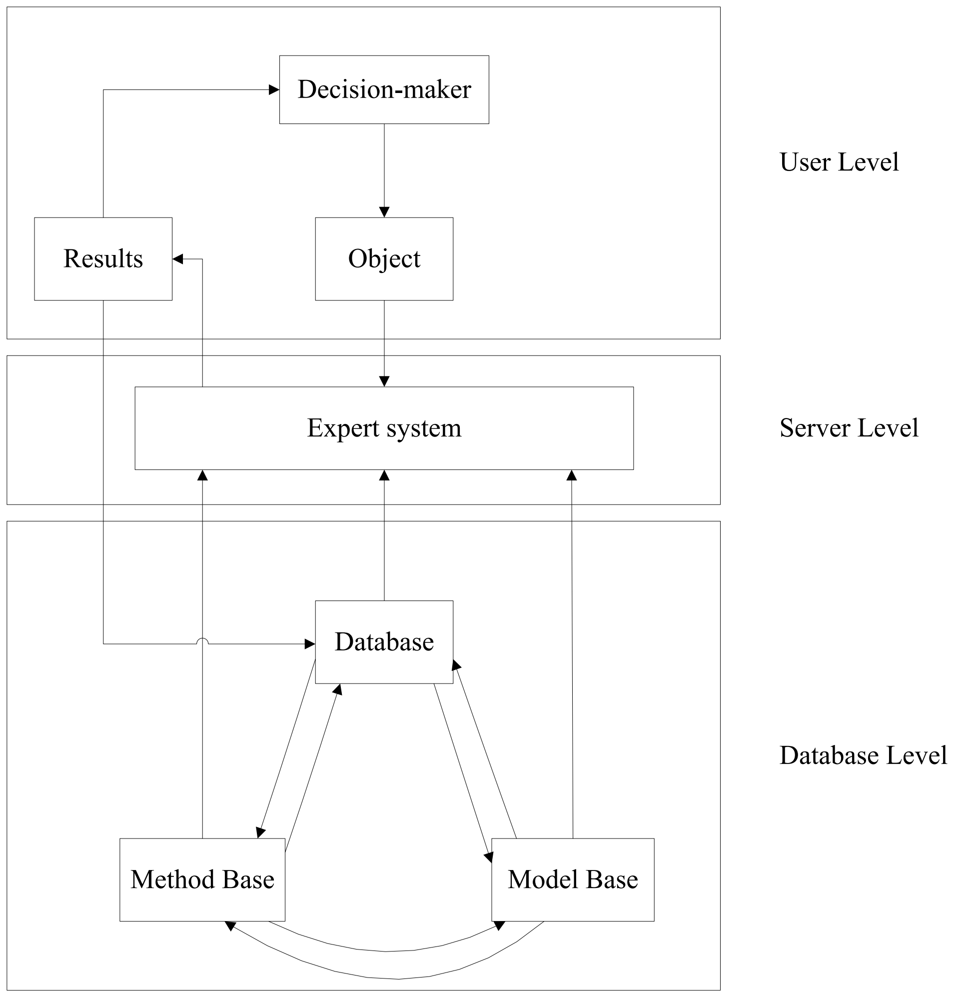

Figure 3. Design of Knowledge-based FMDSS

(1) User level: User software and hardware requirements are low, requiring only the normal browser which can easily interact with the system to complete system queries, statistical computations, analyses and decision-making capabilities.
(2) Server level (expert system): This includes the webserver and the application server. Users extract data for their particular needs from the database through the webserver. Then data analysis and calculations are performed on the application servers. The final display occurs on the user's browser via the webserver's format. Models, methods and analysis, synthesis and applications of the knowledge base all occur on the server level.
(3) Data services level: This refers to the network database and data warehousing accessed for analysis. A distributed network database is generally used for online analysis.

6.3.4 Integrated FMDSS

An integrated forest management decision support system is a man-machine interactive information system based on GIS, expert system (ES), DSS and database (DB) technologies. It utilizes decision-making science and silvicultural theory and methods to solve structured, semi-structured and unstructured decision problems.

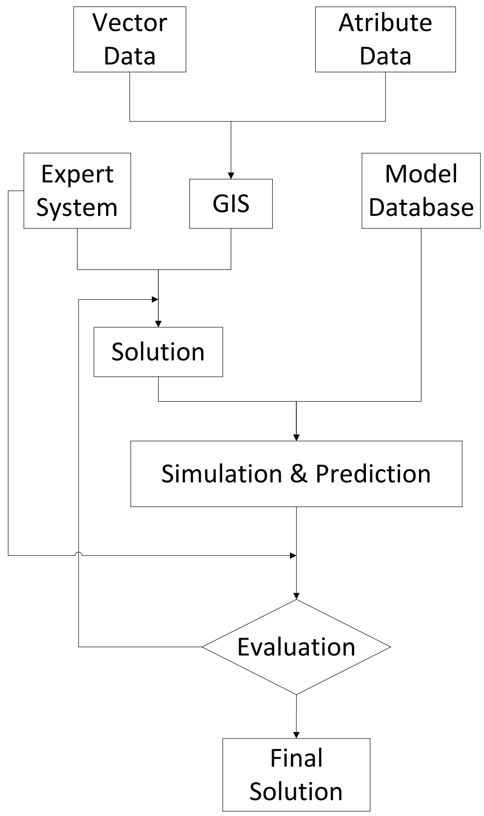

Figure 4. Designs of Integrated FMDSS

Work process of Integrated FMDSS:

(1) providing relevant background material
(2) identifying problems
(3) listing possible solutions
(4) managers make effective decisions

6.3.5 Current FMDSS use in forest management in China

The three FMDSS mentioned above are widely used in China. Decision-makers usually select the appropriate FMDSS according to the specific type of problem with which they are concerned.

When decision-makers need to know about issues such as geographical distribution, they usually choose GIS-based FMDSS. By using this, they can become familiar with the attributes, quantities and the geographical distribution of forest resources (Wang et al. 2010), thus obtaining valuable input for decisions such as 'where to harvest' and 'how much to harvest'. In addition, they can also use GIS-based FMDSS to ascertain the location and scale of the occurrences of forest pests (Shi and Li 1996), diseases and forest fires (Pang et al. 2011) and makes informed decisions on control measures, as well as selection and deployment of personnel.

In the forest management decision-making process, decision-makers in forest management often encounter problems such as identification of pest species, selecting measures for fighting forest fires according to the surrounding environment and control methods for particular types of forest pests and diseases, and so on. In order to solve these problems, decision-makers usually tend to choose Knowledge-based FMDSS. By using it, they can find answers to specific issues through man-machine dialogue accessing the knowledge base in the system (Yi et al. 1995).

In order to achieve multi-objective management of forest resources, decision-makers need to know the different possible outcomes of the management plan. This requires simulating different management scenarios and predicting results. In this case, they will choose the IFMDSS. Combining the characteristics of GIS-based FMDSS and Knowledge-based FMDSS, IFMDSS can generate the desired results of forest management plans via appropriate simulations (Shao et al. 2003) Decision-makers can then attempt to optimize the management plan based on the simulation results (Shao et al. 2006). In addition, Integrated FMDSS plays an important role in predicting the occurrence and spread of pests and forest fires.

6.4 Discussion and conclusions

Research on decision support and related information systems for forest management in China began in the early 1990s. Before then only a small amount of software had been developed to process forest resource statistics and contribute basic information to environmental appraisals. Neither economic efficiency nor decision-making processes inherent in forest management were usually considered.

As forest management in China evolved, research on economic analysis and evaluation and aids to decision-making for forest management eventually appeared and proliferated. At the same time, in order to address challenges to forest management such as massive basic databases for analysis, complicated computing schemes, and challenging decision-making scenarios, some scholars began to examine the design of information systems for forest management; and to date some achievements in research and development on decision support systems (DSS) for forest management in China have been realized. As a result, such systems are beginning to effectively aid forest managers in solving a wide variety of problems and challenges of forest management.

At the same time, the regular use of forest decision support systems in China is not widespread. And few uses among these systems tend to be complex applications relying extensively on modern information technologies. Some users are still struggling to incorporate the full potential of mathematical optimization methods, multi-objective techniques, and expert system support. Thus although results show that there is a great deal of research being conducted in China on the development of knowledge management tools and decision support systems, to date relatively few are being utilized to their full potential.

References

He and CC 2005. Discuss the problems about forest classification management. Forest Inventory and Planning 30: 7-8.

Liang, X. 2001. Forest classification management. Beijing, China Forestry Publishing House.

Liu, D. 2001. Tenure and Management of Non-State Forests in China since 1950: A Historical Review. Environmental History 6(2): 239-263.

Pang, L., Xie, Y., Tang, X. Construction of forest fire prevention WebGIS system based on GIS component in Nanning. Practical Forestry Technology (4): 62-64.

Shao, G., Dai, L., Li, Y., Liu, Y., Bai G. 2003. FORESTAR. Journal of Forestry Research 14(2): 141-145.

Shao, G., H. Wang, L. Dai, G. Wu, Y. Li, R. Lang, and B. Song. 2005. Integrating stand and landscape decisions for multi-purposes of forest harvesting. Forest Ecol. and Manage 207(1-2): 233-243.

Shao, G., Wang, F. Dai, L., Bai, J., Li, Y. 2006. A density-dependent matrix model and its applications in optimizing harvest schemes. Science in China Series E: Technological Sciences 49: 108-117.

Shi, S. and Li, D. 1996. GIS and forest pest management. Forest Pest and Disease (3).

State Forestry Administration P.R.China. 2011. Forest resources statistics of China. From http://www.forestry.gov.cn/CommonAction.do?dispatch=index&colid=58

Wang, H., Dong, F. Xie F. 2010. Changes of Spatial Pattern of Forest Resources and Analysis of Management Based on GIS. Journal of University of Jinan (Sci.&Tech1) 24(1): 79-83.

Yi, H., Bai, L., Ji, P. 1995. The research and development of forestry expert system. Forest Resources Management 2: 28-30.

7 The design and use of forest decision support systems in Denmark

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7.1 Introduction

7.1.1 The Danish forest sector

The Danish forest area is 570,800 ha and accounts for approximately 13.2% of the land area. The area of other woodlands is estimated at 47,500 ha or approximately 1.1% of the land area. The largest forest areas are located in the central parts of the Jutland peninsula, while the largest forest percentage is located near the capital region and the municipality of the island Bornholm. In the most recent National Forest Inventory (2004-2008) the forest area is categorized into: coniferous forest (42%), broadleaf forest (32%), mixed broadleaves and coniferous forest (14%), areas with Christmas trees and greenery (2%). A total number of 64 different tree species were categorized in the trial plots. Estimating the crown cover of each tree species allowed for an approximation of the area share of the species. Coniferous tree species account for approximately 52% of the forest area, broadleaves 44% and the remaining 4% was classified as non-forested. Norway spruce (*Picea abies*) is the most common species, and covers 17.1% of the forest area, followed by: beech (*Fagus sylvatica*) - 12.9%; pine (*Pinus ssp*) – 12%; oak (*Quercus robur*) – 9.6%; Sitka spruce (*Picea sitchensis*) – 6.1%; *Abies normania* – 4.5%; Maple (*Acer pseudoplatanus*) – 3.5%; and ash (*Fraxinus excelsior*) – 3.4%.

The inventory reflects an increasing share of broadleaves compared to earlier statistics (Larsen and Johannsen 2002), where broadleaves covered approximately 37% (some differences in the inventory procedure may have caused this dramatic increase). The age-class structure varies and only a smaller part of the broadleaf area consists of old stands. Less than one third of the beech area is older than 100 years and more than 95% of the oak area is younger than 100 years. The most common harvest regime is clear-cut felling, accounting for 68% of the area, 20% is naturally regenerated and 11% is un-even aged managed. The average total standing volume was estimated at 112.8 million m^3. The broadleaves account for 54%. In 2004-2008 the annual harvested timber volume varied between 1.8 and 2.9 million m^3. Site productivity varies and is highest on Zealand, Fün and the eastern part of the Jutland peninsula. (Nord-Larsen et al. 2009).

The average annual income per hectare on larger private forest estates was minus DKK 55 in 2006 and DKK 100 in 2007. Including income from other sources (e.g., hunting) the total income was approximately DKK 1,000 per hectare between 2004 and 2007 (Dansk Skovforening 2009).

In general, in Denmark there are rather detailed rules for what any given forest owner is allowed to do in his/her forest. For instance, 85% of the forest area is registered as forest reserve and must not be converted to any other land use. The first Danish forestry regulation was issued in 1805. The present Forest Act from 2004 has three primary objectives:

- To conserve and protect the Danish forests and to increase the forest area.
- To promote sustainable forest management by the inclusion of economic as well as ecological and social values. An holistic approach should promote the establishment of robust (wind- and disease-resistant) forests, ensure the production of the forests, conserve and increase the biological diversity, and ensure that proper attention is given to landscape beauty, natural history, cultural history, environmental protection and outdoor recreation.
- The administration of the Forest Act should endeavour to strengthen advisory services and information to private forest owners on sustainable forest management.

The Forest Act restricts the maximum area share of Christmas trees and greenery in the forest at 10%, but allows for coppice forest management and forest grazing covering a total of up to 10%, and open nature areas may be established covering up to 10% as well.

7.1.2 Planning problems in the Danish forest sector

The Danish Ministry of Environment implements the National Forest Inventory (NFI) to continuously monitor the forest resource. Such information has been important in forming Danish forest policy over the years, and also to set new targets for increasing the area share of forest. Similar large-scale problems and analysis are made on a regular basis to estimate the amount of carbon stored in the forest biomass and forest soil. Results show that forests play an important role as part of the national obligation to meet climate mitigation targets.

Ever since the Danish forest planning system was revolutionized by the German forester Hans-Georg von Langen in the 1760s, forest planning has been seen as one of the most important areas/disciplines in ensuring sustainable forest management. Both the private and public sector have developed rigorous planning systems. Since the 1950s, the Danish State Forest central administration units (Forest Agency 1921-1986, Forest and Nature Agency 1986-2010, Nature Agency 2010-) was organized with a separate Department for Forest Inventory and Planning, which performed 15-year strategic and tactical plans at the district level (each district having a size between 1,500 ha and 20,000 ha, mergers causing an increasing size over the years), which were subsequently implemented at the district level and revised on an annual basis (Table 1).

Table 1. Historical events in Danish forest planning

1763	J.G. von Langen is invited by the Danish King to implement sustainable forest management and planning in the Royal forests of North Zealand (Christensen 1988; Fritzbøger 1994; Serup 2004)
1800	Principles of sustained yield forest management are implemented in some larger private forest estates (Serup 2004)
1805	Act on Conservation of Danish Forests which should ensure forest areas were never replaced by other land uses in designated private and public forests (Serup 2004)
1850	Forest planning in Danish State Forests is organised in the unit of Forest Regulation (Serup 2004)
1860-1880	Systematic forest management plans are developed for a number of large private forest districts
1866	The private consultancy company owning large forest areas, Danish Heathland Company is

	established
1897	Discussion club for foresters (later Danish Association for Forest Owners) is established
1904	The first Danish Forest Extension Service member organisation County Vejle is initiated
1949	Danish Association for Forest Owners and Danish Heathland Company establish forest planning divisions (Christensen 1988)
1964	The first versions of the forest planning system SR-plan are used by the unit of Forest Regulation (Sørensen 1991)
1978	The forest planning computer system Tauron, based on SR-plan, is developed by the Danish Forest and Nature Agency and Danish Heathland Company (Christensen 1988)
1978	First edition of Forest Accounting tables (Christensen 1988)
1984	The private forest planning company KW-Plan is established and offers digitizing and area estimations to private forest estates
1989	The forest planning system Proteus is introduced at the national conference "Planning and Management in Danish Forestry"
1999	LandInfo is applied by the Danish Heathland Company
2000	Danish Forest Accounting Tables software is developed for the private forest sector (Enevoldsen 2001)
2001	More than 10 years after it was launched, the planning software Proteus is implemented by the Danish Forest and Nature Agency (Andersen et al. 2004)
2002	National Forest Inventory (NFI) system is applied for national statistics on forest data (Brunner et al. 2005).

The most important element in these medium- to long-term plans was the emphasis on exercising good and sustainable forest management – the most prevalent objective being timber production. The head of the Department during that period was always an educated forester. This situation has gradually changed for several reasons. Today the Department has been merged into the Department of Economics and Area Management, including not only forest areas but nature areas in general. The goal of ensuring sustained yield and timber for public consumption is nowadays replaced by sustainable management aiming at providing public services such as clean water, recreation, biodiversity, carbon storage and sustainable extraction of natural resources. Finally, it also aims to enhance public awareness about forest and nature services.

Currently the Nature Agency is revising the structure of the forest planning process, a change which may be a significant step away from the previous rationality-based planning platform. One issue being discussed is whether the strategic and medium to long-term plans should be cancelled and replaced by less costly inventory reports and project reports which are more focused on delivering public services. This redirection of forest planning discourse may be seen as a result of change in characteristics of the planning problems which attract the most attention from the policy arena.

Planning problems in the private forest sector are less policy-focused and more directed towards business-related issues. More than 67% of the forest area is owned by private persons or companies, 4% is owned by private foundations, 20% by the State Forests, 6% by other public authorities (e.g., municipalities, the Ministry of Defence, churches), and for 3% of the area we do not know the owners. The ownership varies geographically. In the central parts of Jutland and on Zealand, more than 70% of the forest area is privately owned.

Estates below 5 ha account for 64% of the total number of forests, but only 7% of the forest area. Estates above 1,000 ha account for 0.2% of the total number of forests, but 34% of the forest area. Less than 50% of the forest area employs foresters and 17% has no forester supervision. The majority of owners receive their main income from other sources than forestry, i.e. agriculture or other business. The reasons for owning forests depend on the characteristics of the forest owner. Based on a survey among private forest owners in Denmark, Boon et al. (2004) categorized Danish private forest owners into three groups: (1) the classic forest owner to whom the forest has economic importance; (2) the hobby owner who enjoys work and recreation in the forest; and (3) the indifferent farmer to whom the different values provided by the forest are equally (un)important. Implications of this typology for forest policy formulation and implementation are discussed.

During the last 25 years, a number of larger forest administrators have been implementing medium-term and short-term planning models. The Danish Nature Agency (previously the Danish Forest and Nature Agency) and HedeDanmark (previously the Danish Heathland Company) have developed their own planning systems. The aim of this development is to promote data management and sharing, growth, harvest and land use modelling, and the establishment of flexible mapping systems. The total number of private consultants on forest planning systems is approximately six; KW-Plan being the largest presently. The planning systems are mostly based on geographical information systems (GIS) linked with stand list registers and growth and harvest models (e.g., LANDINFO, PROTEUS, TAURON, PLANKAT/PC-KORT), which allow for medium-term/tactical planning. Advanced decision tools such as optimization and multi-criteria decision-making decision support systems (DSS) have not been implemented. Participatory approaches are mostly implemented in public forests where user councils are established and used for involving the public and stakeholders in the development of visions for establishing National Parks in Denmark.

7.1.3 Problem type categories

The majority of DSS are used on problems related to large or medium-sized forest companies (private or public) or on problems related to forests owned by small-scale non-industrial private forest owners (NIPF). Rarely, DSS have been used to supply information for strategic decisions on national forest policies. A few examples exist, mostly presenting NFI data and simulation of carbon storage in Danish forests. The analysis of forest land use and harvesting strategies are usually made on a <u>strategic/long-term and national basis.</u> <u>Spatial</u> aspects are ignored and carbon is considered a <u>semi-marketed product</u> since it is not yet traded in a free market, but is part of the measures to meet Danish mitigation targets. Since this analysis considers both private and public forest land, many stakeholders are involved (Problem Type 1: strategic (long-term), non-spatial, national level, multiple objectives, market wood products, multiple decision-makers/stakeholders).

A number of <u>stakeholders</u> are involved in preparing the <u>tactical</u> (medium-term) regional/district level State Forest plans including authorities (e.g. municipalities, regional councils), organizations (e.g., Danish Association for Nature Conservation, forest owners, user groups) and local business enterprises. Forest products such as timber and fuel wood are <u>marketed</u>. However, the majority of services produced are non-marketed (e.g., recreation, berries, drinking water, carbon storage). Most hunting rights are sold on a free market, and within restrictions related to the group sizes, private forest owners are entitled to claim a fee from visitors to their forest. The problem is typically first stated as long-term planning problem, concerning strategies for the long-term use of the forest resource. In particular the public forest sector or some larger private forest estates in very urbanized settings involve a range of stakeholders in defining the objectives and strategies (Problem type 2: strategic (long-term), forest level, spatial with neighbourhood interrelations, multiple objectives, market wood products, market services, multiple decision-makers/stakeholders). It is then followed as a tactical medium-term spatial problem with neighbourhood relations and non-market services concerns for scheduling activities on a 10-15 year perspective (Problem type 3: tactical (medium-term), forest level, spatial with neighbourhood interrelations, multiple objectives, market wood products, market services, non-market services, single decision-maker). Lastly, operational planning follows for scheduling harvest activities, road maintenance etc. on a yearly or seasonal basis (Problem type 4: operational (short-term), forest level, spatial with neighbourhood interrelations, multiple objectives, market wood products, single decision-maker).

Private forest estates are usually owned by a single owner/decision-maker. An important first step is the development of strategic long-term plans (Problem Type 5: strategic (long-term), forest level, spatial with no neighbourhood interrelations, multiple objectives, market wood products, single decision-maker) followed by tactical medium-term targets on revenue, forest land use policies, certification etc (Problem Type 6: tactical (medium-term), forest level, spatial with neighbourhood interrelations, multiple objectives, market wood products, single decision-maker). The forest planner projects on an annual basis the stand lists at forest and estate/district levels. Registration of changes in stand establishments and changes in tree species at stand level is updated by forest-educated staff. Stand level planning decisions regarding manpower and machines are sometimes made using information about resource needs and potential benefits. Often decisions are influenced by spatial aspects regarding avoiding too large clear-cuts or neighbourhood relations minimizing the risk of wind-throw. The tasks related to stand-level decisions are aggregated and compared to the targets made at forest or district level. Many of the planning systems allow for transfer of information to the machine planning system. For both privately and publicly owned forest, the decisions are often guided by multiple goals concerning timber, recreation, biodiversity protection or hunting.

7.1.4 Objectives

To obtain an overview of existing applications of DSS in Denmark, as well as a better understanding of the potentials of decision support, the objectives of this country report are to:

- Collect an overview of the most common DSS and computerized tools used in Danish forestry
- Describe the main characteristics of the DSS and tools
- Describe what characterizes the decision problems, the decision environment and the decision process in private and public forest planning
- Discuss the limitations and potentials of DSS (including more advanced multi-criteria DSS) to enhance the quality of decision-making

7.2 Materials and methods

7.2.1 Data and information collection

In order to achieve the above-mentioned objectives, a selective number of forest administrators were interviewed to provide information about their use of DSS. Furthermore a literature review of Danish journal articles and web pages related to the forest sector was performed. Regarding understanding the potentials of multiple criteria DSS, we examined the interviews made with participants and representatives involved in forest administration and forest related planning problems. A specific case: the highly complex policy process of designing the establishment of National Parks in Denmark, was used in the interview. The case study was designed to disclose the involved decision-makers' and stakeholders' perception of the decision process, as well as stakeholder attitudes towards multiple criteria DSS in Denmark. We argue that despite the case dealing with National Parks, it is a most relevant example of the complexity of the decision process Danish forest and nature managers, and in particular public authorities, are dealing with.

Information about the applications of DSS in Danish forestry was based on interviews with representatives from larger public and private forest administrators and a literature review. The qualitative interviews were made based on a structured agenda developed for the meeting, and adapted to the organization in question. The interview was taped, transcribed and coded (Kvale 1996) and a summary with statements was mailed to the respondents, who then returned comments, if any. The interviewees from organizations included three forest superintendents from the Danish Forest and Nature Agency, the Director of a private forest planning company KW-Plan, two foresters from the planning consultant company Orbicon, and a forester from the Danish Forest Extension Service.

The assignment of the problem type category was done by comparing each planning problem considered for both private and public forest organizations with the suite of potential categories. Subsequently, the authors assessed which problem category each DSS was linked with.

As a special case we used the National Park process to collect data from a range of forest sector stakeholders for assessing the potential use of DSS for complex forest and land use decisions (multiple objectives/multiple stakeholder settings). Experience from the DSS inventory revealed that the applications of complex DSS were limited in the public sector and absent in the private. Therefore, we tried to increase our understanding of the challenges facing researchers in promoting complex DSS by implementing a semi-structured qualitative interview of selected stakeholders involved in the sustainable forest management and the Danish National Park process. This process benefits from being multi-dimensional in terms of exploring trade-offs between economic, ecological and social needs, and multi-participatory since stakeholders from both private forestry, NGOs, and public forestry were involved in the process. We interviewed five of the 32 members of the National Steering Committee. Interviewees included representatives of the Danish Forest Owners Association, the Danish Nature Conservation Association, the Danish Outdoor Recreation Council, the Danish Forest and Nature Agency and the association Danish Agriculture. The interviews addressed two main subjects: i) interviewees' perception of the characteristics of the policy process, and ii) interviewees' attitude towards the integration of complex DSS during the final phase of the actual decision-making stage.

7.3 Results

7.3.1 Overview of the use of DSS in the Danish forest sector

The results section is organized into two main sections. The first section presents an overview and more detailed description of the DSS used in the Danish forest sector. The second section presents the results of the perceptions of the potential use of DSS in complex forest and nature management in Denmark, based on interviews with stakeholders involved in the Danish National Park process (see section 2.1 for a more detailed description). The results of this will be applied for discussing the current applications of DSS in the forest sector and also the perspectives for enhancing and targeting the development of DSS according to the planning problem types the sector is facing.

Table 2. DSS used in the Danish forestry sector

Problem type	Computerized tool/DSS	Models and methods	Knowledge management techniques (if applicable)	Methods for participatory planning (if applicable)
1	No DSS reported			
2	PROTEUS	GIS Stand level growth and yield models Economic accounting Simulations		
	PEB	Stand level growth and yield models Economic accounting Simulations Optimisation Multi-criteria decision analysis		Potential
3	PC-KORT	GIS Stand list information		
	TAURON	Stand level growth and yield models Economic accounting Simulations		
	PLANKAT	Stand level growth and yield models Economic accounting Simulations		
4	LANDINFO	GIS Stand list data Regeneration models		
	SØK	Stand level simulation of growth, yield and economic		
5	TAURON	Stand level growth and yield models Economic accounting Simulations		

	PLANKAT	Stand level growth and yield models Economic accounting Simulations	
6	PLANKAT	Stand level growth and yield models Economic accounting Simulations	
	RODPOST	Optimisation of harvest assortments	
	KUBIK	Sorting and simulations	Database storing harvest measurement lists

A compilation of the DSS used in the Danish forest sector is presented in Table 2, applying the structure for Danish planning problems presented in section 2.1. No computerized tools/DSS were reported for Problem Types 2, 3 and 6, respectively focusing on stakeholder involvement and strategic planning problems.

7.3.2 Forest level

Planning at this level most often would involve large to medium-scale planning with spatial neighbourhood relations, multiple stakeholders (public forestry) or single owners. The use of DSS varies and depends on the size of the forest estate. Small forest estates (small NIPFs, <50 ha) often have no DSS or in the best case a forest map and a stand list. Larger estates would normally apply DSS including growth and harvest predictions and long- and medium-term planning horizons.

Large and medium-scale forestry planning

PROTEUS can be applied at all levels within the Danish Nature Agency, from the single stand to compartment, to forest, to forest district, regional and national level. The conceptual ideas of PROTEUS were presented at a national conference in 1989, but the development was not initiated before 1999 when the Danish Forest and Nature Agency and Carl Bro A/S signed a contract on its development. The software was launched in 2001, and new modules have been added to the planning system since then. PROTEUS is based on annual planning principles, aggregating from the stand level. Growth and yield, area and economic budgets are interlinked between years and planning periods which provide the opportunity to develop long-term planning. PROTEUS contains three graphical user interfaces: i) maps, ii) a stand list, iii) hierarchical pathfinder linked to a server database containing all geographical information about each stand. PROTEUS is only used by the Danish Nature Agency.

PC-KORT and **PLANKAT** are developed by KW-plan and are interlinked, which allows for updating area and harvest budgets. PLANKAT contains a stand list and graphical interfaces where the user may choose harvest and thinning regimes, regeneration, growth and economic models. PLANKAT simulates tactical 10-year plans with annual planning information. Additional planning modules for fertilizing, Christmas tree production, and working plans are developed. PC-KORT is a GIS module linked with all area information, and digitizing facilities are included which allow the user to create thematic layers, update the map, and change the compartment structure. PC-KORT includes a 3-D visualization module for simulating landscapes and the results of management decisions. This system is implemented on many larger private forest estates as well as NIPFs in Denmark.

LANDINFO is an information management system applied mainly by HedeDanmark and includes area information, maps and digitizing facilities. The system is linked to stand lists and the TAURON system which includes growth and yield simulations, regeneration models, area and economic budget models. TAURON develops tactical 10-year and annual plans.

PEB is a multi-criteria forest planning software developed for research and teaching by Peter Tarp at University of Copenhagen (Tarp 2006) and has not yet been implemented in private or public forestry. Based on strategic goals the software develops tactical 10-year plans and annual operational plans at stand and forest level. It includes growth and yield simulators, regeneration and economic models, and an assessment of biological and recreation values which are included in the multiple criteria linear programming optimization model. The model has been applied for developing small-scale medium- and short-term forest plans on private forest estates.

7.3.3 Stand level

All the planning systems above include stand-level growth and yield simulators. **KUBIK** developed by KW-Plan is a harvest DSS, which allows the user to simulate effects of different assortment distributions.

SØK was developed by KW-Plan in 2000, and includes a graphical user interface where the user can simulate different stand-level decisions. The user can choose between a range of tree species, site qualities, assortment distributions, update price and cost information, and calculate the resulting growth and yield as well as income, regeneration costs, and net present value. **RODPOST** is applied for optimizing the assortment distribution of single trees, based on information about the length and diameter of the log. The system is widely used in private and public forestry, research and teaching as well as by stakeholders for scenario analysis.

7.3.4 Characterizing the forest planning process and decision settings

This part of the analysis is deducted from interviews made with stakeholders involved in the Danish National Park process, which was chosen as the planning problem. The interview included a theme for introduction and ‘warming up’, followed by thematic questions on the planning problem applying cognitive mapping methods, and a discussion of relative importance of planning issues/criteria in decision-making. The interviews confirmed that the suite of DSS normally applied in forest planning had merits in terms of suggesting solutions for sector-specific planning problems, in particular regarding marketed wood products. The answers to such planning questions would benefit from rational-based analysis, since the objective (profit maximization), problem formulation, problem analysis and choice of decisions to some extent are clear and rational. However, when it comes to more stakeholder driven decision processes, the interviews confirmed that the planning problem types become multi-dimensional and are far from being rational and comprehensive. Despite the fact that problem complexity may reduce the relevance of DSS complexity, the interviews reveal that case-specific DSS aiming at scientifically based simulations of potential consequences could be valuable in establishing a sound decision basis.

7.4 Discussion and conclusions

The planning problems vary between the private and public forest sectors. Where most public planning problems would require the involvement of multiple stakeholders and more emphasis on marketed services than wood products, private forest planning decisions are usually made by a single decision-maker focusing on strengthening the business aspects of the plan. The survey and interviews revealed that the DSS in most cases supports the development of a business plan. When comparing the common Danish forest planning problem types (see section 1.3) with the features of the DSS, we note the following major differences which will be discussed in the following:

- Most planning problems at any spatial and temporal scale are in reality spatial problems, but have been handled as non-spatial problems in most DSS.
- Most planning problems at any spatial and temporal scale are characterized by multiple objectives, but this is not explicitly handled in the models, but rather by forest planners interpreting the objectives and assigning tasks in the activity plans.
- Most planning problems at any spatial and temporal scale in the public forest sector include multiple stakeholders, but the DSS are rarely designed to develop an interactive play between the planner and the stakeholders. Rather, geographical interfaces allow the stakeholders ex post to access geo-information related to marketed services.
- Dynamic aspects and risk minimization are not included in the DSS. However, most forest-level tools allow for some scenario modelling without assigning risks to it.
- The planning for small NIPF has usually been based on a description of the forest state and seldom with information on the future growth and harvest potentials.

The DSS revealed in this review could be categorized into at least three distinct types. The first group simulates the consequences of strategic decisions on national forest policies. The second group usually involves a number of stakeholders in preparing the medium-term plans. Private forest holdings usually prioritize the information collection and modelling of forest products and marketed goods. However, monitoring impacts on services and non-marketed goods is usually only undertaken by holdings which are part of a forest certification scheme. In general private forest owners are only required to document sustainable management if they are inspected by the Danish State Forest authorities.. The DSS and their GIS facilities allow for the inspection of spatial consequences of stand-wise management decisions. However, there exists no explicit incorporation of the spatial constraints or aims in the simulations. The last group includes standalone DSS to simulate stand growth, economic returns etc. In that sense this country assessment reports a rather limited number of advanced DSS applications in the Danish forestry sector compared to other European countries. Some of the responses from the interviews indicate that this may be linked to the relative importance of the forest sectors in the respective countries. It could be argued that advanced DSS at the forest level, including spatial and dynamic modelling elements, would be in high demand by medium to large-size forest estates. However, only a few developers are really active in the Danish market and the costs of developing/purchasing the software for Danish conditions is expected by the owners to be higher than the benefits. Therefore, basic information such as stand list information and GIS approaches are applied for the majority of small-scale NIPFs. However, larger scale forest owners with long-term planning requirements often emphasize the need for growth and yield models, regeneration and economic models, linked within annual and medium-term tactical plans. Surprisingly, no computerized tools/DSS were reported for assisting stakeholder involvement and solving strategic planning problems (Problem Types 1 and 2). A follow-up questionnaire revealed that stakeholder involvement and strategic planning are important steps in public forest planning. The stakeholder involvement and strategic planning usually follows formalized procedures in public meetings, hearings, workshops, but is seldom supported by computerized DSS. The respondents argued that the complexity of such processes is high and the demand for knowledge and expertise rarely would focus on the DSS but rather on procedures which would encourage trust building between stakeholders and the facilitation of consensus solutions.

A complementary assessment of the 'usefulness' of complex DSS in the Danish forest sector was implemented. As a special case we used the National Park process to collect data from a range of forest sector stakeholders. The interviews of selected stakeholders in the Danish National Park as well as the interviews with representatives from larger public and private forest administrators about their applications of DSS revealed some interesting viewpoints on the pros and cons of applying more advanced DSS.

The interviews reflect the fact that DSS to some extent help decision-makers to articulate values and objectives and to increase the transparency of inherent assumptions shaping the decision process (Keeney and Raiffa 1976; Day et al. 1987; Carroll et al. 1993). Interestingly some of the interviewees argued that DSS might lead to the local formulation of projects being standardized to a form, which would not capture the goal/intention of the local participants in case public participation was needed in the planning process. The element of 'business as usual' was mentioned as a factor discouraging the integration of more complex DSS in forest planning. Few people are used to working within this kind of logic and may feel much more confident with the traditional dialogue- and paper-based deliberative approach. Some of the respondents argued, that if 'black-box' modes were avoidable, complex DSS could contribute to reduce complexity. One of the software developers feared that flexibility may decrease and it would be even harder to handle uncertainty if more advanced optimization procedures were introduced in the planning models. It is important that the software users accept the DSS methods, reasonable time requirement, and sufficient support and guidance for successful implementation (Hämäläinen et al. 2001). A general conclusion based on the coding of the interviews is that most DSS are currently developed for planning problems where technocratic solutions are requested/accepted and where mainly expert knowledge is needed (Figure 1).

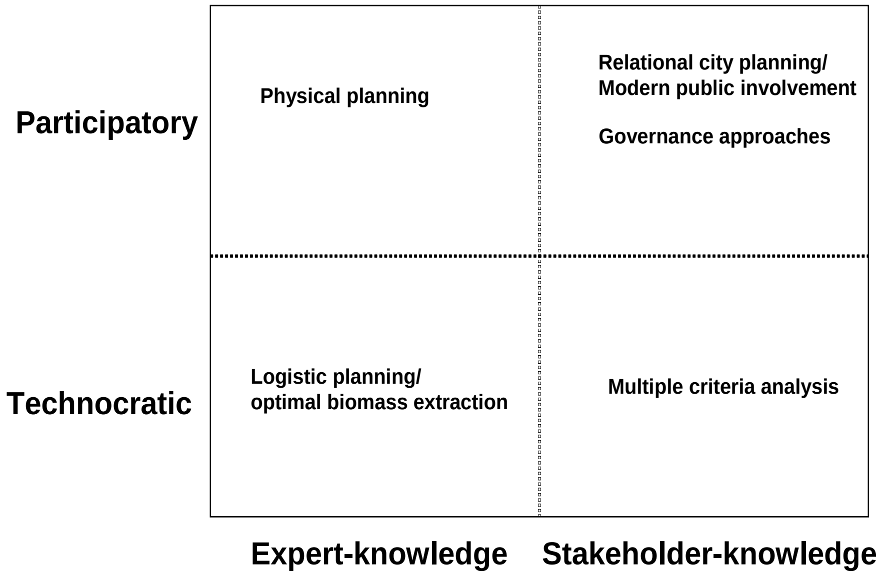

Figure 1. Some examples of planning problems/approaches in cases where either participatory or technocratic approaches are requested/accepted, and expert or stakeholder knowledge is demanded for suggesting solutions.

The results of this country report show that DSS could contribute to a decision environment where decisions are made in a rational manner and based on technically and scientifically sound solutions. One deficit may be that many DSS lack participatory features and may in fact exclude people from participating in the planning process, despite the fact that planning decisions may affect their life. This reflects a conflict between technocratic science-based decisions proposed by technocrats/experts and more open and local decision processes relying less on science. Daniels and Walker (2001) state that citizens demand technically sound decisions, but as situations become more complex, fewer people have the technical background needed to either meaningfully contribute to or criticize the decisions. On the other hand, these complex decisions often affect people's lives. The duality of striving for technical competence and participatory/democratic processes creates a compelling dynamism between a narrow approach of expertise and a broad politic of inclusion. Forest services and non-marketed goods are often public goods. People feel that they should have a voice in at least public, but also in many private decisions that affect their utility. But how can that voice be meaningful if the terms, concepts and technical trade-offs are all new or unacceptable to them? Finding ways to increase the quality of technical expertise, while simultaneously increasing stakeholders' inclusion in decision processes, is certainly a challenging task in bridging the gap between science and development of DSS for the forest sector.

The need for development of DSS in the private forest sector diverts from the public one. Not surprisingly, private forest holdings request tools for managing the forest resource and making rational, business-oriented decisions. The management of forest products is often complemented by additional income sources related to experience economics, e.g. hunting, concerts, guided tours, or team building courses. Interestingly, short-term decision tools or planning approaches seem to replace medium- to long-term planning tools. Some of the private stakeholders suggest that as a result of uncertainty about future markets and aims of the forest estate, the value of medium-term information is relatively low compared to the costs of planning. What is currently discussed is the increasing need for knowledge management, entrepreneurship and business development to make the forest business viable.

References

Andersen, B. E., Buttenschøn, C., Dralle, K., Friese, S., Retsloff, T. and Skyum, J. 2004. Digital forvaltning ved planlægning af Skov- og Naturstyrelsens arealer. Perspektiv nr. 6, Geoforum.

Boon, T.E., Meilby, H. and Thorsen, B.J. 2004. An empirically based typology of private forest owners in Denmark: Improving communication between authorities and owners. Scandinavian Journal of Forest Research 19 (Supplement 4): 45-55.

Brunner, A., Johannsen, V. K. and Vesterdal, L. 2005. Effekten af statsskovenes overgang til naturnær drift på kulstofbinding i skovene. Center for Skov, landskab og Planlægning – KVL Arbejdsrapport fra Miljøstyrelsen Nr. 10 2005.

Carroll, C., Pandian, J.R.M. and Thomas, H. 1993. The role of analytic models in strategic management. International Review of Strategic Management 4:3-59.

Christensen, J. 1988. Skovplanlægning i Danmark. Hovedopgave ved skovbrugsstudiet. Den Kgl. Veterinær- og Landbohøjskole, Frederiksberg, Maj 1988.

Daniels, S. E. and Walker, G.B. 2001. Working through environmental conflicts: The collaborative learning approach. Praeger Publishers, Westport (CO).

Dansk Skovforening, 2009. Regnskabsoversigten 2007 – overskud på landsplan [Forest accountings 2007 – surplus at the country level]. Danish Forest Owners Association. Available at: http://www.skovforeningen.dk/site/nyheder/1195/ Accessed. January 2011. [in Danish]

Day, D.L., Desarbo, W. and Oliva, T. 1987. Strategy maps: A spatial representation of intra-industry competitive strategy. Management Science 33:1534-1551.

Enevoldsen, K. 2001. Nyt økonomi PC værktøj til skovadministration. Skoven 2/2001. p. 58.

Fritzbøger, B. 1994. Kulturskoven. Dansk skovbrug fra oldtid til nutid. Miljøministeriet, Skov og Naturstyrelsen, Gyldendal, København, 440 p.

Hämäläinen, R.P., Kettunen, E. and Ehtamo, H. 2001. Evaluating a framework for multi-stakeholder decision support in water resources management. Group Decision and Negotiation 10:331–353.
Keeney R. and Raiffa, H. 1976. Decision with multiple objectives: preferences and value trade-offs. Wiley, New York.

Kvale, S. 1996. Interviews: An introduction to qualitative research interviewing. Sage Publications, Thousand Oaks, California.

Larsen, P.H. and Johannsen,V.K. (eds.) (2002). Skove og plantager 2000. [Forests and Plantations 2000]. Danmarks Statistik, Skov & Landskab og Skov- og Naturstyrelsen. 171 p.
Nord-Larsen, T., Johannsen, V.K., Vesterdal, L., Jørgensen, B.B. and Bastrup-Birk, A. 2009. Skov og plantager 2008 [Forests and plantations 2008]. University of Copenhagen, Faculty of Life Sciences, Skov & Landskab, Hørsholm. 21 p. [in Danish]

Serup, H. 2004. Ordnet skovbrug i Danmark 1800-1950 - planlægning og dyrkning på Silkeborg Statsskovdistrikt og Hvidkilde Skovdistrikt. Ph.d.-afhandling, Den kgl. Veterinær- og landbohøjskole, Skov & Landskab, 2004, pp. 97- 159.

Sørensen, V. K. 1991. Simulering i skovplanlægning – nordiske tiltag på området. Hovedopgave. Den Kgl. Veterinær- og Landbohøjskole, Institut for økonomi, Skov og Landskab, Sektion for skovbrug, Frederiksberg.

Tarp, P. 2006. Principles of sustainable forest and natural resource management. The Royal Veterinary and Agricultural Univeristy, Danish Centre for Forest, Landscape and Planning, Division of Economics, Policy and Management Planning. Part II, pp.165-271.

8 Design and use of forest decision support systems in Estonia

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8.1 Introduction

The Republic of Estonia is located in northern Europe on the eastern coast of the Baltic Sea. The total area of Estonia is 45,227 km^2, with a distance from north to south of 240 km and from east to west of 360 km. According to the inventory of the 2009 National Forest Inventory (NFI), Estonia has 22,050 km^2 of forest land, which represents approximately half of the country. According to the Forest Act, forest land is land listed in the land register as forest land or land of at least 0.1 ha where woody plants with a height of at least 1.3 m and with crown closure of at least 30% grow (RT I, 2006).

Based on the geographical division of plants, Estonia primarily belongs to the northern area of the nemoral-coniferous or mixed forest belt of the temperate zone of the northern hemisphere. The main tree species is Scots pine, the share of which is 34% of forest area and 30% of growing stock. The mean volume per hectare is 229 m^3. The second most common tree species is birch (Silver and Downy), with a share of 31% of forest area and 23% growing stock. The third most important species is Norway spruce, having a share of 16% of forest area and 23% of growing stock. Other ranking species are aspen and alder (Grey and Black) (Estonian Environment Information Centre, 2010).

A total of 19,267 km^2 of forest areas have an owner, of which 9,463 km^2 is private; 9,771 km^2 is state; and 33 km^2 is municipal forest. Roughly 2,700 km^2 of forest areas have no owner (Estonian Environment Information Centre, 2010). Forest land without an owner is former private land, the potential owners of which did not wish to claim it or to which nobody was entitled.

After the Second World War, a huge proportion of agricultural land was no longer being used, and was afforested or became covered with forest; thus, during the last 60 years, forest area has increased from 14,200 km^2 to 22,050 km^2 (Estonian Environment Information Centre, 2010). This has resulted in an unbalanced age structure of Estonian forests. Sustainable forest management expects that the total amount of cutting is not higher than the total volume growth. Thus, a landscape-level decision support system is a helpful tool.

In Estonia, in 46% of forests the proportion of the prevailing tree species is less than 70%. Therefore, forest management is a difficult task as different tree species have a different optimal rotation age. Thus, a stand level or even a tree level decision support system is an efficient application program.

Approximately 31% of Estonian forest land is covered with management restrictions. Strictly protected forests in Estonia cover an area of 1,823 km^2, which makes 8.2% of the total forest area (Estonian Environment Information Centre, 2010). The number is relatively large compared to other European countries, but according to the Estonian Forest Development Programme it does not ensure the preservation of forest biodiversity, characteristic forest types and ecosystems. The objectives set in the programme are based on consensus, which expresses the readiness of the society to give up the income from forest management for environmental values. But on the other hand, the opportunity cost of forest conservation has not yet been calculated.

8.1.1 Prevalent forest management and decision-making problem types in Estonia

Following the dimensions and forest management problem types in Estonia suggested by FORSYS; seven different types (Table 1) can be defined:

T1 – forest inventory and tactical management planning
T2 – operation management planning by forest owner
T3 – planned management activity approved by state
T4 – tactical management planning for protected areas
T5 – long-term planning and prediction of wood flow in management
T6 – long-term choice of management for single stand
T7 – long-term choice of activities for the purpose of nature protection

Table 1. Prevalent problem types in Estonia according to FORSYS dimension categories

Dimensions		Types						
		T1	T2	T3	T4	T5	T6	T7
Temporal scale	Long term (strategic)					X	X	X
	Medium term (tactical)	X						
	Short term (operational)		X	X	X			
Spatial context	Non spatial	X				X	X	
	Spatial with neighbourhood interrelations		X	X	X			X
	Spatial with no neighbourhood interrelations							
Spatial Scale	Stand level	X		X			X	
	Forest level		X		X	X		X
	Regional/national level							
Parties involved	Single decision-maker	X	X	X	X	X	X	
	More than one decision-maker/stakeholders							X
Objectives	Single	X	X	X		X		
	Multiple				X		X	X
Goods and services	Market non-wood products							
	Market wood products		X	X			X	
	Market services							
	Non-market services				X			X

8.1.2 Enacted legislation in forest management

In Estonia for forest management, it is obligatory to have forest inventory data about every stand; the data must be gathered no more than 10 years ago. Forest inventory is a licensed job in Estonia; thus, only companies who have a forest inventory licence, can undertake it. At the moment 14 organizations have the licence, including the Estonian University of Life Sciences and State Forest Management Centre. Forest inventory is carried out according to the *Forest Inventory Instruction*, which was enacted on the basis of the Forest Act (RTL, 2009). The instruction comprises definitions, methods and mathematical models to calculate stand characteristics. Every company has their own software to handle and process inventory data, some of those are developed by the author of the current report. The *Forest Inventory Instruction* was compiled by a work group which consisted of representatives from forest inventory companies, the Private Forest Centre, governmental organizations, and the Estonian University of Life Sciences.

Criteria and instructions for management planning are fixed by law with the *Instruction for Forest Management*. This document defines minimum density before and after thinning, minimum age by species for clear-felling, minimum number of seedlings for planting, etc. The document was compiled by a work group which consisted of representatives from forest inventory companies, the Private Forest Centre, governmental organizations, and the Estonian University of Life Sciences.

Forest inventory data have to be entered in the Forest Register (FR), which is managed by the Estonian Environment Information Centre (EEIC). This is a state agency administered by the Ministry of the Environment. For public use, data in the FR are partially available in a web-based information system (http://register.metsad.ee/avalik/). For every stand, only some of the variables (age, diameter at breast height and share of volume) about first layer species are available for public use. The register provides no information about owners. Full access outside the EEIC has been granted for the Estonian University of Life Sciences and may be given for forest inventory companies and forest owners, upon applying for permission.

The EEIC manages the information system EELIS, which contains all available spatial information about nature conservation in Estonia. It is a geographical information system, where every object which needs some level of protection is presented. EELIS is not for public use, it is available only for those whose work or ownership is related to nature conservation restrictions, e.g. forest inventory companies, forest owners, governmental environment organizations, universities, etc.

As 31% of Estonian forest land is covered with management restrictions; therefore, some forest owners would prefer to exchange their forest with areas where restrictions do not apply. In Estonia, it is possible to exchange one’s own land; the exchange is managed by the Ministry of the Environment. Lands are exchanged only with equal value or with little compensation. Land price is calculated by a methodology compiled by the Estonian University of Life Sciences. The methodology has also been enacted with a regulation (VVM, 2008). The Estonian Land Board (ELB) carries out land price calculation and has developed an application according to the methodology. The same methodology is used by some private forest companies which have to evaluate their biological assets for accounting.

Another option by the state is to buy the areas for a certain purpose (e.g. the Ministry of Defence buys areas for military practice). For this, another methodology, a little bit different from that used in the case of exchange, is used to calculate the price of the forest land. This methodology was also compiled by the Estonian University of Life Sciences and enacted with a regulation of the Minister of Defence (KM, 2005). The same methodology is used by some private forest companies for calculation of the price of forest land which they intend to buy or sell.

8.2 Materials and methods

The author of this report has participated in the preparation of legislation on forestry and forest management plans as well as in the development of forestry software for different private companies; therefore, no separate surveys were carried out for this report.

8.3 Results

Most models and methods are described in relevant legislation on the basis of which companies have developed their own information systems.

Table 1 refers to legislation in which the models and methodologies are presented; the following abbreviations are used for respective acts:

- FII – *Forest Inventory Instruction* (RTL, 2009)
- IFM – *Instruction for Forest Management* (RTL, 2006)
- NPA – *Nature Protection Act* (RT I, 2004)
- FEVM – *Forest Land Exchange Value Calculation Methodology* (VVM, 2008)
- FBVM – *Forest Land Value Calculation Methodology* (KM, 2005)

The ELB handles a public map server (http://geoportaal.maaamet.ee/) with different thematic web map applications, through which the ELB mediates various spatial data managed by different owners. For forest owners and managers the most important applications are the following:

- Land Information application
- Restrictions Information System application
- Estonian Nature Information System application
- Soil Map application
- Private Forest Centre application

The Estonian University of Life Sciences has developed the Forest Modeling Information System (ForMIS, http://formis.emu.ee/), which contains four different modules: Growth and Yield Tables, Dendrometric Formulas, Forest Equations, and Sample Plot Data (Sims, 2009). It is introduced in the FORSYS wiki (http://fp0804.emu.ee/wiki/index.php/Main_Page). This web-based information system, combining empirical data and existing knowledge of forest development, enhances the use of forestry metadata and forest models manipulation and verification/validation procedures. In principle, the information system contains two parts – empirical data management and models evaluation. Data management includes data verification in data recording into the database, outlier detection after data recording and several standard procedures (e.g. stand level data calculation from tree data).

Sample plots data module in ForMIS is a tool for data handling. Currently the database comprises 1,078 sample plots with 3,548 measurements encompassing all trees. To the module of growth and yield tables have been collected a total of 240 sets of tables from 23 European countries, containing 1,135 growth and yield tables and 23,552 data rows. A module of dendrometric formulas was included in ForMIS for systematizing and sharing empirical dendrometric formulas. The information system is expected to become a useful tool for modellers as well as for the end-users of the models.

Mostly forestry companies have developed their own personal information system (PIS) and a commercial or a freeware GIS is used for spatial data management. In the GIS software, the ELB offers some spatial information for public use via a Web Map Service. The information system EELIS, developed by the EEIC, is used for forest restrictions management. Every cutting, reforestation, etc. has to be approved before cutting by the EEIC and they use the FR for managing all that information; thus, different decision-makers fulfil the same task in management planning.

The FII contains models to calculate site index, stand volume, volume increment, and stand relative density. All those models are available also in ForMIS.

The IFM contains rules for minimum basal area before and after thinning, minimum age for final felling, a minimum number of plants per hectare for reforestation, etc.

The NPA defines the size of areas around protected objects and restrictions for management.

The FEVM contains only models to predict forest assortments from stand, including a simple diameter distribution function, a stand height curve model, and an assortment calculation model derived from a taper curve model.

The FBVM is developed from the exchange value calculation methodology and contains additionally models to predict forest growth (stand level height, diameter, and density) by one-year step, thinning and final felling prediction methods, and a price calculation (including the NPV) method. This is a complete description of stand level growth simulation including a certain management regime. Most of the models are available also in ForMIS. Some of them, however, are too complicated to be included in ForMIS.

Table 2. List of problem types and their solutions.

Problem type	Tool/DSS	Models and methods	Decision-maker	Participatory process	Knowledge management
T1	PIS	FII, IFM	Forest inventory company	Interrelated actions upon which decision-makers have their own tasks and consult each	Data management has been centralized by government
T2	PIS, GIS	FII, IFM	Owner		

T3	FR	FII, IFM	EEIC	other, have the same result – owners activities are approved.	and it is shared for participants of the process.
T4	PIS, GIS, EELIS	FII, IFM, NPA	Owner		
T5	PIS	FII, IFM, FBVM	Owner	Owner's personal issue	PIS
T6	Under developmen t	Under development	Owner	Owner's personal issue	PIS
T7	Under developmen t	Under development	Owner	Owner's personal issue	PIS

8.4 Discussion and conclusions

Estonia has 90 years of history in forest inventory and therefore the directive for that is well stated to unify data collected by different companies. In Estonia, the forest management plan prepared by forest inventory companies is used for tactical planning. The traditional management regime for the next 10 years is planned without concerning neighbouring stands; thus, no spatial analysis is needed. Inventory and stand variables calculations are carried out according to the FII and management operations are selected if needed according to the IFM. Computers have a long history in Estonian forestry. Computerised calculations were first used in Estonia in the 1960s at computing centres.

The traditional forest management regime for a stand is usually selected according to the main tree species which has the highest share of volume; therefore, a pure stand has the same management regime as a highly mixed stand with the same main tree species as a pure stand. This tradition is about to change, as recent studies and projects are carried out to develop new models and update current models in forestry legislation. As more and more information systems are common in everyday work, it allows more complex solutions to be developed for selecting management regimes.

Forest owners manage their own forests and select the management operation from the forest management plan, considering also neighbouring stands (problem types T1-T4); therefore, for spatial decision support, GIS software is needed. However, all rules are described in the IFM; thus, all necessary models and methods are available. Before a forest owner can carry out a management operation, it must be approved by the EEIC. They have their own information system, the FR, where forest inventory data, spatial nature conservation data, etc. are available. This information system is also based on the models and methods given in the FII, IFM and NPA. Thus, efficient computerized tools for solving problem types T1-T4 are available in Estonia.

Management regime is more difficult to select if any management restrictions are applied (problem type T4). All this information is available in the application EELIS, where forest owners or managers can see the spatial structure of restricted areas. Allowed operations are described in the NPA.

For predicting available forest resources in the long term using the traditional management regime (problem type T5), the respective manual is available for developing a stand level growth simulator. Such a prediction does not consider the spatial structure of stands. The simulation is used also for long-term cash flow prediction. Thus, efficient computerized tools for solving problem type T5 are available in Estonia.

Estonian forests are mostly mixed stands; therefore, for optimal management a more complex solution is needed than the traditional management regime selected according to the main tree species (problem type T6). A methodology for solving that problem is under development. Long-term management planning concerning nature protection (problem type T7) is needed, but the methodology is not ready for public use. Therefore, problem types T6 and T7 do not have computerized solutions in Estonia.

References

Estonian Environment Information Centre, 2010. Yearbook Forest 2009.

KM, 2005. Maaüksuste ja nendel paiknevate metsade hariliku väärtuse hindamismetoodika Kaitseministeeriumi valitsemisalas. 02.05.2005.

RT I, 2004. Looduskaitseseadus [Nature Protection Act]. RT I, 2004, 38, 258. [https://www.riigiteataja.ee/akt/13338169]

RT I, 2006. Metsaseadus [Forest Act], RT I, 2006, 30, 323. [https://www.riigiteataja.ee/akt/13249748]

RTL, 2006. Metsamajandamise eeskiri [Instruction for Forest Management], RTL 2007, 2, 16. [https://www.riigiteataja.ee/akt/13299966]

RTL, 2009. Metsa korraldamise juhend [Forest Inventory Instruction], RTL 2009, 9, 104. [https://www.riigiteataja.ee/akt/13124148]

Sims, A. 2009. Information System of Dendrometric Models and Data – a Tool for Modeling of Forest Growth. PhD thesis. Estonian University of Life Sciences.

Sirgmets, R., Kaimre, P. and Padari, A. 2011. Economic Impact of Enlarging the Area of Protected Forests in Estonia. Forest Policy and Economics 13(3): 155-158.

VVM, 2008. Kaitstavat loodusobjekti sisaldava kinnisasja riigi poolt omandamise ja ettepanekute menetlemise kord ning kriteeriumid, mille alusel loetakse ala kaitsekord kinnisasja sihtotstarbelist kasutamist oluliselt piiravaks ning kinnisasja väärtuse määramise kord ja alused. [https://www.riigiteataja.ee/akt/13133361]

9 The use of forest decision support systems in Finland

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9.1 Introduction

9.1.1 Finland's forests and their ownership

Situated within the Eurasian boreal forest zone, Finnish forests are dominated by coniferous tree species. Forestry land in Finland covers a total area of 26.3 million ha, of which 20.1 million ha are forest land (Finnish Statistical Yearbook of Forestry 2010). 3.0 million ha are protected or under restricted use; these forests are located mainly in northern Finland. The total growing stock volume of 2,206 million m^3 consists of a mixture of Scots pine (65%), Norway spruce (24%) and various deciduous species (mainly birch) (11%), with even-aged forestry the dominant management method.

Forestry and its associated industries directly account for the employment of 70,000 people in Finland, representing just under 3% of the total national labour force. Although decreasing in importance, the forestry sector currently makes up around 5% of Finland's GDP, with forest-derived products comprising nearly 20% of total exports (Finnish Statistical Yearbook of Forestry 2010).

Non-industrial private forest (NIPF) owners represent the major ownership group in Finland and account for 60% of all forests in the country. Of this area, 76% is owned by families and the rest by heirs or jointly by siblings, cousins etc. Forest ownership in Finland is typically passed down to the next generation in the form of an inheritance. Around 345,000 NIPF holdings currently exist in Finland, with an average size of 30 ha (holdings below 2 ha excluded; source: Hänninen and Peltola 2010).

State-owned forests (25% of total forest area, largely located in northern and eastern Finland) are managed by Metsähallitus, a state-run enterprise which, along with its commercial forestry duties, is responsible for the supervision of natural parks, fostering biodiversity and both the recreational and cultural values of state forests. Other public forests (6% of total forest area) are managed by municipal bodies, foundations and the church, while private industrial forests (9%) are owned by wood-processing companies. The management of the latter is typically intensive.

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9.1.2 Prevalent forest management problem types in Finland

i) Non-industrial private forest (NIPF) holding-level tactical planning

Regional Forestry Centre (FC) units (in total 13 units located across Finland) are the dominant actors in holding-level forest planning, and they also act as advisory and supervisory agencies for non-industrial private forestry. This governmental role in NIPF planning is to direct family-run forestry operations towards management that follows the principles of sustainability and good silvicultural practice, but which are also simultaneously in line with owners' objectives (Hokajärvi et al. 2009). The particular values and wishes of private owners (e.g. forests for scenery or recreation) have usually been taken into account by setting aside individual stands or parts of stands, delaying treatments of stands, and adjusting the amount and timing of harvests during the 10-year planning period. From January 2012, there will be only one national FC unit, with 13 regional offices. This reorganisation will mean the establishment of two main strands of private forest planning: (i) free of charge forest resource reports describing the forest resources of the holding, as well as management guidelines based on the principles of good silvicultural practice; and (ii) client-oriented planning paid for by the forest owners. However, state subsidy remains in the form of the provision of free basic forest inventory data. Due to historical and institutional factors, there is reason to assume that the 10-year holding-level plan remains the default management instrument in private forestry.

Planning problems here can be categorised as: **Medium term (tactical), Spatial with no neighbourhood interrelations, Forest level, Single decision-maker, Multiple objectives, Market wood products, Market services, Non-market services**.

ii) Selecting stands for felling – from tactical to operational timber sales planning

In this planning task the tactical plan is operationalised by using the treatment suggestions and stand data to compile a harvesting reserve, with current profitability values guiding the forest owner in operational decision-making.

Planning problems here can be categorised as: **Short term (operational), Spatial with no neighbourhood interrelations, Stand level, Single decision-maker, Single objective, Market wood products.**

iii) Regional Forest Programme (RFP)

Finland's national objectives for the use of forests are defined in the National Forest Programme (Finland's National Forest Programme 2010), a Government resolution prepared as part of a participatory political process led by the Ministry of Agriculture and Forestry (MAF). In turn, the FC organisation is responsible for leading the process of compiling Regional Forest Programmes (RFPs). RFPs establish outlines for a range of activities in each region, including forest management, industrial timber use, non-wood production, recreation, nature conservation and rural development (Saarikoski et al. 2010). The framework of the RFPs, as well as the issues that must be included within them, are largely outlined in forest legislation, but also contain a number of general goals of the National Forest Programme.

According to the Forest Decree (1200/1996), RFPs must be prepared in close cooperation with the main forestry stakeholder groups and environmental authorities. To this end, MAF has established Regional Forest Councils, which assist the FC units in drafting and following-up the RFPs. Appointed by MAF based on the advice of the FC units, each of these councils consists on average of 20 members who sit for a term of three years, representing forest owners, the forest industry, regional authorities and several NGOs.

Planning problems associated with RFPs can be categorised as: **Long term (strategic), Non-spatial, Regional level, More than one decision-maker, Multiple objectives, Market wood products, Market non-wood products, Market services, Non-market services**.

iv) The natural resource planning (NRP) process of Metsähallitus

The objective of the NRP process is to develop a balanced land-use allocation plan that takes into account the different demands associated with the utilisation of the state forests located within the area covered by each NRP. These plans define the intensity and main lines of forest management operations for the forthcoming 10-year period, but also consider longer-term sustainability. The NRP process includes the following phases: evaluation of the current state of the planning area and operational environment, goal analysis, creation of alternatives, their evaluation and selection of one alternative as well as its further specification, implementation and follow-up. Goal analysis means that stakeholders ultimately select the relevant objective variables for further analysis. These variables often cover one or more of the following perspectives: economy, social issues, ecology and multiple-use. The process is often iterative, so that certain phases - especially goal analysis, creation of alternatives and evaluation - can be repeated. In the core of the process is the stakeholder group that participates in all phases of planning. Their ultimate aim is to create a widely-accepted proposition that defines and justifies the strategy alternative they recommend for the region.

Planning problems associated with NRPs can be categorised as: **Long term (strategic), Spatial with no neighbourhood interrelations, Regional level, More than one decision-maker, Multiple objectives, Market wood products, Market non-wood products, Market services, Non-market services**.

v) From strategic to operational/tactical level in Metsähallitus team area

NRPs do not take spatial constraints/aspects (e.g. transfer costs of harvesting machinery, road building and maintenance costs) into account, which can lead to non-optimal harvesting solutions. As a result, more accurate operational/tactical-level planning is needed in the allocation of yearly stand-level harvesting. As each region is further subdivided into teams, yearly cutting budgets can be defined at team level in terms of the desired timber assortment composition, distribution of different felling schemes (initial thinning, thinning, regeneration felling) and time of harvest. Each local team is also constrained in terms of its operations by the NRP plan, e.g. the minimum area of old growth forest.

Planning problems here can be categorised as: **Short term (operational), Spatial with neighbourhood interrelations, Regional level, More than one decision-maker, Multiple objectives, Market wood products, Non-market services**.

9.1.3 Objective

The objective of this national report is to illustrate the utilisation of different forest decision support systems (DSS) by describing the planning processes considered to be representative of Finland. This means that the definition of forest DSS used here is holistic, i.e. it includes all planning tools, systems and approaches that are or could be present in these processes.

9.2 Materials and methods

The descriptions of forest planning problems outlined in the previous section, the use of DSS, as well as the analyses described below are all based on a range of sources, including material published as a result of real-life planning processes, research articles which describe the development of the DSS and which study the actual planning processes involved, experience gained during development projects by both the authors and other stakeholders, as well as the practical experience of the authors.

In more detail, the following materials were utilised:

- Forest DSS
    - MELA – described in FORSYS wiki (http://fp0804.emu.ee/wiki), see also http://mela2.metla.fi/mela/julkaisut/oppaat/mela2009.pdf
    - SIMO – described in FORSYS wiki, see also www.simo-project.org/documentation/SIMO_manual.pdf
    - MONSU – described in FORSYS wiki
    - MESTA – described in FORSYS wiki
    - Excel worksheet containing both SWOT and AWOT data and priority calculations – see Pesonen et al. (2001)
- Models and methods used in forest DSS
    - Hynynen et al. (2002) describe most of the models of tree/stand development used in the above-mentioned forest planning systems
    - Several research articles (see references in the relevant sections) that describe the multi-criteria decision support (MCDS) techniques and their use in planning processes
    - MCDS support application MESTA, described in FORSYS wiki www.mesta.metla.fi
- Knowledge management (KM)
    - Published information describing the outcomes of planning processes (e.g. NRPs and RFPs from different areas)
    - Quality-management systems employed by Metsähallitus and FC units, as well as publications outlining the development history of NIPF planning, e.g. Tikkanen et al. (2010)
    - Several research articles that describe the role of KM in these processes
- Participation
    - Documents which describe the outcomes of various planning processes (e.g. NRPs and RFPs from different areas) and which analyse participatory procedures in Metsähallitus (e.g. Wallenius 2001)
    - Quality-management systems and participation guides devised by Metsähallitus and FC units (Asunta et al. 2004), as well as articles outlining the development history of NIPF planning (Tikkanen et al. 2010)
    - Several research articles related to participation in these planning processes

9.3 Results

9.3.1 Summary of studied planning processes

Table 1. Overview of the presented planning problems with respect to the utilisation of DSS.

Planning problem	DSS	Models and methods	KM techniques	Participatory planning methods
3.2 NIPF holding-level planning	MELA	Numerous empirical models describing the development of the forest, potentially involving (J)LP optimisation	Quality-management system, Reuse of stand border data, Survey determining owner's previous actions, aims and anticipations, Stand data in GIS, DBMS	-
3.3 NIPF operational timber sales planning	MONSU + WEB service	Current profitability method ('winning value' calculation based on Faustmann's formula)	Use of decision-making rules, GIS user interface	-
3.4 RFP	MELA, MESTA internet application	Numerous empirical models describing the development of the forest, (J)LP optimisation, MAV-type approach, Voting techniques	Cognitive mapping, SWOT analysis	Stakeholder group work, Internet questionnaire, Public hearings
3.5 NRP	Excel worksheet containing SWOT and AWOT data and priority calculations	AHP, SMART, SMAA etc.	Utilisation of local knowledge, Expert knowledge, GIS-based tools using stand and other collected data for the creation of buffer zones etc.	Stakeholder group work, Internet questionnaire, Public hearings
	MELA	Numerous empirical models describing the development of the forest, (J)LP optimisation		
	MESTA Internet application,	MAV-type approach		

Planning problem	DSS	Models and methods	KM techniques	Participatory planning methods
	Excel worksheets containing MCDS data	Utility analysis, Voting techniques		
3.6 Metsähallitus operational/ tactical planning	SIMO	Heuristic optimisation (Tabu Search)	Expert knowledge to estimate future timber demand, GIS+DBMS	-

The DSS presented in Table 1 vary considerably in their development histories.

MELA: The MELA planning program has a long development history of more than 25 years, originating from the creative thoughts by Professor Pekka Kilkki at the University of Helsinki, with the program and its methods (e.g. JLP) continuously developed by the Finnish Forest Research Institute's forest planning research group (MELA group). Used in numerous different practical calculations, MELA has been mainly employed in regional- and state-level cutting scenarios. For a more detailed description of the development history of MELA, see Nuutinen et al. (2011) and Siitonen (2009).

MONSU: MONSU was developed by Professor Timo Pukkala at the University of Joensuu (now the University of Eastern Finland). Development began in the late 1980s, with the program since used for many purposes, particularly in research projects in which multi-objective planning method development has taken place. For an outline of the main contents of MONSU, see Pukkala (2004, 2006).

SIMO: SIMO was developed at the University of Helsinki during a three-year research project (2004-2007) funded by major forestry companies and public forestry organisations in Finland (see www.simo-project.org). The current sponsor and main developer of SIMO is the private company Simosol Oy. For an overall view of SIMO and its development history, see Rasinmäki et al. (2009).

AWOT in Excel: The combined use of SWOT analysis and the MCDS method was initially developed in 2000 as part a research project at the Finnish Forest Research Institute (Kurttila et al. 2000). This approach has subsequently undergone further development and as a result other MCDS methods can now be used to prioritise SWOT factors and groups (for additional details, see Kangas et al. 2008).

MESTA: The first version of the MESTA internet application was tested around 10 years ago as part of a research project at the Finnish Forest Research Institute (Pasanen et al. 2005). The use of the system was subsequently expanded to cover participatory planning situations, including NRP and RFP processes (e.g. Hiltunen et al. 2009).

Excel worksheets involving the application of MCDS methods: The use of different general MCDS methods in Metsähallitus-led NRP processes has been applied in a number of cases, e.g. see Pykäläinen et al. (1999) and Hiltunen et al. (2008, 2009).

9.3.2 Non-industrial private forest (NIPF) holding-level tactical planning

Utilisation of different DSS in the planning process

Growth analysis and other statistical models included in MELA are typically employed to predict the development of stands. Management suggestions for the first 10-year period are usually based on planner's field investigation and subjective considerations, while later treatments are selected based on optimisation results, with sustainable yield and maximum allowable felling calculated subject to the restrictions of the Forest Act (1093/1996) and Forest Decree (1200/1996). MELA is used for such calculations in a rather straightforward manner by forest planners working for FC units.

Models and methods used in the forest management DSS

The various models found within MELA are used to update stand data and to simulate their future development. Compiling holding-specific forest plans also occasionally involves the use of the JLP algorithm (Lappi 1992) included in MELA.

Application of KM

The overall planning process is standardised by a quality-management system devised by the FC (Tikkanen et al. 2010) which provides online guidelines on various aspects of planning, including how to account for different forest variables, how to perform calculations and how to ascertain the preferences of individual landowners. This material is useful for both new (to understand the process) and more experienced planners (as a guide to check their work). In addition, the FC's database also contains information describing customer-oriented processes associated with scenarios involving landowners with varying levels of forestry knowledge and experience. This information helps planners adjust their service based on the customer at hand and improves both the effectiveness and cost-efficiency of planning work.

Existing stand delineation data from the forest resource database is normally reused, as well as any usable information related to the timing of previous forestry operations. Local knowledge held by the owner is also exploited during the process, while expert knowledge (e.g. of planners' colleagues) may be utilised when difficulties relating to stand treatment arise during field investigation.

Participation procedures

With the exception of communicating directly with the forest owner, no participation tends to be involved due to the cultural-historical tradition of strong ownership rights and the decision-making power of private forest owners in Finland.

9.3.3 Selecting stands for felling – from tactical to operational timber sales planning

Utilisation of different DSS in the planning process

Current profitability analysis is employed to determine whether it would be economically more rational for a forest owner to continue growing timber for one more year, or to fell the trees and invest the resulting income in an alternative investment offering a certain rate of return (Nyyssönen 1999). In present-day applications of current profitability analysis, planning calculations are carried out using the MONSU planning system (Pukkala 2004), with the results then presented to the landowner via the internet (Figure 1).

Presented in monetary terms (€/year), these results should be easy to understand, even for forest owners who are not familiar with forestry terminology. Felling is recommended for all stands with the potential to accommodate thinning and for all mature stands with negative current profitability value. MONSU also calculates estimated timber sales income for individual stands. Based on current profitability analysis, the application has been developed and used for individual NIPF owners/customers by the forest planning consultancy firm Metsämonex Ltd. for a number of years.

Models and methods used in the forest management DSS

The current profitability values of individual stands are calculated using the following formula:

$CPV = I_a - p(A_t + A_l)$

where CPV is the current profitability value, I_a is the value increment (€/ha/a) of the stand, p is the rate of return (%/a) offered by the alternative investment object, A_t is the timber value of the stand (€) and A_l the value of the bare land (€).

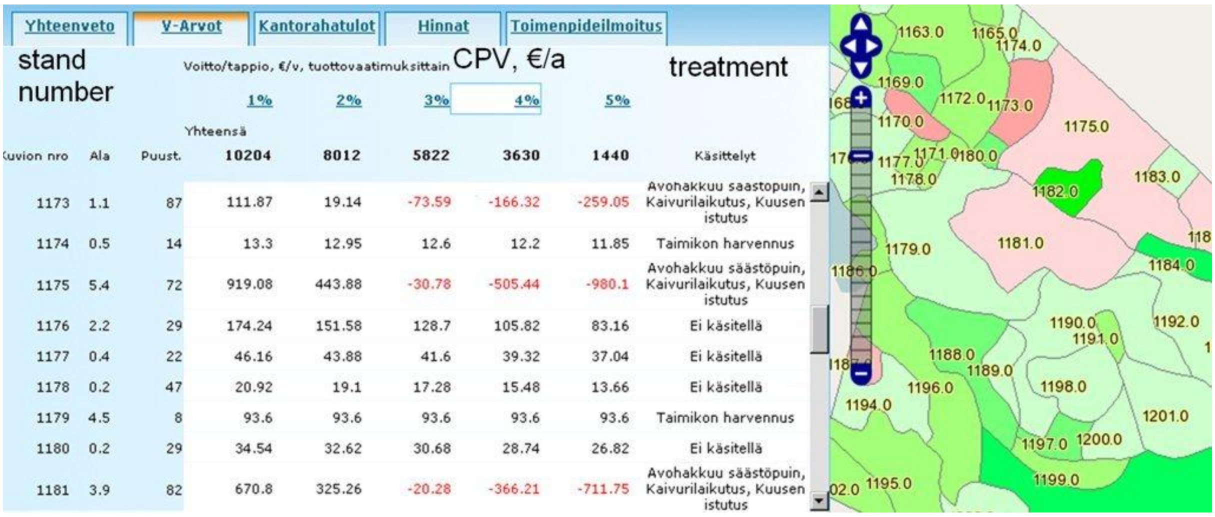

Figure 1. The current profitability values (CPV €/a)) of different forest stands as presented online in both list and map format.

Application of KM

The application of KM here – and currently mainstream practice in Finnish forestry - involves simulating alternative management scenarios for individual forest stands. When selecting the treatment schedule for each individual stand, the following decision rules are used:

(i) Regeneration felling is proposed for mature stands with negative current profitability values.

(ii) For young and middle-aged forest stands, treatment options are selected based on the thinning models found in the official forest management recommendations (Hyvän metsänhoidon suositukset 2006).

(iii) For open areas, reforestation is advised in all cases according to official recommendations (Hyvän metsänhoidon suositukset 2006).

Participation procedures

Aside from that of the forest owner, no further participation is involved.

9.3.4 Regional Forest Programme (RFP)

Utilisation of different DSS in the planning process

The phases of the RFP planning process can be outlined as follows:

(i) Situation analysis examining operational environment, forest resources, forest use and development potential (MELA and SWOT can be used).

(ii) Construction of several forest land-use scenarios based on discussion with stakeholder groups (MELA is used here).

(iii) Illustration of alternative scenarios by predicting the values of indicator parameters (MELA is used here). The results of MELA calculations, such as economic and employment effects, are further processed via the use of input-output statistics and associated models.

(iv) Selection of the most preferable scenario (voting techniques could be used here).

(v) Development of a more detailed programme description, i.e. including a definition of programme objectives and action plan.

(vi) Descriptive impact analysis, with the results included in the final version of the programme.

As part of recently-completed RFPs, three 'basic' cutting scenarios have been created in MELA for all FC regions: (a) the average cutting level will remain the same as in the past five-year period, (b) maximal sustainable cuttings, (c) maximum cuttings (within the limits of forest legislation and recommendations for good silvicultural practice). FC units have been encouraged to formulate their own scenarios in collaboration with forestry councils. A maximum 'set aside' scenario has also often been calculated to describe the cost of nature conservation. The creation of these scenarios in MELA has largely been carried out by reseachers from the Finnish Forest Research Institute.

The main indicator values used in the scenarios are largely derived from solutions calculated in MELA, with the indicator variables themselves proposed by MAF (e.g. drainage, protected area, amount of decaying wood, usage of woodchips, NIPF owner income from timber trade, experience in the forestry sector, quality of water protection scheme, maintenance of habitats of special ecological importance, multiple-use potential of forest). However, FC units have also been encouraged to devise their own indicators.

The preferred scenario is then selected mainly via descriptive discussions, first involving the Regional Forest Council, followed by the board of directors of the FC unit. Ministry guidelines include the proposal that a decision table (indicator values for each scenario) be constructed and the 'Borda-count' voting method used to support discussions. However, MCDS tools have not been widely employed.

Models and methods used in the forest management DSS

National forest inventory (NFI) data used include tree-level measurements of sample plots, with both tree- and stand-level models used in MELA to simulate future stand development. In addition to natural processes, forest management operations are also simulated to take place at specified times. Cutting scenario solutions are derived from solving the LP problem in MELA via use of the JLP algorithm (Lappi 1992).

Application of KM

The following KM techniques may be employed in RFPs:

- SWOT: the main tool used in situation analysis by all Regional Forest Councils.
- Common overall process structure; phases and guidelines for the content of RFPs are suggested by MAF.
- Metla has produced data and carried out calculations for RFPs to illustrate different forest management scenarios. NFI data form the basis of these calculations, supported by GIS- and DBMS-derived solutions which together act as a large-scale forest data repository and management system, on the basis of which new knowledge is created.
- Expert knowledge is also utilised frequently in the RFP process, mainly in qualitative form. RFP procedure often includes several expert-groups (e.g. biodiversity, timber production and rural SME development), providing both expert knowledge and preference information.
- Tacit knowledge, obtained from local stakeholders, is collected in various settings including public hearings and internet surveys.

Participation procedures

One of the main aims of RFP is to function as a discussion-forum involving the region's forestry stakeholder groups. The most important of these forums are the Board of Directors and Forestry Councils of FC units. As members of the Board of Directors of FC units, the forest industry, forest owners and environmental authorities thus participate in actual decision-making. The Forestry Council represents a wider discussion forum; FC units ask major stakeholder groups to nominate their own candidates. Participation in these official groups is typically conducted using normal meeting procedures and without the use of DSS. In addition, FC units have, to varying degrees, encouraged several other groups to participate, with hearings, surveys, web pages and feedback sheets representing attempts to open up the RFP process. Additional analysis of RFP participation procedures can be found in Kangas et al. (2010) and Saarikoski et al. (2010).

9.3.5 The natural resource planning (NRP) process of Metsähallitus

Utilisation of different DSS in the planning process

The core of the NRP process is the creation and multi-criteria evaluation of alternative management strategies. Various different forest management principles and land use allocations are analysed and their effects determined. Although planning problems associated with NRP are categorised as reflecting a long-term strategic and regional process, NRP also utilises to some degree an exogenous spatial approach (e.g. Kurttila 2001) in which spatial constraints for important areas (e.g. forests near lakes, Capercaillie lekking arenas) are defined in GIS. The main DSS used in NRP calculations is the MELA forest planning system, supported by GIS analyses. These analyses are performed by experts working on behalf of Metsähallitus, based on demands from the Metsähallitus working group and the participating stakeholder group.

Models and methods used in the forest management DSS

The models and other analytical methods used in MELA are described in more detail in the FORSYS wiki (additional references can be found therein), while descriptions of the various MCDS techniques typically employed in a forest planning context can be found in Kangas et al. (2008). For example, at the beginning of each NRP process SWOT analysis is often used for the analysis of the present state and future expectations regarding the operational environment. After the NRP process for Western Finland, SWOT analysis was augmented by the analytic hierarchy process (AHP) MCDS technique (Pesonen et al. 2001), while during the NRP for Eastern Finland (Itä-Suomen… 2008), voting techniques (e.g. Kangas et al. 2006) were used to establish the ranking order of the nine selected decision-making criteria. In the selection of the most suitable alternative management system, stakeholder group negotiations have been supported with utility analysis (Kangas et al. 2006, Pykäläinen et al. 1999, 2007), voting techniques (Hiltunen et al. 2008, Pykäläinen et al. 2007), and, most recently, with the Mesta internet application (Hiltunen et al. 2009).

Application of KM

The working model for the RFP process has been developed and improved based on experience (e.g. Asunta et al. 2004), and is also described in Metsähallitus' quality-management system. Best practice guidelines for the different PR, meeting and group work techniques have been devised with the help of the experiential/tacit knowledge of the key participants.

Databases and GIS are employed for the storage and management of forest inventory data, as well as the storage of (and to geographically locate) public feedback. Hierarchical information logistics to and from local, regional and national levels (see Hujala and Kurttila 2010) are important in this kind of planning situation.

Expert knowledge is utilised frequently, for instance to overcome missing yield functions for multiple-use products and biodiversity-related goals. Expert knowledge is also exploited in order to evaluate plan outcomes with respect to the quality of the ecological network and the quality of the area for hunting. Tacit knowledge held by local communities is also collected e.g. from public hearings and internet surveys.

During the two most recent NRP processes (Ostrobothnia and Eastern Finland), the so-called 'dream-world' approach - based to some degree on the Systems Intelligence approach (e.g. Hämäläinen and Saarinen 2004) - has been used in stakeholder group member workshops.

Participation procedures

A participatory approach was adopted for natural resource planning by Metsähallitus about 20 years ago (see Wallenius 2001), the core of which involves an invited stakeholder group that participates throughout the planning process. For example, a recently completed NRP process included a stakeholder group whose 20 members represented local authorities and interest groups. During this process the expectations of citizens regarding the utilisation of the planning area were determined by providing them with the opportunity to participate in seven public discussions and hearings. A total of 133 citizens participated. In addition, an open internet survey was organised in which citizens were invited to answer questions relating to the intensity of different Metsähallitus activities. 613 citizens answered this questionnaire. Finally, the regional council of Metsähallitus expressed their opinion regarding the created strategy alternatives.

9.3.6 From strategic to operational/tactical level in Metsähallitus team area

Utilisation of different DSS in the planning process

An approach attempting to solve an operational planning problem using a DSS was tested in the Kuhmo region of north-eastern Finland, an area of 253,000 ha and 60,000 forest stands. The goal of the project was to minimise harvesting costs by focusing operations in specific areas each year. A yearly stand-level harvesting plan was produced covering an initial four years, with felling allocations then established for the two following three-year periods (i.e. the remainder of the 10-year planning period). Calculations were carried out by collaboration between the forest planning consultancy firm Simosol Ltd. and a forestry student via use of the SIMO forest planning software. This approach is publicly available for outside use, but has not yet gained operational popularity.

Models and methods used in the forest management DSS

The spatial nature of the planning problem was tackled by first simulating alternative treatment schedules for stands and then switching the planning context to a higher spatial level at which the optimisation problem was formulated. Spatial aggregation of harvesting was targeted by generating treatment alternatives at department level (derived from stand-level decision alternatives) and setting a constraint for optimisation that harvesting in each department could take place a maximum of twice during the 10-year planning period. The department-level management alternatives thus consisted of all the possible combinations of two harvests, ranging from "no harvests for the target year" to "100% of potential harvests executed during the target year" at 10% harvest activity intervals. Goals and constraints were then formulated as a goal programming problem, i.e. minimising distance from the goals, with the problem then solved via use of heuristic optimisation.

Application of KM

Expert knowledge was used to derive the goals for the optimisation problem. While the overall goal for total harvesting level was established as part of the NRP process, a number of different sub-goals - relating to timber assortments and harvesting methods - were also developed based on market demand. Here GIS and DBMS were applied.

Participation procedures

No public participation was involved.

9.4 Discussion and conclusions

DSS in planning processes involving private forest ownership

In Finland it is commonly assumed that use of a tactical forest management plan can feasibly solve the majority of decision-making problems facing private forest owners. Indeed, an examination of the coverage of valid plans arguably reveals the Finnish forest planning system to be a success story (Ollonqvist 2001). However, a number of different incentives have been used to sell plans to forest owners (Hokajärvi et al. 2009), resulting in a situation in which the current form of planning dominates the forest planning services market. In contrast, strategic holding-level planning has been neglected and operational planning now tends to be based too heavily on the recommendations of the tactical plan. This has probably reduced the use of existing DSS in private forestry. With the changes currently taking place in the structure of forest ownership in Finland, planning services need to be diversified towards the strategic and operational levels, and new kinds of DSS and services developed (e.g. Eyvindson et al. 2011, Hujala 2009). Computer software tools may play a greater role in these services than they do today.

At present many forest owners are somewhat disconnected from the forest planning process; the state takes care of the forest inventory, while the updating of data is also tightly coupled to the 10-15 year inventory cycle, as, in fact, is the entire planning process itself. A number of ongoing development projects are currently attempting to address these issues, such as the "Social Forest Planning" project (see: www.vtt.fi/sites/socialforest/?lang=en) in which both ends of the problem are being addressed. To solve the need for the continuous updating of forest inventory data, a method is being developed to utilise mobile phone camera images as a data source. This would enable owners to independently update the database with information regarding the physical state of his/her forests, with data then easily obtained from a web-based DSS that generates continuously updated forest management plans. This DSS has two main purposes: (i) to enable an owner to formulate and express their own personal forest ownership goals - thus leading to an automatic change in forest utilisation if these goals change - and (ii) to compare the outcomes of different development scenarios enabling, for instance, what-if analyses. However, these comparisons may also necessitate the use of MCDS techniques which must be easy to use and understand.

In Finland, prevailing management planning practices relating to NIPF holdings appear to be well-grounded on stable, in-built methods, models and knowledge management. However, the current underuse of DSS means that simulation control and (spatial) optimisation in particular are not used to properly address issues from an owner’s perspective. It is evident that these kinds of features should and will be included in DSSs and practical planning services in the future. Only then will planning calculations used in the creation of alternative forest plans effectively incorporate landowners’ personal preferences.

Recently increased societal demands placed on forests, as well as the economic and other benefits of co-operation, indicate the need for participatory and/or co-operative planning in privately-owned forests; this includes the development of planning processes that simultaneously enable participation and respect ownership rights (Nuutinen et al. 2011). In this regard, pilot projects may represent an effective method of developing best practice guidelines for these kinds of sensitive processes, to which forest owners have previously taken a largely negative stand.

DSS in Metsähallitus forests

Metsähallitus has been a pioneer in the utilisation of various modern DSS and participatory techniques in its NRP processes, as exemplified by the use of the MELA planning system in the creation of true management alternatives, as well as the employment of different MCDS methods in multi-criteria evaluation of these alternatives. As a result, stakeholder groups have often found a commonly acceptable strategy with which to manage their region's state forests. However, disagreements have arisen, including, on a smaller scale, cutting operations in some sensitive areas. In addition, NRP processes have clearly suffered from a lack of multiple-use models. These models should show how, for instance, game populations or the recreational value of an area are affected by forest management operations and the resulting changes in forest structure, while another aim has been to define the monetary values of these kinds of forest uses. In addition, the creation of different and efficient alternative NRP strategies needs further development, with differences between proposed alternative management schemes in some cases only nominal.

The forest planning work carried out by Metsähallitus is a good example of a hierarchical planning system (see Hujala and Kurttila 2010). At present there exists a need to develop DSSs so that the activities of regional NRPs can be translated to the sub-area level; an attempt towards finding a solution to this problem was presented in section 3.6. However, in this case it was not possible to directly consider road-building or -maintenance costs, harvest machinery transport costs or the designation of optimally-clustered cutting areas. The uppermost level in the planning hierarchy is also important, since the combined outcome of each NRP plan effectively represents a national-scale management system. Current practice is such that the content of alternative NRP plans are, to some degree, constrained by the decisions of Metsähallitus HQ. The increasing pressure being placed on state forests in terms of their use for multiple (sometime conflicting) purposes highlights the need for some kind of national-level coordination, with clearer targets set for NRPs in different areas.

Utilisation of DSS in RFPs

So far the overall utilisation of DSSs in the creation of RFPs - in particular in the creation and evaluation of alternative forest management schemes - has been modest (Saarikoski et al. 2008). RFPs could potentially adopt some of the ideas featured in Metsähallitus' NRP processes. One reason for modest utilization of DSS can be the original statutory nature of the RFP: their outcome is a target programme, which includes targets for different forest utilization forms and forest management activities. The reality of achieving these targets is at least partially secured through the calculation of regional cutting possibility calculations. Compared to the (rather similar) NRP processes carried out by Metsähallitus - which also differ from RFPs in the respect that Metsähallitus has full powers to implement the former - a clear difference exists in terms of the creation of true alternative strategies and the use of MCDS techniques.

The results of the study carried out by Saarikoski et al. (2010) suggest that the RFP process should include facilitated information exchange of issues pertaining to forest management practices, timber markets and the protection of biodiversity. However, attempts to engage the general public in the RFP process have as yet been rather ineffectual. The process has also fallen short of expectations regarding the reconciliation of opposing perspectives and the production of jointly-accepted strategies, an issue on which the development and improved utilisation of DSS should focus. The biggest challenges lie in finding suitable approaches with which to constructively address conflicts, as well as the development of RFPs that will contribute to actual changes in forest management.

As part of a recent research project (Tikkanen et al. 2009), an idealised RFP process was developed and made available to the appropriate planning professionals at each FC unit. This 'ideal' process included the usage of scenario-building techniques, the creation of SWOT in connection with MCDS (e.g. Kurttila et al. 2009), use of the Q-sorting technique, computer-assisted analysis of stakeholders' cognitive maps, MESTA, as well as the application of Approval Voting and SMART/SWING ratings in Microsoft Excel. The employment of these techniques was tested in pilot schemes, with the practical implementation of these suggestions facilitated through the publication of an online support guide (www.oamk.fi/luova/metsaohjelma/?sivu=index.htm), including instructions, case-studies and a pre-prepared Excel worksheet. Currently ongoing, the completion of these RFP processes will reveal whether the above recommendations have been put into action.

Finnish forest planning problems - Gaps and the needs for DSS development

Forest planning is a continuously evolving discipline, and one which needs to develop in line with, or ahead of, changing management goals, practices and societal demands. Current and future development needs relating to forest planning in Finland can be summarised as follows:

- Forest inventory practices are changing drastically with the development of new remote sensing-based technologies. As a result, data available in the future will be clearly more detailed than that obtained traditionally at stand level. This development should enable the use of micro-segment grid-cells as units in planning calculations. As a result, there will likely be a real demand for explicit spatial optimisation approaches that are able to determine optimal - or at least practically feasible - felling areas.
- Increasing interest in the multiple use of forests has been evident for some time. More recently, much emphasis has been placed on modelling ecosystem services and their respective monetary value. Despite this development, models that are usable in forest planning calculations are still largely focused on timber-related issues. A more diverse model base would therefore enable the inclusion of the goals of a wider range of participants in the planning process.
- Forest management practices are also diversifying (e.g. Pukkala et al. 2011). In particular, continuous cover forestry is becoming more commonplace; in the future it may even supplement even-aged forest management practices, fulfilling the needs of multi-objective forest owners who may not accept clear-cut-based management techniques. As a result, the need to develop appropriate management instructions and models, as well as ways to transform even- to uneven-aged stands and the adoption of a new forest planning system is evident.
- The results of this report also reveal the currently inadequately-utilised potential of the integration of knowledge management tools and techniques in participatory forest planning processes. This is most relevant in RFP and NRP processes in which the integration of stakeholders' views and cultural-historical contextual knowledge with explicit forest resource information is crucial for the legitimacy of the management process.

References

Asunta, A., Hiltunen, V. and Väisänen, M. 2004. Metsähallituksen luonnonvarasuunnittelu. Suunnitteluohje. Metsähallituksen metsätalouden julkaisuja 47. 72 p. (In Finnish).

Eyvindson, K., Kurttila, M., Hujala, T. and Salminen, O. 2011. An internet-supported planning approach for joint ownership forest holdings. Small-scale Forestry 10(1): 1-17.

Finland's National Forest Programme 2015 - Turning the Finnish forest sector into a responsible pioneer in bioeconomy. 2010. Government Resolution 16 December 2010. 54 p. Available at: http://www.mmm.fi/en/index/frontpage/forests/forest_policy.html [accessed 01 November 2011].

Finnish Statistical Yearbook of Forestry. 2010. Finnish Forest Research Institute. 452 p.
Forest Act. 1093/1996. Available in English at: http://www.finlex.fi/en/laki/kaannokset/1996/en19961093 [accessed Aug 17, 2010].

Forest Decree. 1200/1996. Available in English at: http://www.finlex.fi/en/laki/kaannokset/1996/en19961200 [accessed Aug 17, 2010].

Hiltunen, V., Kangas, J. and Pykäläinen, J. 2008. Voting methods in strategic forest planning – experiences from Metsähallitus. Forest Policy and Economics 10: 117-127.

Hiltunen, V., Kurttila, M., Leskinen, P., Pasanen, K. and Pykäläinen, J. 2009. Mesta: An internet-based decision-support application for strategic-level natural resources planning. Forest Policy and Economics 13: 1-9.

Hokajärvi, R., Hujala, T., Leskinen, L.A. and Tikkanen, J. 2009. Effectiveness of sermon policy instruments: forest management planning practices applying the activity theory approach. Silva Fennica 43(5): 889-906.

Hujala, T. 2009. Owner-driven decision support in holding-specific forest planning. Dissertationes Forestales 85. Doctoral Thesis, University of Helsinki. 40 p + 4 articles.

Hujala, T. and Kurttila, M. 2010. Facilitated group decision making in hierarchical contexts. In: Kilgour, D.M. and Eden, C. (Eds.). Handbook of Group Decision and Negotiation. Advances in Group Decision and Negotiation, Vol 4. pp. 325-337.

Hynynen, J., Ojansuu, R., Hökkä, H., Siipilehto, J., Salminen, H. and Haapala, H. 2002. Models for predicting stand development in MELA System. The Finnish Forest Research Institute, Research Papers 835. 116 p.

Hyvän metsänhoidon suositukset. 2006. Metsätalouden kehittämiskeskus Tapio. Metsäkustannus Oy. 100 p. (In Finnish).

Hämäläinen, R.P. and Saarinen, E. (Eds.). 2004. Systems intelligence: discovering a hidden competence in human action and organizational life. Helsinki University of Technology, Systems Analysis Laboratory Research Notes A88. 320 p.

Hänninen, H. and Peltola, A. 2010. Metsämaan omistus 2006-2008. Metsätilastotiedote (SVT Maa-, metsä- ja kalatalous) 28/2010. 12 p. (In Finnish).

Itä-Suomen luonnovarasuunnitelma 2008-2017. 2008. Metsähallituksen metsätalouden julkaisuja 61. 151 p. (In Finnish).

Kangas, A., Laukkanen, S. and Kangas, J. 2006. Social choice theory and its applications in sustainable forest management – a review. Forest Policy and Economics 9: 77-92.

Kangas, A., Kangas, J. and Kurttila, M. 2008. Decision support for forest management. Managing Forest Ecosystems, Volume 16. Springer. 222 p.

Kangas, A., Saarinen, N., Saarikoski, H., Leskinen, L.A., Hujala, T. and Tikkanen, J. 2010. Stakeholder perspectives about proper participation for Regional Forest Programmes in Finland. Forest Policy and Economics 12(3): 213-222.

Kurttila, M. 2001. The spatial structure of forests in the optimization calculations of forest planning - a landscape ecological perspective. Forest Ecology and Management 142: 129-142.

Kurttila, M., Pesonen, M., Kangas, J. and Kajanus, M. 2000. Utilizing the analytic hierarchy process (AHP) in SWOT analysis - A hybrid method and its application to a forest-certification case. Forest Policy and Economics 1(1): 41-52.

Kurttila, M., Leskinen, P., Tikkanen J. and Niskanen A. 2009. Alueellisten metsäohjelmien kehittäminen toimintaympäristön näkökulmasta [Developing Regional Forest Programmes from the view of the operational environment]. Metsätieteen aikakauskirja 3/2009: 183-197. (In Finnish).

Lappi, J. 1992. JLP: A linear programming package for management planning. The Finnish Forest Research Institute. Research Papers 414. 134 p.

Nuutinen, T., Anola-Pukkila, A., Hirvelä, H., Kärkkäinen, L. and Mäkelä, H. 2011. Information and communication technology connecting mathematical modelling with multipurpose forest management. Journal of Forest Planning 16: 91-98.

Nyyssönen, A. 1999. Kiertoaikamalli Suomen metsätaloudessa Metsätieteen aikakauskirja 3/1999: 540–543. (In Finnish).

Ollonqvist, P. 2001. Forest policy objectives and institutions in Finland 1917–1997 – success story of forest policies in Finland. In: Palo, M., Uusivuori, J., Mery, G. (eds.) World forests, markets and policies; World forests, Vol. 3. Kluwer Academic Publishers, Dordrecht. pp. 437-439.

Pasanen, K., Kurttila, M., Pykäläinen, J., Kangas, J. and Leskinen, P. 2005. MESTA - Non-industrial private forest owners' decision-support environment for the evaluation of alternative forest plans over the internet. International Journal of Information Technology and Decision Making 4(4): 601-620.

Pesonen, M., Kurttila, M., Kangas, J., Kajanus, M. and Heinonen, P. 2001. Assessing the Priorities Using A'WOT Among Resource Management Strategies at the Finnish Forest and Park Service. Forest Science 47(4): 534–541.

Pukkala, T. 2004. Dealing with ecological objectives in the Monsu planning system. Silva Lusitana, Special issue (2004): 1-15.

Pukkala, T. 2006. Muut kuin puuaineiset tuotteet metsäsuunnittelussa. Metsätieteen aikakauskirja 1/2006: 72-91. (In Finnish).

Pukkala, T., Lähde, E. and Laiho, O. 2011. Metsän jatkuva kasvatus. Joen forest program consulting. Joensuu. 229 p. (In Finnish).

Pykäläinen, J., Kangas, J. and Loikkanen, T. 1999. Interactive decision analysis in participatory strategic forest planning: Experiences from state owned boreal forests. Journal of Forest Economics 5(3): 341-364.

Pykäläinen, J., Hiltunen, V. and Leskinen, P. 2007. Complementary use of voting methods and interactive utility analysis in participatory strategic forest planning: Experiences gained from western Finland. Can. J. For. Res. 37(5): 853-865.

Rasinmäki, J., Kalliovirta, J. and Mäkinen, A. 2009. SIMO: An adaptable simulation framework for multiscale forest resource data. Computers and Electronics in Agriculture 66: 76-84.

Saarikoski, H., Weckroth, T., Leskinen, L.A., Laitala, M. and Tikkanen, J. 2008. Alueellisten metsäohjelmien 2006–2010 laadinnan hyväksyttävyys ja vaikuttavuus – Analyysi alueellisista metsäohjelmista. Working Papers of the Finnish Forest Research Institute 94. 23 p. (In Finnish).

Saarikoski, H., Tikkanen, J. and Leskinen, L.A. 2010. Public participation in practice – Assessing public participation in the preparation of regional forest programs in Northern Finland. Forest Policy and Economics 12(5): 349-356.

Siitonen, M. 2009. Metsälaskelmat metsätalouden ja -politiikan palveluksessa. In: Haapanen, R. and Hujala, T. (Eds.). Taksaattorien taipaleelta. Sata ja yksi vuotta suomalaista metsänarviointia. Taksaattoriklubi. Helsinki. pp. 274-285. (In Finnish).

Tikkanen, J., Kangas, A., Pykäläinen, J., Hujala, T., Kurttila, M. and Leskinen, P. 2009. Vaikuttava ja hyväksyttävä alueellinen metsäohjelma: ehdotus metsäohjelman laadinnan kehittämiseksi. Metsätieteen aikakauskirja 3/2009: 245-254.

Tikkanen, J., Hokajärvi, R. and Hujala, T. 2010. Development phases of forest planning on private lands in Finland: perspective of planners' work. Small-scale Forestry 9(3): 331-347.

Wallenius, P., 2001. Osallistava strateginen suunnittelu julkisten luonnonvarojen hoidossa. Metsähallituksen metsätalouden julkaisuja 41. Edita Oyj. Helsinki. 346 pp. (In Finnish).

10 Forest decision support tools in Germany

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10.1 Introduction

10.1.1 The forest sector in Germany

Germany is characterized by a temperate and humid climate with more or less cold winters. Only the Alpine area at the southern border also comprises cold climates. Hot and dry summers may appear at irregular intervals. The vegetation period is long due to extended transition periods in spring and autumn. Forest damages from natural hazards occur mostly on smaller scales and are often correlated to the heterogeneous soil conditions. Therefore the natural vegetation of Germany is a fairly closed and productive forest, which would cover almost the whole land area. Only salt marshes and dunes on the coasts, mires which are too wet and poor in nutrients, steep rocks and avalanche tracks in the high mountains as well as the heights above the climatic timber-line would be free from trees. The natural tree species composition is dominated by European beech (*Fagus sylvatica* L.). This tree species derives its exceptional competiveness by a high shade tolerance, which enables it to establish very early below almost closed forest canopies (Ellenberg 2009).

After centuries of deforestation and forest degradation one third of Germany's land area – i.e. 11.1 million ha – was rehabilitated by age-class forest, which is often dominated by conifers. Today Germany's forest consists of 72 tree species - 69% conifers (28% spruce, 23% pine and 8% other conifers) and 31% broadleaved trees (15% beech, 10% oak, 16% other non-coniferous trees). The non-sustainable exploitation of forests and their reforestation in the middle of the 20th century resulted in an overrepresentation of medium-old age-classes today. The artificially large proportion of conifers and stand structures susceptible to storm cause higher levels of forest damage than expected by natural forest conditions. The growing stock amount to approx. 3.4 billion m^3 (36% spruce, 21% pine, 7% other conifers, 17% beech, 9% oak, 10% other non-coniferous trees), i.e. 330 m^3 per ha. The average annual increment is 11 m^3 per year and ha (Bundesministerium für Ernährung 2004; Oehmichen et al. 2011).

The forest has traditionally productive, protective, and recreational functions in the German society. 94 % of the forest area is used for timber production. About 50 million m^3 of timber is cut per year. Three-quarters of the harvested timber is from conifers. One half of the timber cut is processed as round wood. The raw wood is primarily used by the paper, wood-based panel and sawing industries. An increasing portion of wood is used for generating energy. Raw material processed to become half-finished goods is further used for building in timber and system-building, the furniture industry and wood crafts or trade. Further forest products are fish, game and other services. The forest serves with 24% of the forest area for biodiversity conservation, with 56% for the protection of landscapes and specific natural elements, and with 31% as protective forest for soil, water and other ecosystem services. Germany is one of the most densely populated countries in Europe. Due to the importance of forest for the recreation of the general public, the access to the forest area is generally

permitted by the federal forest act (Ministerial Conference on the Protection of Forests in Europe 2007; Bundesministerium für Ernährung 2004, 2009; German Timber Promotion Fund 2007; Statistisches Bundesamt 2009).
The German forest area is divided into 3% German trust, 20% communal, 33% state, and 44% private forest. There are a total of 2 million private forest owners. The majority are responsible for less than 10 ha of forest. Nevertheless Germany has 28,000 forest management companies with more than ten hectares of forest area and 273,000 so-called mixed companies, i.e. companies active in agricultural and forest management. German forest management companies provide 72,000 full-time positions. For this reason, their economic impact in rural areas is important. More than 90% of the income in forestry is acquired from timber sales. Apart from forest management companies and forest owners, the forest industry sector includes more than 3,200 forest service companies and forest managers. They are likewise settled in structurally weak rural areas and employ 15,000 people. The turnover of forestry in Germany accounts close to 5 billion € (Mrosek et al. 2005; Seintsch 2010; German Timber Promotion Fund 2007).

Germany's forest is protected by forest and environmental laws on national and state level. The objectives of the legal framework are to protect the forest area, to form the legal basis for forest ownership as well as the financial and technical support of forest owners, and to provide regulations for the sustainable management of commercial, protective and recreational forests. With respect to the legal framework, the forest owner is the solely responsible person for each parcel of forest. Stakeholders in forestry are the local population depending on the forest functions and income from the forestry sector, the timber industry, and organizations representing interests in agriculture, nature conservation, hunting, recreation and sports (BWaldG 1975; BayWaldG 2005).

10.1.2 Forest management planning

Forest management plans have a long tradition in German forestry. As a result of the timber crisis during the 18th century, Hans Carl von Carlowitz developed a comprehensive concept for the sustainable management of forest (von Carlowitz 1713) and Johann Friedrich Judeich documented (Judeich 1871), that forest management planning has to solve a classical allocation problem: silvicultural activities have simultaneously to be assigned to certain forest locations and time periods of a sustainable management unit. Today, forest planning consists of state regional and sector plans, forest management plans at forest enterprise level, and silvicultural planning on forest stand level. Forest management plans exist for about three-quarters of the forest area – i.e. the whole state forest area, communal forest enterprises larger than 50 ha and private forest enterprises larger than 100 ha.

Long term strategic goals (> 10-20 years) are documented by guidelines for silviculture and sustainable forest management. The goals usually embrace the intended forest management type and tree species composition usually derived from the forest site classification. Forest management plans are then developed for a time horizon of 10-20 years. They are in force for sustainable forest management units, which is usually the forest enterprise. The planning process typically consists of the following steps: (i) The present status of the forest enterprise is investigated by a forest inventory and an operation analysis. The main parameters recorded by the enterprise forest inventory are the tree species composition, the age class distribution, growing stock, increment and the status of the stand regeneration. (ii) Based on the strategic goals, on the results of the status report, and on the present socioeconomic aspects the forest management objectives are defined on the enterprise level. (iii) The forest area is then stratified into silvicultural management units – usually forest stands. According to the silvicultural guidelines and present stand structures, the silvicultural objectives and actions are derived and the expected target values of management objectives are predicted. The silvicultural planning is mostly carried out by a field inspection of the forest stands. (iv) Finally the stand level data are summarized and the silvicultural planning is adjusted to the management objectives on enterprise level. (v) Most commonly the forest management plan consists of a textbook, which contains the results of the status report, a description of the management goals, and target values for the implementation of the forest management plan. The textbook is supplemented by a forest management map, a forest stand management textbook and the site classification. The implementation of the forest management plan is then realized by annual operational plans. At the beginning of each annual planning period the annual cut is specified, balancing the sustainable annual cut defined by the forest management plan with the timber harvest of recent years, the silvicultural treatment options, and the expected timber market. The future amount of forest damages is usually not included into the considerations. Further aspects of the operational plans are the areas for artificial regeneration and pruning, capacity planning, and the game management.

Forest management plans are supervised by the state forestry administration and tax authorities. Forest certification forms an additional and voluntary control level for the sustainable management of forests. In Germany 66% of the forest area is certified by the Programme for the Endorsement of Forest Certification Schemes (PEFC), 4.3% by the Forest Stewardship Council (FSC) and 0.5% by the agricultural organization Naturland e.V. (BMELV 2009).

The different concepts of forest management planning in Germany are described by monographs – i.e. control methods (Paulsen 1797), geometric (Cotta, 1804) and volume approach (Hartig 1795), age class methods (Judeich 1871) and business management (Speidel 1972). Comprehensive descriptions of the present methods exist in several professional textbooks (von Gadow 2005; Kurth et al. 1994; Knoke et al. 2012). Detailed descriptions of the applied forest management principles are documented in the guidelines of the state forest administration and enterprises (e.g. Bayerisches Staatsministerium für Ernährung. Landwirtschaft und Forsten 1982; Bockmann et al. 1998).

10.1.3 Decision problems in forest management planning

Forest management planning in a densely populated country is a complex process. Generally speaking, the most relevant task of forest management is to balance the conflict between the economic interests of the forest owner with the ecological and social requirements of the society. Decision problems in forest management can be found on many different spatial and temporal scales and contexts. Decision problems of forest farmers are mostly restricted to stand level with a planning horizon of one or two human generations. Larger private or communal forest owners and state forest administrations have to manage several thousands of hectares of forest land with strategic production goals for many decades, tactical plans for sustainable yield and complex operational plans for timber harvesting operations. Spatial contexts with the interrelation of different spatial sub-units play an important role in the planning of silvicultural actions, personnel placement, and timber harvest logistics. Finally, the forest policy level defines the framework, how forest management planning is implemented and formulates strategic goals and funding procedures on a provincial level by forest law and administrative orders. Basically, all rights and obligations for decision making in forestry practice are hold by the forest owner. Depending on the ownership structure and the legal regulations or informal business practices for the participation of stakeholders, one or more decision-makers are involved in the planning processes. For instance, forest farmers decide by themselves, but are supervised by state foresters and are involved in official planning processes, when their forest is affected e.g. by the NATURA 2000 management.

Forest planning experts in Germany were scored within the FORSYS COST Action (for methods see section 10.2) to describe decision problems in forest management planning to be supported by computerized tools. They reported 329 problem types according to the FORSYS classification scheme and 118 subject-specific decision problems. A cluster analysis was applied to identify the main problem types. The results show three main groups (A to C) with a correlation of spatial and temporal scales (Figure 13). The classification variables for goods and services build an own cluster (P) with no specific linkage to one of the main groups (A to C). Considering the abundance of these variables a set of seven main problem types important for the application and development of decision support tools is derived (Table 2).

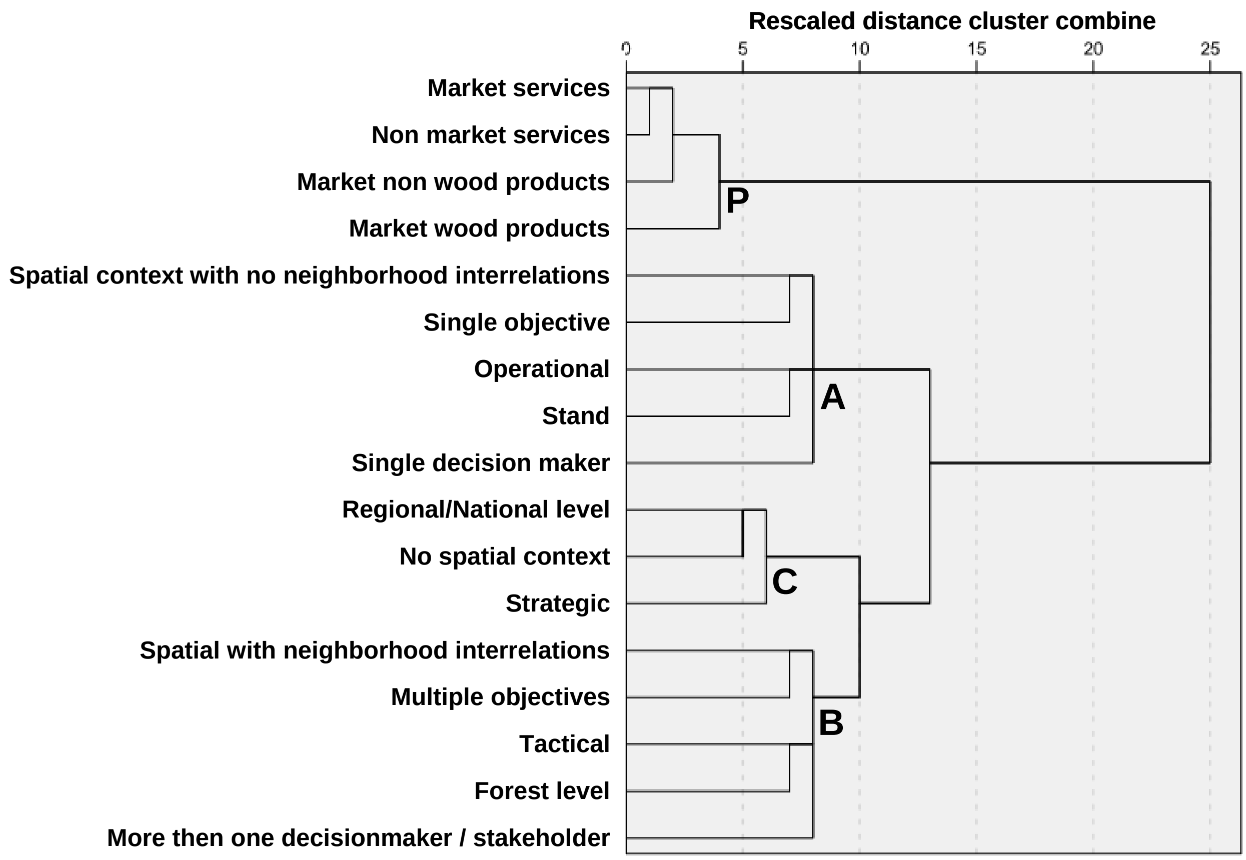

Figure 13. Dendrogram derived from hierarchical cluster analysis using Euclidian distances and the Ward linkage method.

Table 2. Main problem types for the application of computerized decision support tools. Classification derived from the result of the cluster analysis (A, B and C) and the abundance of the classification variables for goods and services (frequencies < 5% of the reported problem types were excluded).

Problem type	Spatial scale	Temporal scale	Spatial context	Objectives	Parties involved	Goods and services
A1	Operational	Stand level	Spatial context with no neighbourhood interrelations	Single Objective	Single decision-maker	Market wood products
A2						Market wood products, Market non-wood products
A3						All products and services
B1	Tactical	Forest level	Spatial context with neighbourhood interrelations	Multiple objectives	More than one decision-maker / stakeholder	Market wood products
B2						All products and services
C1	Strategic	Regional / national level	No spatial context	Multiple objectives	More than one decision maker / stakeholder	Market wood products
C2						All products and services

10.1.4 The objectives of the study

The objectives of this study are (i) to summarize existing approaches for computer-based decision support tools in Germany based on expert knowledge and to specify them by the FORSYS classification schemes for problem types, knowledge management approaches and participatory methods, and (ii) to describe existing decision support tools tested or applied in forestry practice.

10.2 Materials and methods

In order to summarize the existing approaches for computer based decision support tools, a survey was conducted at universities providing forest science, state forest research institutes, state forest administrations, state forest enterprises, forest owner communities, forest owner representatives and forest information industry. Within each organization, the heads of the departments and institutes involved in forest management planning were asked to fill out a postal questionnaire and to forward it to the staff, respectively. A total of 245 experts were scored. 36 respondents answered the request. 24 experts filled in the form. 12 persons replied not to be involved in the development and application of specific DSS.

The questionnaire is divided into three segments: (i) At first the respondents have to define problems, which are solved or intended to be solved by the application of computer based decision support tools. Following the definition of a problem it has to be classified according to the FORSYS classification scheme by temporal and spatial scales, spatial context, type of objectives, parties involved, as well as goods and services addressed. (ii) Then the respondents have to assign developed and/or applied computer-based decision support tools to the problems defined in the first work step. The tool has to be described in detail concerning methods and models applied as well as the deployed methods of knowledge management and stakeholder participation. (iii) The respondent has to register with his name and contact data.

In the second part of this article decision support tools tested or applied in forestry practice are described based on the results of the questionnaire and a review of scientific publications and technical documents. The results of both surveys are organized in a relational database and grouped according to the problem types, applied methods, knowledge management and stakeholder participation aspects.

10.3 Results

10.3.1 Characteristics of the forest sector for computerized decision support tools

When the decision problems reported by forest planning experts (see section 10.1.3) are assigned to the different stages of the management process, the majority of problems are related to the selection of objectives and the planning process (43%) as well as to forest inventory and other control processes (45%). Problems existing in organizations and the implementation of management plans (12%) play a subordinate role. The decision problems are more related to forest enterprise tasks (77%) than to governmental tasks (23%). Within forest enterprises two-thirds of the problems are related to the production and one third to the financial management. Consequently, decision problems focusing on silvicultural tasks form a priority (39%) followed by controlling within forest enterprises (17%) and governmental supervision of sustainable forest management (18%). The remaining problems can be assigned to the fields of accounting (6%), cooperation with partners (2%), forest valuation (5%), timber harvest (6%) and sales (3%), and training of private forest owners by governmental organizations (4%).

The respondents reported 98 mostly end-user specific software applications supporting forest management decisions. Two-thirds of the applications are in operation. Frequently, different problem-specific applications were combined from modules of a larger software collection. Therefore the reported applications could be allocated to 42 software systems. The majority of the systems can be classified as management information systems (28%) followed by computer simulation models (19%), transaction systems (13%), decision support systems (11%), geographic information systems (6%) and combinations of these systems (23%). Management information and transaction systems are also the most applied tools to solve the previously described decision problems, whereby decision support systems in a strict sense play a subordinate role (Table 3). The majority of the systems address planning (48%) and control processes (19%) or a combination of both (9%). 10% of the tools cover the whole management process (Table 4). Several systems are designed to support singular decision problems (e.g. for silviculture problems or harvesting problems), but the majority focus on the support of multiple management tasks i.e. to integrate accounting, controlling, forest valuation, silviculture, and harvesting into one system.

Table 3. Classification of computerized tools and their application to decision problems in forest management planning
(DSS=Decision Support System, GIS=Geographic Information System, MOD = Statistical or Simulation Model, TS = Transaction system)

Type	Proportion in computer tools	Application to forest management
DSS	11%	4%
GIS	6%	3%
GIS+MOD	4%	7%
MIS	28%	30%
MIS+GIS	2%	3%
MOD	19%	9%
TS	13%	21%
TS+GIS	9%	17%
TS+MIS	4%	4%
TS+MIS+GIS	2%	1%
TS+MIS+GIS+MOD	2%	1%

Table 4. Application of decision support tools in different phases of the management process

Objectives & Planning	Organization & Implementation	Inventory & Control	Proportion
+			48%
	+		12%
		+	19%
+		+	9%
	+	+	2%
+	+	+	10%

The respondents reported that 55% of the systems deploy or are related to knowledge management techniques. Mind mapping, database management systems, geographical information systems, data mining and ontologies are used to identify and structure knowledge. Expert systems based on rule-based models and decision trees allow machine reasoning. Handbooks, web portals and visualization techniques are used to transfer and share knowledge.

Participatory methods are applied for the identification of problems, design and problem modelling, and decision-making. Restricted groups of stakeholders and experts are consulted to identify problems by structuring methods and workshops, to model problems by group work and modelling techniques, and support decision-making through forest information systems and scenario analysis. The public is only involved into the problem identification by interviews and through structuring methods.

10.3.2 Decision support tools in German forestry

10.3.3 Data-oriented tools

For the last decades the investment of forest enterprises into information technology has focused on the gathering, storage, and organization of data and information. Therefore most forestry software products aggregate enterprise data to management information by the application of data modelling, database algorithms and information representation techniques (ABIES ITS Gmbh 2010; GISCON Systems GmbH 2011; Genowald 2011; Ostdeutsche Gesellschaft für Forstplanung mbH 2009) (Table 5). The results of these methods are quantitative criteria on different spatial and temporal scales i.e. annual cut, costs and revenues on stand and district level. Approaches for the real-time integration of information from field staff and sensors into the management systems reduce the gap between data pools and actual forest state. They offer the opportunity for a fast operational planning e.g. to react on insect attacks (Baier et al. 2006) and forest fires (Haß 2010) as well as to change from periodical planning schemes into a dynamic forest inventory and planning process (Redmann et al. 2010; Nordwestdeutsche Forstliche Versuchsanstalt 2011b; Bombosch et al. 2011).

Forest valuation methods play a key role in forest management planning. Usually forest assets and timber values can be derived from market data. The computerized methods range from simple value factor methods (Mühlhausen 2010) to sophisticated tools for the calculation of timber assortments (Kublin 2003), harvesting costs (Bombosch 2011), and integrated tools to calculate revenues and forest values (Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg 2002; Weiß 2011). It is more difficult to derive non-market service values. Therefore a set of methods consisting of contingent valuation method, choice experiments, the benefit transfer approach, and the travel cost method are tested and applied for decision support tasks (Elsasser et al. 2007).

Public relations and the support of practitioners via the internet play a major role for forest administrations and NGOs. Mainly content management systems are used to deliver textual and graphical information to target groups (e.g. www.waldwissen.net). These document and communication oriented tools support forest planning by scientific and practical information e.g. recommendations for tree species selection (Lässig 2009).

Data-oriented tools were mostly developed by information industries according to the demands of customers and by state forest administrations to improve governmental workflows. Therefore the acceptance of data-oriented tools is high and the systems are widely applied in Germany’s forestry sector.

Table 5. Examples of data-oriented tools tested and/or applied in forestry
(DBMS = database management system, RDBMS = relational database management system, GIS = geographic information system, prefix Web = web-based component)

Computerized tool/DSS	Models and methods	KM techniques	Methods for participatory planning	FORSYS Problem type
ABIES (ABIES ITS Gmbh 2010), FIP2000 (Ostdeutsche Gesellschaft für Forstplanung mbH 2009), Proforst (GISCON Systems GmbH 2011)	RDBMS, spreadsheet, GIS, business process models	DBMS	Problem modelling by a multi-access system for experts	A1, B2
Waldinfoplan (Genowald 2011)	RDBMS, spreadsheet GIS, business process models	WebDBMS and WebGIS	Problem modelling by a web-based system for experts and forest owners	A1, B1
WebBetriebsplaner (Nordwestdeutsche Forstliche Versuchsanstalt 2011b), DSW2 (Redmann et al. 2010)	RDBMS, GIS, growth and yield model, timber assortment planner, GIS	WebDBMS and WebGIS	Web-based, multi-access system for experts and forest owners	A1, B1
WinForstPro (Latschbacher GmbH 2011)	RDBMS, GIS, spreadsheet, business process models	WebDBMS and WebGIS	Web-based, multi-access system for experts and business partners	A1, B1
BayWIS (Millitzer 2008)	RDBMS, GIS, business applications	DBMS	Problem identification and decision-making for governmental experts	A3, B2, C2 all problem types with spatial context
BDAT (Kublin 2003), HOLZERNTE (Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg 2002)	Timber assortment model based on mathematical equations	Model equations	Planning process by experts	A1, B1
FSMW (Baier et al. 2006)	RDBMS	DBMS	Multi-access system for experts	A3, B2

10.3.4 Model-oriented tools

Due to data gaps induced by the lack of measurability or economic restrictions enterprise data are often not available or insufficient to solve a decision problem and to predict criteria in future environments, respectively. Therefore models are applied to produce synthetic data to fill these gaps and to develop management scenarios. Three model-driven approaches can be distinguished (Table 6):

(i) Statistical models describe the relationship between one and more variables by mathematical equations. They are deduced from scientific or enterprise data by statistical analysis. Examples are computerized yield tables (Nagel 2010; Lembcke et al. 2000), assortment tables and models (Kublin 2003), models to predict risks caused by storm, insects, and climate change (Kohnle 2011; Baier et al. 2007; Hanewinkel et al. 2011; Kölling et al. 2009) as well as different remote sensing based systems to gather information from spectral data (IQ wireless GmbH 2011). Geostatistical models include the spatial interrelation between variables and are applied to depict spatial contexts e.g. potential natural vegetation covers (Ewald et al. 2009) and climate sensitive tree distribution maps (Kölling et al. 2009; Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg 2001).

(ii) Simulation models shape real objects as forest stands in computer systems using theoretical or statistical functional relationships between the system elements and their environment. Forest growth models are applied to simulate the development of forest stands under different management options. The individual tree models SILVA (Pretzsch 2009) and BWinPro (Nordwestdeutsche Forstliche Versuchsanstalt 2011a) are increasingly deployed by forestry to forecast different silvicultural production programs for several decades. They are based on relationships of tree dimensions and growth derived from forest growth experiments. Physiological aspects are investigated in the field and in laboratories to integrate plant processes and their interrelation into forest models to project the forest development in a changing environment on stand (Grote et al. 2002) and enterprise levels (Chertov et al. 2002). The environmental conditions are projected - i.e. by regional climate models to forecast the climatic conditions in the 21st century (Ebell et al. 2008) and soil/water balance models (Federer 1995) to predict forest site conditions under different climate conditions. Another common field is the simulation of the timber harvesting processes. Discrete event simulation is applied to derive management information of different harvesting systems. Software agent systems are used to model the behaviour of different members of the wood supply chain (Ziesak et al., 2004). In many cases not all important factors can be included in a projection, and error terms must be added to the management information. Hence, the Monte-Carlo simulation is widely applied to generate random distributions of criteria and to derive their expected values and dispersion parameters (Hildebrandt et al. 2011).

(iii) Several approaches exist for the integration of different models. The system DSS-WuK incorporates climate, nutrition, water balance, forest growth, and risk models together with financial valuation methods to predict the forest states on regional scales and for any single location in Germany. Specific spatial algorithms were developed to integrate the different temporal and spatial scales (Forschungszentrum Waldökosysteme 2011). The experimental system KOMET integrates solvers for the prognosis of forest growth, timber harvest, and assortment supplemented by methods to compare forest stands and to apply spatial analysis on enterprise levels (Döllerer 2007). A further approach to integrate models from natural and social science is the GLOWA initiative of the German government. On the landscape level, models were combined to complex clusters supporting decision-making for the future development of the main rivers Elbe and Danube (Bundesministerium für Bildung und Forschung 2005).

The majority of model-oriented tools originate from scientific studies. Therefore their concepts are oriented to scientific questions and hypothesis testing. They are implemented in forestry practice by user friendly interfaces (e.g. management models), vivid presentations (e.g. geographic information systems) or by the integration of abstract model components into larger user oriented systems (e.g. DSS-WUK). The application of simulation models is growing due to increasing data demands.

Table 6. Examples of model-oriented tools tested and/or applied in forestry

Computerized tool/DSS	**Models and methods**	**KM techniques**	**Methods for participatory planning**	**FORSYS Problem type**
Standardised yield tables (e.g. Nagel 2010; Lembcke et al. 2000) and supplements (e.g. Bösch 2003)	Mathematical equations, spreadsheet	Model equations	Planning tasks of experts	A1, B1, C1
Computer supported yield-table models (e.g. Bergel 1985) and supplements (e.g. Reimeier et al. 2001)	Mathematical equations, spreadsheet	Model equations	Planning tasks of experts	A1, B1, C1
WEHAM (Dunger et al. 2004)	Distance independent individual tree model	Model equations	Problem modelling and decision-making for experts	A1, B1 , C1, all problem types without spatial context
SILVA (Pretzsch 2009), BWIN (Nagel et al. 2006)	Distance dependent individual tree model	Model equations	Problem modelling and decision-making for experts	B1 including stand level
PHENIPS (Baier et al. 2007)	Statistical and process model equations, GIS	Model equations	Problem modelling and decision-making for experts	A1 including forest level
Climate risk maps for tree species selection (Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg 2001; Kölling et al. 2010), WINALP (Ewald 2009)	Mathematical equations, GIS	Model equations	Problem modelling and decision-making for experts	C1 including spatial context without neighbourhood interrelations
DSS-WUK (Forschungszentrum Waldökosysteme 2011)	Integration of statistical, stochastic, process and spatial models	Model equations, master model	Prognosis available for the public	C2 including spatial context without neighbourhood interrelation

10.3.5 Decision-oriented tools

Based on data (3.2.1) and model (3.2.2) oriented tools, forest decision support systems model decision processes in forest management planning. They are deployed to support forest managers in the selection of best choices related to management objectives by standardized, but flexible and user-friendly methods. These methods can address single or multiple criteria related to discrete or continuous management options in one- or multi-stage decisions, are able to manage decision under safety, risk or uncertainty, and are capable of supporting single decision-makers or groups of them.

The reported decision methods include the support of silvicultural decisions by multi-criteria- analysis (Felbermeier et al. 2004), non linear optimization (Roessiger et al. 2011) and decision trees (Bachmann 2011). Forest management planning on enterprise level is assisted by multi-criteria-analysis on the operational level (Felbermeier et al. 2007a) and by the optimization of forest enterprise values on the strategic level (Felbermeier et al. 2007b). 2-D-cellular automatons and multi-criteria approaches are developed to provide decision methods in land use and forest landscape planning (Fürst et al. 2010) (Table 7).

Decision-oriented computerized tools are a new development in Germany's forestry sector. The systems are developed by scientists in close cooperation with project partners from forestry practice. The systems achieved prototype status and are used in test applications by forestry operations and forest administrations.

Table 7. Examples of decision oriented tools and systems tested and/or applied in forestry (MCA=multi criteria analysis, LP = Linear programming, DBMS = database management system, RDBMS = relational database management system, GIS = geographic information system)

Computerized tool/DSS	Models and methods	KM techniques	Methods for participatory planning	FORSYS Problem type
ZEUS (Felbermeier et al. 2004)	RDBMS, MCA	DBMS	Problem modelling and decision-making for experts	A3, B2 including strategic level
LIFT (Felbermeier et al. 2007a)	RDBMS, MCA, GIS	DBMS	Problem modelling and decision-making for experts	A2, B1
OPTIM (Felbermeier et al. 2007b)	RDBMS, growth and yield model, natural risks model, assortment model, LP	DBMS, Model equations	Problem modelling and decision-making for experts	B1 including strategic level, excluding spatial context
PYL/GISCAME (Fürst et al. 2010, PI Solution 2011)	2-D-cellular automaton, MCA, RDBMS, GIS	DBMS	Problem modelling and decision-making for experts and stakeholders	B2, C2 including spatial context with neighbourhood interrelation

10.4 Discussion and conclusions

The main results of the study are that forest management problems defined by German experts are very heterogeneous, and data or model-oriented decision support tools are widely applied. Nevertheless decision-oriented tools - meaning decision support systems in the sense of Sprague (1980) - are rarely used, despite their potential to support decision-making in complex situations. The reasons for this can be found in historical developments:

- Sustainable forestry in Germany has a tradition of almost three centuries. Sophisticated methods of forest management are proven applied by professional foresters for many decades and there seems no need for a change.

- Since the middle of the 19th century, powerful provincial forest administrations were established to manage the state forest districts and control the private and communal forest owners. Combined with a long-time forestry education in governmental and university schools, professionals did not see a demand for the application of decision support systems, which provide less information than the analytic capabilities of the local foresters. Therefore only provincial transaction and management information systems were developed to support the administration of the state forest districts.
- Private forest covers 44% of the German forest, which coincides with the mean European conditions, but 57% of the private forest consists of forest enterprises with less than 20 ha, compared to 17% on the European level. The forest owners are mainly farmers, who follow traditional objectives and management options based on local experiences. The application of decision support systems in small-scale forestry is difficult, since there exists almost no information about the forest of a farmer and decision support systems would have to provide a very high local precision to meet the farmer's expectations.
- German forest enterprises and timber industry are traditionally in different ownership. Timber harvest and processing is linked by open regional timber markets, and therefore no decision support systems optimizing the whole timber supply chain were established.

The reorganization of the German forest sector modified this situation in recent years:

- State forest districts were transformed to state-owned forest enterprises, which strengthened financial management goals and led to the development of business information and decision support systems.
- Private forest owners are increasingly organized in forest owner communities to face the market power of a concentrating timber industry. More and more forestry professionals are hired by communities to develop strategies for the optimization of silvicultural treatments, timber harvest and sales. In this sector, a new commercial market develops for forest information and decision support systems.
- The value of forest and timber increased in the last few years due to a higher demand for timber and forest assets in financial portfolios. Therefore the interest to improve the financial performance of forestry increased, and more money is invested in the development of decision supporting systems for financial analysis in forestry.

Summarizing the results of this study and the recent developments of the forest sector in Germany the following conclusions can be drawn:

- An increasing number of forest management information systems are applied in Germany. It can be expected that new capabilities in remote sensing, information harvest and modelling will further increase the availability of management information. Forest managers responsible for the development of forest ecosystems in a densely populated country under changing economic, social and ecological environments will increasingly rely on such systems.
- The investigation shows that there exist no general key problems or standard situations to be solved. Therefore flexible methods are needed to support forest managers in the solution of ill-structured problems and combine the forester's empirical knowledge with computational capabilities.

Two strategies may be pursued to support the development of decision support systems for sustainable forest management:

- A DSS-generator (Sprague 1980) could be established and used as a foundation for the development of specific forest decision support systems adapted to different scales, users and tasks. Such a universal instrument applicable for forestry does not exist and needs research in interdisciplinary teams covering forest science, mathematics, linguistics and computer science. Presently scientific projects do not usually have the lifetime to solve these fundamental scientific questions.
- An alternative step by step strategy can be the formulation of a framework as a standard for the development of decision support tools for forest management purposes. The decision support tools could be used for the development of a DSS-generator as well as for specific forestry decision support systems. The framework could define basic principles for the development, interaction and integration of decision support tools. This would release forest scientists from the technical workloads of software engineering and support them in the rapid development and integration of specific decision support systems for forest research and management tasks.

References

Abies ITS Gmbh, 2010. ABIES-FIS: Das moderne Forst-Informations-System. 4pp

Bachmann. M. 2011. Umsetzung einer EDV-unterstützten Beratungshilfe zur Verjüngungsplanung bei Privatwaldberatung am Beispiel von Borkenkäferkalamitätsflächen in Mittelfranken mit Hilfe des Expertensystems Solvatio. Personal communication.

Baier, P., Pennerstorfer, J., Schopf, A. 2007. PHENIPS - A comprehensive phenology model of Ips typographus (L.) (Col., Scolytinae) as a tool for hazard rating of bark beetle infestation. Forest Ecology and Management 249, 171–186.

Baier, U., Majunke, C., Otto, L.-F. 2006. 80 Jahre Forstschutzmeldedienst in den ostdeutschen Ländern. AFZ/Der Wald, Allgemeine Forst Zeitschrift für Waldwirtschaft und Umweltvorsorge, 783–785.

Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten, 1982. Richtlinien für die mittel- und langfristige Forstbetriebsplanung in der Bayerischen Staatsforstverwaltung (Forsteinrichtungsrichtlinien).

BayWaldG, 2005. Waldgesetz für Bayern. Bekanntmachung vom 22. Juli 2005.

Bergel, D. 1985. Douglasien-Ertragstafel für Nordwestdeutschland.

Bockmann, T., Saborowski, J., Dahm, S., Nagel, J., Spellmann, H. 1998. Die Weiterentwicklung der Betriebsinventur in Niedersachsen. Forst und Holz 53, 219–226.

Bombosch F. 2011. HeideHP. http://www.forstwissen.de, 03.11.2011.

Bombosch, F., Bobey, K., Sohns, D., Friedel, S. 2011. Automatisierte Erfassung der Bestockung während der Holzernte. AFZ/Der Wald, Allgemeine Forst Zeitschrift für Waldwirtschaft und Umweltvorsorge, 24–29.

Bösch B. 2003. Neue Schätzhilfen für Wuchsleistungen der Hauptbaumarten. http://www.fva-bw.de/forschung/index2.html, 02.11.2011.

Bundesministerium für Bildung und Forschung. 2005. GLOWA – Globaler Wandel des Wasserkreislaufes. 42pp

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, 2004. Bundeswaldinventur. http://www.bundeswaldinventur.de, 05.02.2011.

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, 2009. Waldbericht der Bundesregierung 2009. 117pp

BWaldG 1975. Gesetz zur Erhaltung des Waldes und zur Förderung der Forstwirtschaft in der Fassung vom 31. Juli 2010.

Carlowitz, H.C. von 1713. Sylvicultura oeconomica: Anweisung zur wilden Baum-Zucht. (Reprint), TU, Bergakademie, Freiberg.

Chertov, O., Komarov, A., Andrienko, G., Andrienko, N., Gatalsky, P. 2002. Integrating forest simulation models and spatial-temporal interactive visualisation for decision making at landscape level. Ecological Modelling 148, 47–65.

Cotta, H. 1804. Systematische Anleitung zur Taxation der Waldungen, Sander, Berlin. 216pp

Döllerer, M. 2007. Die KOMET-Architektur. Eine Integrationsplattform für forstliche Entscheidungsunterstützungskomponenten. Dissertation, Technische Universität München. 122pp

Dunger, K., Bösch, B. 2004. Das potentielle Rohholzaufkommen 2003 bis 2022, Göttingen, Presentation, www.bundeswaldinventur.de/media/archive/224.pdf, 02.11.2011.

Ebell, K., Bachner, S., Kapala, A., Simmer, C. 2008. Sensitivity of summer precipitation simulated by the CLM with respect to initial and boundary conditions. Meterologische Zeitschrift 17, 421–431.

Ellenberg, H. 2009. Vegetation ecology of Central Europe. Cambridge Univ. Press, Cambridge. 756pp

Elsasser, P., Meyerhoff, J. 2007. A Bibliography and Data Base on Environmental Benefit Valuation Studies in Austria, Germany and Switzerland. Part I: Forestry Studies., Hamburg. Arbeitsbericht des Instituts für Ökonomie. 14pp

Ewald, J., Kölling, C. 2009. Wo der Wald an seine Grenzen stößt: Höhenverbeitung der Baumarten in den Nordalpen. LWF aktuell, 34–36.

Federer, C.A. 1995. BROOK90: A simulation model for evaporation, soil water and stream flow, Version 3.1. Documentation.

Felbermeier, B., Mosandl, R. 2004. Zukunftsorientierte Forstwirtschaft. Entwicklung eines forstlichen Entscheidungsunterstützungssystems (ZEUS) auf der Grundlage von Untersuchungen verschiedener Waldbehandlungsoptionen in Forstbetrieben Mittelschwabens. Ökosystem-Management 1. 122pp

Felbermeier, B., Gaudlitz, G. 2007a. Entwicklung eines forstlichen Entscheidungsunterstützungssystems für kommunale Forstbetriebe im Ballungsraum München. Forst und Holz 62, 19–22.

Felbermeier, B., Knoke, T., Mosandl, R. 2007b. Forstbetriebsplanung unterstützen durch lineare Programmierung. AFZ/Der Wald, Allgemeine Forst Zeitschrift für Waldwirtschaft und Umweltvorsorge 62. 115-116.

Forschungszentrum Waldökosysteme, 2011. Decision Support System - Wald und Klimawandel. http://www.dss-wuk.de. 02.11.2011.

Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg 2001. Baumarteneignung Fichte und Buche bei Klimawandel. http://www.fva-bw.de/forschung/index2.html, 03.11.2011.

Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg 2002. Kalkulationsprogramm Holzernte, Freiburg. 130pp

Fürst, C., Volk, M., Pietzsch, K., Makeschin, F. 2010. Pimp Your Landscape: A Tool for Qualitative Evaluation of the Effects of Regional Planning Measures on Ecosystem Services. Environmental Management 46, 953–968.

Gadow K von 2005. Forsteinrichtung. Analyse und Entwurf der Waldentwicklung. http://webdoc.sub.gwdg.de/univerlag/2005/forsteinrichtung_2005.pdf. 01.07.2011

Genowald. 2011. WaldInfoPlan - das professionelle Werkzeug für die forstlichen Zusammenschlüsse. http://www.waldinfoplan.de. 03.11.2011

German Timber Promotion Fund 2007. Forest and wood industries in Germany at a glance. 83pp

GISCON Systems GmbH 2011. Proforst: The Forest Information System. System requirements and features. 16pp

Grote, R., Pretzsch, H. 2002. A model for individual tree development based on physiological processes. Plant biology 4, 167–180.

Hanewinkel, M., Hummel, S., Albrecht, A. 2011. Assessing natural hazards in forestry for risk management: a review. European Journal of Forest Research 130, 329–351.

Hartig, G.L. 1795. Anweisung zur Taxation der Forste, oder zur Bestimmung des Holzertrags der Wälder. Ein Beytrag zur höheren Forstwissenschaft; Nebst einer illuminirten Forst-Charte und mehreren Tabellen, Heyer; Stahl, Darmstadt. 200pp

Haß, T. 2010. Mobiles Waldbrandmanagement „mobiFIS“ der Forstverwaltung des Landes Brandenburg. Deutscher Waldbesitzer. Presentation. 24pp

Hildebrandt, P., Knoke, T. 2011. Investment decisions under uncertainty-A methodological review on forest science studies. Forest policy and economics 13, 1–15.

IQ Wireless GmbH 2011. FireWatch: State of the art technology for the early detection of smoke to prevent forest fires. 8pp

Judeich, J.F. 1871. Die Forsteinrichtung, Schönfeld, Dresden. 575pp

Knoke, T. (ed.) 2012. Forstbetriebsplanung als Entscheidungshilfe. Ulmer. 408pp

Kohnle U. 2011. Modellierung von Sturmschäden auf der Basis langfristiger waldwachstumskundlicher Versuchsflächen, Freiburg. Personal communication 25.01.2011

Kölling, C., Bachmann, M., Falk, W., Grünert, S., Schaller, R., Tretter, S. et al. 2009. Klima-Risikokarten für heute und morgen. Allgemeine Forstzeitschrift / Der Wald 64, 806–808.

Kölling, C., Beinhofer, B., Hahn, A., Knoke, T. 2010. Wie soll die Forstwirtschaft auf neue Risiken im Klimawandel reagieren? AFZ/Der Wald , Allgemeine Forst Zeitschrift für Waldwirtschaft und Umweltvorsorge 65, 18–22.

Kublin, E. 2003. Einheitliche Beschreibung der Schaftform – Methoden und Programme –BDATPro. Forstwissenschaftliches Centralblatt 122, 183–200.

Kurth, H., Gerold, D., Ulbricht, R. 1994. Forsteinrichtung. Nachhaltige Regelung des Waldes, Deutscher Landwirtschaftsverlag, Berlin. 592pp

Lässig, R. 2009. Waldwissen.net - Die Internet-Platform für Wald- und Umweltwissen in Mitteleuropa, 2009. In: Thees, O., Lemm, R. (Eds.), Management zukunftsfähige Waldnutzung. Grundlagen, Methoden und Instrumente. vdf Hochschulverlag, Zürich, 589–612.

Latschbacher GmbH. 2011. WinForst Pro. 2pp

Lembcke, G., Knapp, E., Dittmar, O. 2000. Ertragstafel für die Kiefer (Pinus sylvestris L.) im nordostdeutschen Tiefland. Landesforstanstalt, Eberswalde. 101pp

Millitzer, S. 2008. Neue Wege für das Management und die Bereitstellung von Geodaten in der Bayerischen Forstverwaltung. Presentation. 21pp

Ministerial Conference on the Protection of Forests in Europe. 2007. State of Europe's Forests 2007. 247pp

Mrosek, T., Kies, U., Schulte, A. 2005. Clusterstudie Forst und Holz Deutschland 2005. Holz-Zentralblatt Nr. 84. 1113-1117.

Mühlhausen, C. 2010. Und, was ist Ihr Wald wert ? Deutscher Waldbesitzer. http://www.forstpraxis.de/-wald-wert. 03.11.2011

Nagel, J. 2010. ForestTools3: Forstliche Softwaresammlung, Göttingen. 18pp

Nagel, J., Duda, H., Hansen, J. 2006. Forest Simulator BWINPro7. Forst und Holz 61, 427–429.

Nordwestdeutsche Forstliche Versuchsanstalt. 2011a. ForestSimulator BWINPro Version 7.5. http://www.nw-fva.de/index.php?id=194. 03.11.2011

Nordwestdeutsche Forstliche Versuchsanstalt. 2011b. WebBetriebsPlaner. http://www.nw-fva.de/index.php?id=448. 03.11.2011.

Oehmichen, K., Demant, B., Dunger, K., Grüneberg, E., Hennig, P., Kroiher, F., Neubauer, M., Polley, H., Riedel, T., Rock, J., Schwitzgebel, F., Stümer, W., Wellbrock, N., Ziche, D., Bolte, A. 2011. Inventurstudie 2008 und Treibhausgasinventar Wald. vTI Sonderheft 343. 141pp

Ostdeutsche Gesellschaft für Forstplanung mbH. 2009. Forstinformationssysteme und Softwareentwicklung. 9pp

Paulsen, J.C. 1797. Kurze praktische Anweisung zum Forstwesen und zur Veranschlagung der Forsten. Hannover. 152pp

PI Solution 2011. Regiopower. Presentation. http://www.eli-web.com/RegioPower/PDF/02_PiSolution_Pietzsch.pdf. 03.11.2011

Pretzsch H. 2009. Forest dynamics, growth and yield. From measurement to model. Springer. Berlin, Heidelberg. 664 p

Redmann, M., Regenstein, M. 2010. Datenspeicher Wald, Version 2. Allgemeine Forstzeitschrift / Der Wald, 10–11.

Reimeier, S., Kennel, E. 2001. Zuwachstafeln für ausgewählte Baumarten, Kessel, Remagen. 93pp

Roessiger, J., Griess, V.C., Knoke, T. 2011. May risk aversion lead to near-natural forestry? A simulation study. Forestry. Journal of Forest Research. 84 (5): 527-537.

Seintsch, B. 2010. Entwicklungen des Clusters Forst und Holz zwischen 2000 und 2007. Arbeitsbericht. 70pp

Speidel, G. 1972. Planung im Forstbetrieb. Grundlagen und Methoden der Forsteinrichtung, Parey, Hamburg. 267pp

Sprague, R.H. 1980. A Framework for the Development of Decision Support Systems. MIS Quarterly 4, 1–26.

Statistisches Bundesamt. 2009. Forstwirtschaft. http://www.destatis.de. 01.07.2011

Weiß H. 2011. SILVAL. http://haweisoft.de/index-Dateien/silprojekt.htm. 02.11.2011

Ziesak, M., Bruchner, A.-K., Hemm, M. 2004. Simulation technique for modelling the production chain in forestry. European Journal of Forest Research 123, 239–244.

11 The design and use of forest decision support systems in Greece

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11.1 Introduction

Greece occupies the southern end of the Balkan Peninsula in the Eastern Mediterranean basin. The country consists mainly of hilly, mountainous and rocky mainland and a large number of islands scattered in the Aegean and Ionian Seas, (Ministry of Agriculture, 1992). Figure 1 shows the general vegetation map of Greece. It is evident that the great climatic variability affects the diversity of the forests. In the coastal and plain zones (0-300m a.s.l) there are serotinous pine forests with a dense understorey of evergreen broadleaves. In mountainous zones (1200-2000 m a.s.l) there are boreal conifers such as spruce and Scots pine and broadleaves such as birch, which form the southernmost limit of European distribution.

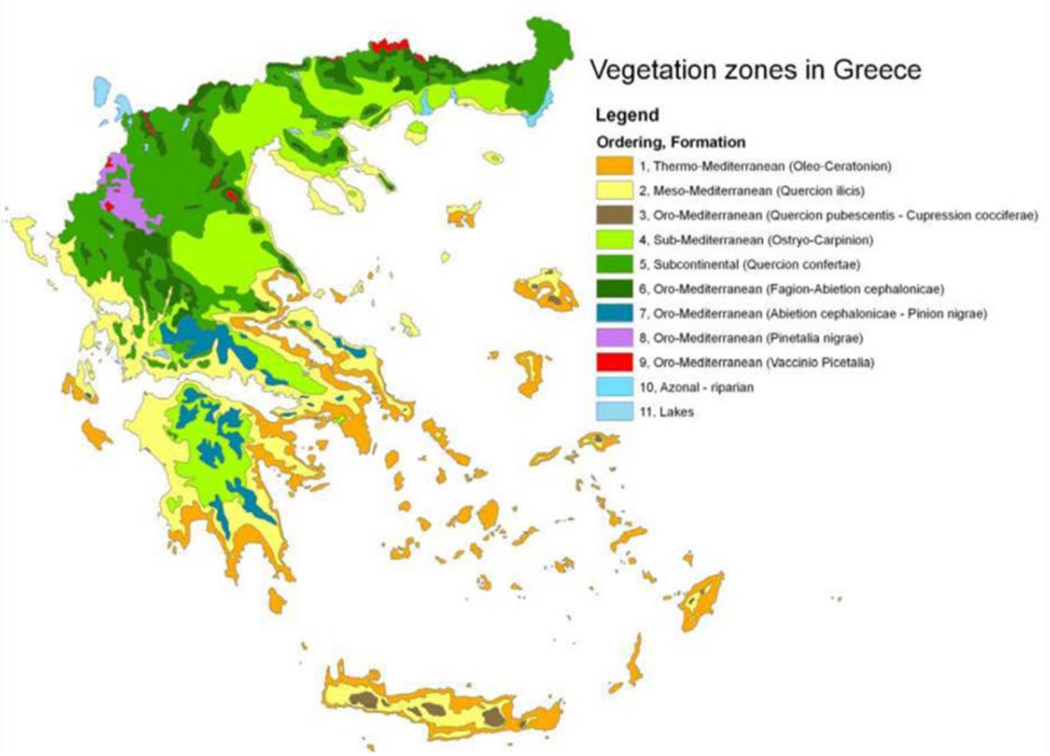

Figure 1. Vegetation map of Greece

In Greece, sustainable forest management is traditionally applied. Due to a number of factors such as the geographic position, the climate, the variable terrain, the geology and the long history of human impact, forests in Greece play a multifunctional role. This is in addition to their productive function which contributes, among other things, to the income and livelihood of the people living in rural areas. Forests also play a very important hydrological, recreational, hygienic and environmental role in the country's economy and the inhabitants' quality of life. The deforestation caused by forest fires, insects and diseases during drought periods, and limited encroaching human activities, is counterbalanced by the natural afforestation of abandoned agricultural and pasture lands, the natural rehabilitation of degraded forest ecosystems, as well as the afforestation activities as part of rural development and afforestation programmes, resulting in a stable proportion of forests in the country, with a tendency to increase. The above developments contribute to the protection of the mountainous mainland of Greece from erosion phenomena. According to the National Forest Inventory (Ministry of Agriculture, 1992) more than one half of the forests and other wooded land (51.58%) is managed for production purposes, 5.18% for recreation, 14.4% for hunting and game management and 28.24% for grazing of livestock and fuel wood production. The greater percentage (74.1%) of the forests in Greece is state-owned and managed by the local Forest Services. Privately owned forests account for only 6.5%, 9% are community-owned forests and a final 10.4% belong to monasteries, the church and charitable institutions. The distribution of this type of ownership structure in Greece reflects the special historic, socio-economic and political conditions of the country (Kazana and Kazaklis 2005).

Greek forest policy is based on the 1975 Constitution (art. 25 and 117) and Laws N. 86/1969, 998/1979 and 1650/1986. All this legislation aims to protect and manage the forests and other wooded land in a sustainable manner, following the implementation of the sustained yield principle. Forest land use changes are prohibited by art. 24 of the country's constitution. State and privately owned forests, other wooded land destroyed by fire or other causes, are immediately declared as reforested land, thus land use change is prohibited. The Ministry of Environment is responsible for forests in Greece. The Forest Service operates under the General Secretariat of Environment and Natural Resources. This is the main body responsible for the protection and management of the state forests and the supervisor of the private forests. Additionally, other bodies/institutions also contribute to the protection and management of forests, such as the Panhellenic Confederation of Agricultural Cooperatives (PASEGES), the Forest Owners Association (FOA), the Geotechnical Chamber of Greece (GEOCG) and the Hellenic Forestry Society (HFS). In the last few years there has been an increasing interest in forest management by non-governmental organizations (NGOs). The main NGOs that have an important influence on various issues regarding forest resources are the Hellenic Society for Nature Protection, Hellenic Ornithological Society, WWF, the Greek Biotope/Wetland Centre and the Arctouros Society (Kazana and Kazaklis 2005). Despite the fact that forestry plays an important economic role in mountainous and semi-mountainous communities of the country, the contribution of the forestry sector to the total Greek economy is very low, barely reaching 0.15% of the Gross Annual Domestic Product. This is firstly due, to the fact that the majority of the country's forests are of low productivity, and secondly that the non-market goods and services derived from forests are not registered in the national accounts (Albanis et al. 2000).

Forest management planning in Greece deals with strategic, tactical and operational problems in decision-making. Decision problems are concerned with the sustainable management of forest ecosystems. This is a long-term goal on a national level affecting all managed forests including market and non-market goods and services. The planning of forest management on a tactical spatial scale in terms of silvicultural decisions is a problem type of great importance. The sustainable development of rural areas that include different land uses is also a long-term, multi-objectives on a local level problem type involving stakeholders and collegial decision-making dimensions considering market and non-market goods and services. The large number of Natura2000 network sites occupying more than 4 million ha poses an increasing demand for new management plans. Special care must be taken on improved protection measures towards biodiversity restoration which is a strategic, multiple decision-makers spatial problem on a forest level, connected with a multitude of objectives while also considering market goods and services. Coppice management comprises more than 1.2 million ha or 48% of the country's forests. The large scale conversion of coppice into high forest is another long-term multi-objectives problem for decision-making, involving many stakeholders and considering market and non-market goods and services. In that context, the identification of conflicting interests between the high demand of fuel wood in the market caused by high oil prices and protection against erosion and climate change mitigation is of major importance for policy makers.

The regulation of livestock grazing in managed forests that are under conversion or regeneration has always been a major operational forest problem for Greek forest managers. The management and rehabilitation of degraded forest ecosystems and the identification of adaptation strategies under climate change is a major multi-objectives strategic problem on a national level considering market and non-market wood products and services. The fighting and prevention of forest fires is another prevalent problem in decision-making that needs long-term strategic planning. It is an operational problem as well, because forest fires have great environmental, social and political impacts. The types of problems pertaining to forest fires can be long-term, non-spatial, on a regional level, with a single decision-maker optimizing a single objective, e.g. estimations of structural forest fire risk. It can also be tactical/short-term, spatial, on the forest level, with a single decision-maker, optimizing multiple objectives e.g. simulation of fire area, time needed for fire fighting forces to reach the site of the fire, cost of fire defence, silvicultural measures to reduce the fire risk in forest susceptible to fires. The increasing demand for multiple uses of forests leads to the identification and marketing of non-wood forest products and services. This has to be incorporated into management planning, both at strategic and operational levels. Land use and land use reclamation especially in the forestry sector is another prevalent problem in decision-making that needs long-term strategic planning.

Greek forest management planning, within the framework of DSS, up to now has been concerned mainly with forest fires and, to a lesser extent, with forest management planning, because forest fires have financial, ecological and socio-economic impacts. Forest fires are very common events in the country and in Mediterranean-type ecosystems. Decision-makers, public and private, express a strong interest in having tools to help them assess the risk of fire and also the changes in financial and environmental values due to forest fire risk on a long-term scale and on a regional or forest-level scale (Iliadis 2005; Kazana et al. 2007). On the other hand, Vakalis et al. (2004a) stress in their study that the most important characteristic of major forest fire incidents, from a societal perspective, is their potential to seriously and irreversibly damage regions of significant natural value. In addition, the extent and severity of such incidents may significantly affect the population and the environment of the adjacent areas. Following a forest fire event, effort should be made to limit its environmental effects. Management decisions should be taken on an operational, spatial forest level and be based on rational and quantitative information about the site-specific circumstances and the possible consequences. Regarding the forest management planning of multiple use of forests, Kazana et al. (1996, 2003, 2005, 2008a) tried to address decision problems on a long-term regional and tactical scale using tools for multi-criteria forest planning and management which are based on interactive multi-objective programming.

The objective of this study was to address the types of problems encountered in decision-making regarding forest management planning that are prevalent in the country and review the existing DSS or computerized tools that have been developed. Further, the DSS are classified according to the problem types and their associated dimensions that they attempt to address, and finally, we discuss how well these tools did address the problems.

11.2 Materials and methods

In this review, we tried to collect all possible information concerning the development of forest DSS in Greece. Sources for our review were national and international journals, the Greek national thesis database and personal communication with forest DSS developers. We encouraged the DSS developers to introduce the material into the FORSYS wiki instead of doing it ourselves. The reviewed publications were analysed, according to the management problem type they deal with, and the models and methods used for their development. Six of the reviewed forest DSS were concerned with forest fire risk assessment or fire risk reduction factors, analysing and optimizing forest fire-fighting strategies on an operational, spatial and forest-level scale and their relationship to the socio-economic and environmental impact. The methods used for DSS development were along general lines: goal programming, fuzzy logic, multi-criteria and heuristics. Object-oriented expert systems and goal-driven forest management planning using a component-based approach were used to incorporate knowledge management. One decision support system deals with strategic planning for the development of the Greek forestry and wood products, but it is not implemented into a computerized system. Six are concerned with forest planning and management, sustainability assessment of investment projects in mountainous Mediterranean areas, impact evaluation of local area sustainable development, environmental risk impact assessment of potential natural and human-made hazard processes in Natura2000 sites and optimal environmental reclamation of former coal mines, and one deals with the financial evaluation and ranking of the beekeeping industry.

11.3 Results

One serious problem in Greek forestry is forest fires. Data shows that Greece has the most severe forest fire problem among the European Union (EU) countries, according to the average burnt area per fire. Despite governments having increased their efforts in forest fire fighting, thousands of hectares of forests are lost. The consequences are loss of lives and goods, soil erosion, damage to wildlife habitats and degradation of watersheds. Thus, it is obligatory for decision-makers, both public and private, who have expressed a strong interest in gaining tools to help governments in assessing the risk of fire along with the changes in the economic and environmental values due to forest fire risk. For the reasons mentioned above, Greek forest management planning regarding forest fires to date have been concerned mainly with the problem type 9 (Table 1), which is trying to give solutions on an operational, spatial and forest level on the area burnt, and the dispatching of utilities, equipment and personnel that would appropriately attack the fire front. Other problem types in the context of long-term, spatial or not, and on the national or forest level regarding other aspects such as silvicultural or forest policy planning and decision-making have also been developed, but to a lesser extent. An overview of the management planning problem types that are prevalent in Greece and the associated decision support systems that have been developed to solve the problems are shown in (Table 1). Regarding the management planning problem in a long-term, non-spatial context (Table 1, problem type 1), the development of the FFIREDESSYS system (Iliadis 2005) aims to give the authorities the ability to take long-term decisions on a national level pertaining to the fire risk objective, in order to distribute their forces rationally and to plan appropriate protection and recovery policies. The main advantage of the FFIREDESSYS system is that it produces the degree of membership (DOM) to the 'Forest Fire Risky Area' fuzzy set, which is a pure and relatively simple number that is a comparable measure of fire danger for each area, thus clearly indicating the forest fire risk. This number can also be easily used for the ranking and for the clustering of the areas. The Knowledge Base, the Inference Engine and the User Interface are the most important parts of the system. The whole system has to be copied into the LEONARDO folder in order to run properly. It has a user-friendly interface that uses menus, screens and pop-up menus. It is used to store not only the actual forest fire data, but also the rules and the facts that affect the reasoning of the system. Object frames are used to store the characteristics of all the objects used in the DSS. The LEONARDO Decision Support System shell was used because it offers a unique development environment and a user-friendly user interface. The Inference Engine is the part of the DSS that manipulates the produced rules in order to generate information. The Inference Engine used is backward chaining with opportunistic forward. This means that it reasons in a backward mode, starting with the goal and firing only each necessary rule. FFIREDESSYS works in both Trapezoidal and Triangular mode. The testing is performed in two phases. First the DSS is tested using the Semi-Trapezoidal membership function in order to determine the Degree of Membership of each prefecture to the fuzzy set 'Forest Fire Risky area'. Then, the Semi-Triangular Membership function is used to evaluate the forest fire risk.

Table 1. Overview of decision support systems in Greece

Problem type	**DSS name**	**Models and methods**	**KM techniques (if applicable)**	**Methods for participatory planning (if applicable)**
1	FFIREDES SYS	Fuzzy system model for forest fire risk estimation	Experts define fuzzy sets and membership functions Knowledge Base containing forest fire data integrated into LEONARDO Executable Knowledge Base	
6	GOVERN ET-DSS	Fuzzy multi-criteria AHP model impact evaluation and socio-economic models	Knowledge base with the MEDMONT spatial natural resource capability	DELPHI, Cognitive Mapping, NGT
	ManagM ED-DSS	Fuzzy multi-criteria AHP model socio-economic and risk impact evaluation models	Knowledge base with natural resource risk impact evaluation models	Combined DELPHI and Cognitive mapping
	Cross border risk assessme nt	Multi Criteria Analysis, unary and binary arithmetic Numerical Array Processor Library	Map classification methods implemented into the spatial processing of STRiM GIS. Map algebra implemented by the (NAP) library	Multi stakeholders collaboration

Problem type	DSS name	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
		(NAP)		
	Coal mines reclamation	Fuzzy logic multi-criteria, binary integer linear programming	Orthophotomaps classification methods GIS capabilities to prepare platform using multicriteria methods. Spatial optimization model	Multi stakeholders collaboration
8	WRR-DSS	Fuzzy system mode, Wildfire simulation models Linear programming	Experts define fuzzy sets and membership functions Knowledge Base containing Intelligent forest management planning. Exsys Prof. Shell.	
	APIDESYS	Fuzzy system model for forest fire risk estimation PROMETHEE II methodology	Experts define fuzzy sets and membership functions data integrated into LEONARDO Executable Knowledge Base	
	FORM	M C Analysis, Interactive Multi-objective linear Programming	Knowledge base containing forest yield data and forest recreation data	
9	WFCM-DSS	Minimal Path Algorithm, Forest Fire simul Tool on Fuzzy/neural systems	Experts define fuzzy sets and membership functions through trial and error approach and neuro/fuzzy methods, rule base	
	FFCM-DSS	Minimal Path Algorithm, Forest Fire simul Tool on Fuzzy/neural systems	Experts define fuzzy sets and membership functions through trial and error approach and neuro/fuzzy methods, rule base	
	FOMFIS	Probabilistic planning modules, Fire simulations, socio-economic risk module	LANDSAT and SPOT images. Fuel mapping, Scenario generation module.	
10	FIREMAN (MIS)	Stochastic simulation of fire, harvest time, management time	Probabilistic analysis of historical databases for fire, harvest, management.	
	MEDMONT-DSS	Rule-based fuzzy multi-criteria model, evaluation, socio-economic and green accounting impact models	Knowledge base with the MEDMONT spatial natural resource capability	
	Strategic study for Greek forestry	Cost - benefit analysis, quantification of inputs and outputs followed by sensitivity analysis	Net present value, internal Interest rate, cost/benefit analysis, Utility analysis and constraints approach. Quantification of inputs and outputs if possible on monetary units followed by sensitivity analysis comparing with the existing situation	

The planning problem of forest fires can be strategic, regional and single objective, helping the authorities to design general policies on the protection and prevention of forest fires, but it is also an operational, spatial problem on the forest level facing multiple objectives. In this case, the respective decision support systems or tools help the decision-maker or authorities to act quickly on the expected fire events and, in the case of real fires, on combating them. There are three tools that were developed to address this problem (Table 1, problem type 9). The Wildland fire crisis management decision support system developed by Vakalis et al. (2004a and 2004b) constitutes an essential part of the operational system. It provides the user with the necessary capabilities to assess the situation of an incident and make the appropriate decisions in order to respond to the accident effectively and efficiently. The following sections briefly describe the methodological framework for the development of the DSS, as well as its functional specifications and design. The model base contains the following types of mathematical models, rules and algorithms: models for estimating the impact and the evolution of the fire accident; and mathematical models for determining optimum routing plans. The Human Machine Interface is GIS-based, and performs the following operations: (a) interacts with the user (b) serves as a front end for entering real-time information into the system (c) provides features for extracting and displaying all information stored in the database (d) illustrates the application site including the mathematical network representation, and all facilities that may be important for the system operation (e) performs all required associations of real-time and/or historical information with the mathematical graph (f) displays the contours that illustrate the impacted area (g) displays the response unit that has to be dispatched for servicing a specific incident (i.e. the output of the dispatching function) along with the optimum route (the output of the routing function) (h) displays the list of responses (i.e. the output of the suppression function) and (i) presents the routing plans.

Keramitsoglou et al. (2004) developed a multi-disciplinary decision support system for forest fire crisis management which is very similar to that of Vakalis et al. (2004a, b) and capable of supporting forest fire crisis management. It operates on a national scale. The system's architecture consists of three structural elements: (i) A model base containing mathematical models, algorithms, rules and a knowledge base, which is utilized for minimizing incidence duration and consequences. (ii) A database containing all the data needed for the system operation. (iii) A GIS-based graphic user interface. The systems can handle multiple fire ignitions and support decisions regarding dispatching utilities, equipment and personnel that would appropriately attack the forest fire front.

The FOMFIS DSS developed by Bonazountas et al. (2007) aims at providing quantitative estimation of the forest fire consequences, while helping users to evaluate options and effectively implement decisions. Its architecture involves an integrated framework of image processing and geographical information systems (GIS) coupled with a number of regional data (geographical, socio-economic and meteorological). The system introduced is a fire risk model, and it is used before the emergence of a fire event for prevention planning and during a fire crisis for supporting the management of resources, as well as for the assessment of possible fire combating strategies and actions. It provides the user with maps (fuel map, NDVI map, risk estimates, map of minimum time path needed to confront a wild fire, aggregated map integrated in an ARC VIEW 3.0 platform) and a software tool integrating the data received from satellite, in situ observations, and producing the abovementioned maps. This software is based on Visual C++ computer language. The system consists of eight modules:

i. The Data Acquisition (DA) module.
ii. Satellite images in the visible part of the solar spectrum from LANDSAT and SPOT satellites and meteorological data.
iii. The Fuel Mapping (FM) module.
iv. The Scenarios Generation (SG) module.
v. The Socio-Economic Risk characterisation module (SRM).
vi. The Probabilistic Planning (PP) module.
vii. The Valuation (VAL) module which is composed of two sub-modules. A function computing an overall fire risk value for a specific area taking into account three aspects: economic, environmental and social. A report generation sub-module employing the output data of the PP module and the User Interface (UI) module. It constitutes the shell for user front-end system operations.

Forest management planning problems are also concerned with tactical, spatial, multiple objectives, stand or forest-level decisions considering marketable wood and non- wood products and services. This problem type is particularly important to forest managers in order to make decisions on different aspects of forest management (Table 1, problem type 8). The decision support tool, Wild fire risk reduction (WRR-DSS) developed by Kaloudis et al. (2008), aims to address this problem type. The system was developed to help forest managers decide which silvicultural or other management measures they have to take or to apply in order to reduce the fire risk in forests that are considered as high fire risk hazards. It is a goal-driven Forest Management Planning-DSS, using a component-based approach. The main purpose of this model is to record design decisions as early as possible. More specifically, this model describes FMP-DSS in abstract terms, by expressing the components and their cohesion. The abstract representation of the model shows the general capabilities of the system and makes it possible to add various technical details at a later detailed design stage. It consists of three abstraction levels. Each higher level is based on the specification of the lower levels. That is, the level of Primitive Data Components stores environmental and forest primitive data, which is used by the level of Derived Data Components and, in turn, supports the level of Intelligent FMP Components. In addition, the level of Primitive Data Components supports the level of Intelligent FMP Components. The analysis and design of the WRR-DSS system, involves, in general: the identification of actors, foresters, data providers, decision-makers; the identification of use cases; the identification of the components that support use cases; and the design of a system model, including identification of sequence diagrams.

Continuing with the same problem type of multiple use forest management at the tactical scale on a forest level, the decision support modelling framework for multiple use forest management (FORM) (Kazana et al. 2003) was developed to provide answers and solutions to forest resource allocation problems while simultaneously trying to satisfy, over time, the longer-term multiple objectives within physical, operational and sustainability constraints. It also fosters the ability to provide analytical support for exploring new alternatives (trade-offs). The decision process involves the identification of different habitats managed under different regimes to meet certain requirements over multiple time periods. The system considers factors such as the establishment of management requirements, the potential of different habitats for a particular management objective under different regimes over time and balancing of the distribution of habitats in order to meet the specified requirements. Multi-criteria analysis was used for the objectives' quantification and typical multiple objective linear programming for the maximization of each objective.

If we see the forest management planning for multiple use forest management in a broader sense and consider that beekeeping is an agricultural activity taking place mostly in forests and that honey production is a non-wood forest product, then we could consider that the APIDESSYS decision support system (**API**CULTURE **DE**CISION **S**UPPORT **SYS**TEM) (Iliadis et al. 2003) can give answers to the tactical scale on forest-level problems. The system utilises the basic financial ratios that express the Liquidity (Current Ratio, Debt structure Ratio), Solvency (Debt to Total Assets Ratio, Debt to Equity Ratio), Efficiency (Total Assets Turnover Ratio, Invested Capital Turnover Ratio) and Profitability (Earnings to Investment, Return on Investment) of the main Apicultural Union Cooperatives. and/or Apicultural Enterprises of the Greek beekeeping industry. In the first stage, the Intelligence phase, the reality was examined, the problem was defined and data was gathered. In the design phase, the PROMETHEE II methodology was chosen to be applied. Six different types of general tests were used to determine the best of two alternative solutions. In the choice phase, general planning for the implementation of the software was performed. The system was developed by the use of the Object Oriented Expert system shell LEONARDO. One of the most important aspects of the system is that it provides a full explanation facility that informs the user about the reasoning process. In other words, the system explains to the user how and why it reached a certain goal. The interface engine of the APIDESSYS system was designed to be rule-based and it consists of facts, rules and object frames. It was designed and constructed to have a main rule set and local rule sets within the object frames. Its most important part, the Inference Engine, is the mechanism that leads to the goal. The Inference Engine strategy applied was backward chaining with opportunistic forward. It starts from the goal and it evaluates only the necessary rules to reach the final decision.

The development, planning and management processes to achieve sustainable development at local and regional level are a highly challenging task. It requires bottom-up social participation approaches to define long-term alternative development interventions and tools to evaluate their environmental, social and economic impacts in space and time. This management planning problem (type 6, Table 1) is addressed by four decision support systems. The GOVERNET system (Kazana et al. 2008a), operates through a transnational network, which promotes cooperation and exchange of experience among the area governance councils, leading towards achieving local sustainable development by using mainly web services and special dissemination meetings and publications. The GOVERNET system has been applied to a wide variety of areas, including mountainous, lowland, semi-urban, and semi-industrial areas, with different development patterns and related problems such as environmental degradation, declining economics, isolation and problems of marketing wood and services. Cognitive mapping and Delphi–like approaches are applied for social participation. Multi-criteria analysis combined with fuzzy logic is used to trade off environmental, socioeconomic and institutional impacts. On the same problem type, the ManagMED spatial decision support system (Kazana et al. 2008b) was developed to assess risks in Natura2000 areas. The intelligence component of the ManagMED spatial decision support system describes and assesses the current state of the model study areas by identifying the entire relevant natural, socio-economic and institutional processes occurring in the model areas. Guidelines were prepared for a working system of local stakeholders, scientists and the model areas' responsible team members, to set up and function in all study areas. The main reason is to apply a group decision-making method in order to elicit and incorporate relevant information into the spatial DSS. The guidelines were also distributed to partners so as to help them collect the basic information from the model areas. This information includes geography, administration, special Natura2000 features, physical environment (climate, topography, geology, soil types, vegetation, wildlife), land use and land use changes (agriculture, forestry, rangelands, recreation, water resources and residence), human resources (population, employment, education, migration), economic resources (primary, secondary and tertiary sectors of the economy), as well as the current management planning processes of the protected model areas.

The motivation for the development of the web-based Decision support system for transboundary environmental risk assessment and management by Pediatiti et al. (2011) was the establishment of a common framework and procedure for environmental risk assessment. This DSS is implemented as a web-based application which enables environmental administrators and decision-makers to undertake generic risk assessment and management identifying areas where detailed risk assessment is required, as well as appropriate risk management options. The web-based DSS serves as an integration platform for the other components of the system: map server, risk assessment indicator database and document database. The main functionality of the web-based DSS includes qualitative risk assessment for the identified environmental hazards, MCA facilitated options appraisal for the selection of applicable risk management options and automated report generation. The map server is used to handle GIS maps that illustrate various steps of the risk assessment procedure. The web-based DSS is implemented using a three-tier architecture, Java EE 5 platform, Java Server Faces and Java Enterprise Beans technologies, and Open Source products for the application server, database and integrated development environment.

Large-scale surface mining methods are activities that adversely impact the environment. Land reclamation after mine closures is a difficult decision. Conventional methods used for reclamation planning are characterised by the lack of data integration and by time-consuming analysis. The long-term spatial management planning problem concerned with this decision is solved with the spatial decision support system (SDSS) developed by Pavloudakis et al. (2009). In this SDSS these problems are minimised, as data integration and analysis are offered within one computerised environment. A geographical information system and multi-criteria decision-making methods, based on binary integer linear programming models, have been integrated to select the appropriate land use in different parts of a post-mining area taking into account social, technical, economic, environmental and safety criteria. On the basis of developed mine maps, the model variables are assessed and incorporated into the objective optimisation function.

Most decisions, in the context of sustainable multiple use forest management, need to be derived after consideration of various impacts, for example environmental, socio-economic and institutional. The MEDMONT multi-criteria fuzzy model is part of the MEDMONT integrated evaluation framework for project sustainability assessment in the mountain

Mediterranean areas (Kazana et al. 2005). The system relates target groups with the project evaluation and monitoring processes and tools by integrating three dimensions: regional spatial scale, level of aggregation and the top-down and bottom-up approach. It involves a natural resource base and capability evaluation, a socio-economic evaluation, an institutional evaluation, green accounting evaluation, a social preference evaluation and an integrated evaluation based on multiple criteria analysis and fuzzy logic. The tools can be used to balance and integrate environmental, social, and economic project impacts in the context of sustainable multiple use forest management. The model structure is based on fuzzy logic, and so can successfully deal with attributes related to project impacts that are vague, subjective or uncertain. The model also incorporates social preferences in the evaluation process to balance natural resources and human resource impacts, which is expressed through its linguistic rule base. The FIREMAN system (Kazana et al. 2007) uses the tool of simulation to forecast the possibility of forest fire, creating fire expansion and behaviour models in various types of ecosystems. The system was based on data collection from three different areas in Greece. Those areas were selected so as to reflect various types of forest ecosystems as they are distinguished by the main forest species. The FIREMAN is a Management Information System (MIS) designed with the aim of helping stakeholders related to forest lands make better decisions with regard to financial issues accrued due to the forest fire danger. In this work, long-term data of forest fire events for three study areas of high and low fire risk were collected, respectively, from the National Forest Service Offices of those areas. Data were also collected on the forest species growth, the wood prices, the reforestation costs, the forest rate of interests, and the volume. The data were analyzed and probability distribution functions were constructed to represent the frequency of forest fire events per year in each study area. A stochastic simulator was then designed using Excel software with two possible states: a) forest fire event and b) no forest fire event. In the case of a forest fire event, forest managers need to face the cost of reforestation and to estimate the forest revenues based on the expected forest growth and the value of the harvestings over the period since the last fire event up the time the estimate is made. FIREMAN also offers possibilities to investigate 'what- if' alternatives for different interest rates with regard to management of the forest ecosystems in the three study areas.

11.4 Discussion and conclusions

The long-term decisions, on a regional scale with a single decision-maker facing a single objective and considering market and non-market services, are well addressed by the FFIREDESSYS tool regarding the estimation of fire risk (Table 1, problem type 1). The tool has proven to be very reliable and its accuracy with the use of the Trapezoidal Membership Function has reached the value of 60% in the prediction of the 10 most risky areas. Fuzzy aggregation connectives (aggregation operators) are used to determine the degree of forest fire risk on a regional basis, since Greece and most European countries are divided in regions. Each region consists of many prefectures. The whole idea, the model and its methods can be used widely in every country of the planet and they have an international interest. The results show that the system offers a much more reliable approach than the use of actual forest fire history.

Operational, spatial planning, multiple objective problems on the forest level with a single decision-maker considering market and non-market goods and services are part of the daily agenda of forest managers. One component of this problem is forest fires (Table 1, problem type 9). Three tools have been developed and tested in order to give solutions and support to authorities to enable them to act fast on the expected fire events and, in the case of real fires, on combating them. The FOMFIS decision support system is a tool for prevention and examination of the spread of a wild fire. The DSS established is based on state-of-the-art technologies in identification of forest characteristics from satellite imagery, simulation of fire behaviour, fire risk assessment, and geographic information systems. It has been applied, verified and validated in the area of Evoia, Central Greece, during a real forest fire event and delivered results close to those defined by the relevant authorities. The multidisciplinary DSS for forest fire crisis management developed by Keramitsoglou et al. (2004) and the GIS-based operational system for wildland fire management developed by Vakalis et al. 2004a, b) combine NOAA satellite images coupled with DSS technologies for efficient decision support during a crisis. The systems were tested in the form of pilot applications in the mountain area of Penteli in the prefecture of Attica in Greece. Penteli is covered with vegetation, which consists of the most flammable Mediterranean species. The results were successful in all tested scenarios under mild and extreme atmospheric conditions. The derived information from the results were also transmitted to the Civil Protection Operation Centre in order to optimize the condition of actions during forest fire abatement. The development of these tools for the solution of this problem planning type, show the urgent need for supporting decision-making in forest fire fighting.

Tactical, spatial planning multiple objective problems on the forest level with a single decision-maker considering market and non-market goods and services are also important issues in forest planning (Table 1, problem type 8). One aspect concerning the prevention of forest fires is to reduce the fire risk by taking regular silvicultural measures. The wildfire risk reduction Decision Support System (WRR-DSS) attempts to address this problem type. It can facilitate and optimize wildfire damage reduction despite uncertainty. The intelligence forest management planning components make extensive use of fuzzy logic techniques to manage the uncertainty and linear programming or the evaluation of the solutions of the primary and secondary objectives and treatment applications. Although the system has been developed for research purposes, it could be operated by a public forest agency. The model aims at providing guidelines for a design process for forest managers and developers, reducing the complexity of this kind of deployment. It describes goal-driven FMP-DSS in abstract terms, by expressing the components and their cohesion. It is a layered, component-based approach. As such, it is flexible in that improvements and the addition or replacement of components can easily be incorporated. Further research is needed with the modelling of forest function and treatment effectiveness in Wildfires Risk Reduction, investigation of fuel growth after the treatment application, the detailed modelling of fuel, especially that of crown, and the modelling of vegetation structure for long-term intervals with or without treatment applications.

The problem type of multiple use forest management at the tactical scale, on a forest level facing multi-objectives and considering market and non-market goods and services is addressed fairly well by the decision support modelling tool for multiple use forest management (FORM). It uses multi-criteria analysis to quantify objectives derived from service functions of forests with regard to silvicultural and operational treatments. Multiple objective linear programming is used to select the optimal management plan combination. The decision support modelling structure used in this tool was applied to the planning and management conditions of the Queen Elizabeth forest park in Scotland. However it is flexible and adaptable to other similar multiple use forest management and planning cases. In this context further research is required to include natural resource response models and social and cultural resource-related information specific to the site or region under concern.

Another case of tactical, spatial planning multiple objective problems on the forest level with a single decision-maker, considering non-wood forest products, but oriented to a more financial aspect, is the APIDESSYS decision support system. This system can play a very important role in evaluating not only each apicultural unit separately, but the whole industry as well. With the application of different 'what if' scenarios, it can evaluate the apicultural cooperatives or enterprises from many different aspects and provide useful information for the decision-making process. In the testing phase, APIDESSYS has proven a very effective tool. This is very important because of its excellent human-machine interaction and its fine and operational explanation facility. The explanation mechanism of APIDESSYS justifies the final outcome and, in this way, the end-user feels confident that the obtained result is accurate. This is really important for the system to gain acceptance in the business and scientific community. The system could be applied not only in the beekeeping industry but also in other sectors of animal production. APIDESSYS is one of the major keys that united apiculturists or apiculture-related enterprises. should use in the developing a more rational and effective management policy. What adds more value to the system is that it produces results faster and which are more reliable than the classical methods used by human experts.

Long-term, spatial planning multiple objective problems on the forest level with stakeholder involvement considering market and non-market goods and services are also important issues in forest planning (Table 1, problem type 6). The GOVERNET tool attempts to assess the long-term planning problem of the promotion of an integrated sustainable development of rural areas in the local or regional level. It incorporates activities of small-medium enterprises and strengthens the relationship of rural to urban areas. The system operates through a transnational network, which promotes cooperation and exchange of experience between the area governance councils aimed at achieving local sustainable development, using mainly web services and special dissemination meetings and publications. The system has been applied in the Cassandra peninsula of Chalkidiki prefecture. This place was chosen because it exhibits a complicated form of development. Rapid urbanization reduced the agricultural and forest land, increased fire risk and changed a rather big part of Aleppo pine forest into olive groves. Despite the pilot character of the application, the results are very promising. On the same philosophy and using the same methodology on models and methods, the ManagMED tool was developed to assess risks in Natura2000 areas. The transboundary environmental risk assessment and management web-based DSS was applied in four pilot trial sites in Greece, Greece – FYROM, Bosnia Herzegovina – Serbia and Montenegro, and Bavaria- Germany – Czech Republic. The preliminary evaluation of the framework and DSS is positive and the applicability of this application at different scales is feasible. Despite the lack of formalized legislative and institutional adoption of this process by regional governments the system successfully addresses the management problem type that it was developed for.

The long-term planning multiple objectives problem, on a regional level considering market and non-market goods and services, regarding the decisions on financial issues accrued due to the forest fire danger is addressed by the management information system FIREMAN. The system has proved to be a very flexible tool, which can enable users to analyze alternative administrative financial scenarios which pertain to the administration of forest ecosystems. At the current stage of development, the system can make decisions about the course of present value as well as the time of the next event to follow, whether this is fire or harvest. It allows also for more development and optimization and can be applied for more types of forest ecosystems. The system was checked on three types of forest ecosystems, giving promising results. Also in this category of problem management planning is the MEDMONT multi-criteria fuzzy model, which is part of the MEDMONT integrated evaluation framework for project sustainability assessment in the mountain Mediterranean areas. The system was applied to a number of country investment projects, and arrives at estimates by incorporating all the different kinds of project impacts.

The long-term strategic study for the sustainable development of Greek forestry and wood products developed by Forest Research Institute (Ministry of Agriculture 1986) was at the beginning a good start for the development of a decision support system that would be able to address the strategic management planning problem type 10 (Table 1) of Greek forests. Despite the good structure and the clear and straightforward approach of the subject this study did not integrated into a computerized tool or to more sophisticated software.

The systems and tools analysed so far cover a fairly good range of the forest management planning problem types that are prevalent in Greece. However, there is still space for the development of new or different tools to cover more problem types, especially long-term and tactical decisions on the stand level with a unilateral decision-maker facing multiple objectives and considering market and non-market products. For instance, a DSS that optimizes silvicultural measures for timber production, biodiversity and labour on a tactical spatial scale on the forest level is of great importance. The main drawbacks of the Greek Forest Service are the non-competitive organizational structures and the low educational level of the forest personnel, which can be considered as the main reasons why DSS have a limited application. The DSS developed so far are the results of personal attempts of PhD students and researchers rather than a targeted strategy of Greek forest policy to face the prevalent management problem types.

References

Albanis, K., Galanos, F. and Boskos, L. 2000. Criteria and indicators for the sustainable forest management in Greece. General Secretariat of Forests and natural Environment, Ministry of Agriculture, Athens. 101 p.

Bonazountas, M., Kallidromitou, D., Kassomenos, P. A. and Passas, N. 2005. Forest Fire Risk Analysis, Human and Ecological Risk Assessment 11(3): 617-626.

Bonazountas, M., Kallidromitou, D., Kassomenos, P. A. and Passas, N. 2007. A decision support system for managing forest fire casualties. Journal of Environmental Management 84: 412–418.

Dimitriou, K. 2002. Spatial decision support systems for environmental planning purposes. PhD thesis, University of Aegean. 402 p.

Iliadis, L.S. 2005. A decision support system applying an integrated fuzzy model for long-term forest fire risk estimation. Environmental Modelling and Software 20: 613-621.

Iliadis, L., Batzios, C., Arabatzis, G and Liakos V. 2003. The APIDESSYS multi-criteria analysis decision support system: A tool for financial evaluation and ranking of Greek Beekeeping industry. In EFITA Conference 5-9. July 2003, Debrecen, Hungary 815-822.

Ioannou, K. 2008. Development of a decision support system for the protection of forests and natural environment from human made hazards. PhD thesis, Aristotle University of Thessaloniki. 170 p.

Kaloudis, S. 2008. Decision support system for the management of forest ecosystems based on geographic information systems and knowledge systems. PhD thesis, University of Athens. 210 p.

Kaloudis, S., Costopoulou, C., Lorentzos, N.A., Sideridis, A.B and Karteris, M. 2008. Design of forest management planning DSS for wildfire risk reduction. Ecological Informatics 3 (1): 122-133.

Kazana, V., Mutch, W.E.S, Fawcett, R.H. and A. Kazaklis 1996. FORM: A decision support system for multiple criteria forest planning and management. Studies in Regional and Urban Planning 4: 101-119.

Kazana, V., Fawcett, R.H. and Mutch, W.E.S. 2003. A decision support modelling framework for multiple use forest management: The Queen Elizabeth forest case study in Scotland. European Journal of Operational Research 148 (1): 102-115.

Kazana, V. and A. Kazaklis 2005. Valuing Mediterranean Forests. Situation in Greece. In: Merlo M. and Croitoru L. (eds) Valuing Mediterranean Forests Towards total economic value. CABI publishing. London. Pp. 229-240

Kazana, V., Bonnieux, F., Campos-Palacin, P., Croitorou, L., Gatto, P., Kazaklis, A., Merlo, M., Paoli, J.C. and Zadnik, L. 2005. MEDMONT: Tools for evaluating investment in the mountain Mediterranean areas - An integrated framework for sustainable development. Final Report, EU DG-Research, Brussels, pp 255.

Kazana, V., Georgiou, K., Gerofoka, P and Panteli M. 2007. FIREMAN: A Management information system for financial forest fire management. Ecology and Safety. 2: 1-10.

Kazana, V., A. Kazaklis, I. Takos, Th. Merou, D. Emmanoloudis, M. Lazaridou, N. Avtzis and A. Boutsimea 2008a. Integrated sustainable development at local level: the GOVERNET experience for mountainous areas. Ecology and Safety International Scientific publications. 2: 218-224.

Kazana, V., Kazaklis, A., Boutsimea A., Chatzigoga, C., Passali, D. (eds). 2008b. A Spatial Decision Support System platform for assessing risks in Natura2000 areas, Special editions, Kavala Institute of Technology, pp300.

Keramitzoglou, I., Kiranoudis, C.T., Sarimveis, H. and Sifakis N. 2004. A multidisciplinary Decision Support System for forest fires crisis management. Environmental Management, 33 (2): 215-225.

Ministry of Agriculture and Rural Development. 1986. Strategic study for the development of the Greek Forestry and timber production 1986-2010. Forest Research Institute Thessaloniki 298 p.

Ministry of Agriculture and Rural Development. 1992. Forest Inventory. Athens. 134 p.

Ministry of Agriculture and Rural Development. 2007. Annual Report of Forest Service Activities. Athens. 70 p.

Pavloudakis, F., Galetakis, M. and Roumposa, Ch. 2009. A spatial decision support system for the optimal environmental reclamation of open-pit coal mines in Greece. International Journal of Mining, Reclamation and Environment, 23 (4): 291-303.

Pediatiti, K., Stanojevic, M., Kouskouna, C., Karydas, M., Zianis, D., Petropoulos, P. and Boretos, N. 2011. A decision support system for assessing and managing environment risk cross borders. Earth Science Informatics, 4 (3): 107-115.

Vakalis, D., Sarimveis, H., Kiranoudis, C.T., Alexandridis, A. and Bafas G. 2004 a. A GIS based operational system for wildland fire crisis management I.Mathematical modelling and simulation. Applied Mathematical Modelling, 28 (4): 389-410.

Vakalis, D., Sarimveis, H., Kiranoudis, C.T., Alexandridis, A. and Bafas G. 2004b . A GIS based operational system for wildland fire crisis management II. System architecture and case studies. Applied Mathematical Modelling, 28 (4): 411-425.

12 Decision support systems for the sustainable management of forests in Britain

Amy Stewart1 and Duncan Ray[18]

12.1 Introduction

12.1.1 The public forest sector

Great Britain has approximately 3 million ha of woodland and forest (1.7 million ha of conifer, 1.3 million ha of broadleaf) which covers about 14% of the total land area (Forestry Commission 2011). Around 27% of this woodland is publically owned, the majority of which is conifer (c. 87%) (Forestry Commission 2011). In Britain, an estimated 1.26 million ha of woodland is sustainably managed under the Forest Stewardship Council (FSC) certification scheme, including all of the publicly owned forest, managed by the Forestry Commission (Forestry Commission 2011).

12.1.2 Forest planning

Britain's forest area is largely managed on a fell-restock basis, although in recent years there has been an increasing interest and activity to transform more of the public forest estate (PFE) to continuous cover forest (CCF) management systems and other low impact silvicultural systems (LISS) which includes CCF. All forest blocks on the PFE are managed for, and feature multiple benefits. Planning across the PFE occurs at 3 levels: 1) strategic forest planning, 2) forest design planning and 3) coupe planning (although in CCF systems there would be a forest management plan for the whole transformation process).

12.1.3 Strategic plans

Each of the devolved countries of Great Britain has developed a Forestry Strategy document (FCE 2007; FCS 2006; FCW 2009) to guide the long-term (50-year) future of forestry through the 21st century. These strategies review the main challenges, and guide policy for change through shorter term action plans (e.g. FCS 2009). Below the national strategic plan, regional strategic planning documents for each forest district management unit (or region in England) provide greater detail for the PFE based on the specific biophysical and societal drivers of the region. The national and regional strategic plans are developed every 10-15 years. They tend to be non-spatial and are defined in a descriptive way, although there are some spatially specific aspects considered in each.

12.1.4 Forest design plans

A forest design plan (FDP) is the primary tactical documentation designed to deliver sustainable forest management (SFM), propose ways to integrate objectives and resolve conflicts, assess the cost of alternative actions, communicate a vision of the future forest to stakeholders and the public, discuss and agree forest plans with statutory consultees, manage change, and organize operational activities from season to season. FDPs describe

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interventions in 10-year phases, with detailed planning at five-year intervals. This is the level of forest planning that is maintained and delivered spatially.

The Forestry Commission (FC) (the government department responsible for forests) is made up of two distinct entities in respect to forest planning. One part manages the PFE through forest districts and creates FDPs. These are produced in cooperation with various internal and external stakeholders. However, decisions are nearly always made by forest planners in a collegial or unilateral way, taking advice from and negotiating with statutory consultees and the public. This part of the FC is called Forest Enterprise in England and Scotland but not in Wales. The other part of the FC is often referred to as the forest authority and is responsible for the approval of FDPs. Staff from the authority are usually therefore consulted at the early stages of design planning.

12.1.5 Coupe plans

Designed features of change are planned in a coupe plan to organize the type and timing of forest operations, particularly the operations of thinning, felling and restocking and how these will be achieved. The restock plan elements of design planning provide information on the species selected for planting into the future.

12.1.6 Regulatory framework

FDPs must meet the UK Forestry Standard which is the UK government's approach to sustainable forestry. Meeting this standard is supported by a number of associated published guidelines. The standard and guidelines provide links to some computer-based decision support tools. It should be noted however, that there is no obligation for forest managers to use any of these tools. The PFE is also audited to assess whether planning and operations meet environmental standards set by the Forestry Stewardship Council (FSC). The FC is the only national forestry organisation producing internationally certified timber.

12.1.7 Objectives

FDPs are the key documents driving forest management on Britain's publicly-owned forest estate. In this chapter we describe a selection of key problems associated with the FDP approach, as well as a selection of other problems associated with the management of the PFE in Britain. These problems are summarized using the FORSYS problem typology. The chapter then describes key features of Decision Support Systems (DSS) which have been developed to help tackle these problems and explains how they have been applied to the FORSYS problems types identified. It should be noted that the chapter refers specifically to forest management in Britain, not the UK. This is because the FC is only responsible for forestry in Britain (although it should be noted that it is a devolved organization with separate authority in the countries of England, Scotland and Wales). The forest estate in Northern Ireland is managed independently by the Northern Ireland Forest Service.

12.1.8 Prevalent problem types

A selection of common forest planning and forest management problems in Britain are described below, and the corresponding problem types listed.

12.1.9 Problem type 1 – timber production target setting

Description: The FC in each of the devolved countries of England, Scotland and Wales needs to project timber production estimates from the public estate over the coming years, to demonstrate its capacity to supply FSC certified wood products to the processing industry in Britain. The problem type is strategic as it is used to set targets for wood production for the public and private sector in England, Scotland and Wales. This helps plan how much home-grown timber can be sourced in the three countries, and thus how much timber must be imported to satisfy Britain's market requirements. The analysis is performed at a devolved national scale from regional amalgamations of production forecast estimates from forest or sub-forest design plans. The timber production target is set through discussion and negotiation between stakeholders.

Summary: Strategic decisions, spatial with neighbourhood interrelations, regional/national level, multiple stakeholders, single objective, for market wood products.

12.1.10 Problem type 2 – design planning to meet multiple objectives

Description: Every 10 years, forest districts in all three countries develop FDPs in a rolling programme for the PFE (these are reviewed every five years). The planning is business critical for the forest district, to ensure that the agreed production forecast for the next five-year period is met. FDPs must also ensure a range of other objectives are met, including social objectives such as recreation and environmental objectives such as conservation of protected species. FDPs require statutory consultation with a number of bodies, public discussion, and agreement with the authority part of FC England, FC Scotland and FC Wales. However, decisions are nearly always made by forest planners in a collegial or unilateral way.

Summary: Tactical decisions, spatial with neighbourhood interrelations, forest level, multiple stakeholders, multiple objectives, for market wood products and market and non-market services.

12.1.11 Problem types 3 and 4 – species selection based on site conditions

Description: Species choice is crucial in terms of ensuring forests are sustainably managed. In Britain, the management of the PFE is regularly reviewed as part of the requirements of the FSC certification scheme, reflecting the adherence to sustainable forest management as described and recommended under the UK Forestry Standard. The UK Forestry Standard specifically addresses species choice, since a fundamental aspect of sustainable forest management is that the species selected should be suited to site conditions (climatic and edaphic). This requirement reduces the need for excessive site amelioration by ground preparation and fertilisation, reducing the impact of reforestation on soils, water and other aspects of the environment.

Britain has no natural woodland, and all semi-natural areas have been highly modified through two millennia of fragmentation and use. The reforestation programme from the beginning of the 20th century used many exotic species, particularly from the US Pacific Northwest (Klinka et al. 1989; Krajina 1969; Pojar et al. 1987). This programme focused reforestation on the infertile, wet, least productive agricultural land. It was common for large scale intensive site amelioration to improve the establishment and productivity success of a chosen species on a range of site types, rather than choose a species suited to site conditions. This practice extended over 50 years or more, and so the practice of species selection in UK forestry was undermined and partly lost in forestry practice. As a result there have been instances where coupe plans have used the productivity of the previous crop as an indicator of future potential, failing to account for the change in policy to a low input site preparation practice, and its consequent effect on site fertility. This has led to poor establishment and poor growth on some sites where the earlier crop was improved by more intensive ground preparation and fertilisation.

The forest planning process in Britain is essentially a tactical design planning process, which at a higher level guides the operational decisions from an indicative set of maps showing species choice and date of intervention within management coupes. The Forest Planning Guidelines require a landscape assessment of the coupes for felling and restocking and for thinning on a five to 10-year plan. Although the design planning is indicative in the sense that detailed forest operations are not specified, the plan will indicate the tree species to be used for restocking felling coupes and act as a guide for operational staff. The problem is that design planning does not routinely deal adequately with the detail of matching tree species to site conditions since variation in the site conditions (slope, aspect, soil type) are not fully considered in the design plan, as the data to support species selection is not well represented in the Forester GIS system (used for FDPs and described in sections 3.1.1 and 3.1.2).

Summary problem type 3: Strategic decisions, spatial with no neighbourhood interrelations, forest level, multiple decision-makers, multiple objectives, for market wood products and market and non-market services.

Summary problem type 4: Strategic decisions, non-spatial, stand level, multiple decision-makers, multiple objectives, for market wood products and market and non-market services.

12.1.12 Problem type 5 - species selection for climate change adaptation

Description: Species choice is becoming increasingly important because of climate change and the introduction by the devolved administrations of policies to increase the adaptive capacity of forests. Country forestry policy teams are sometimes asked by the UK government to undertake climate change impact assessments which review the adaptive capacity of the PFE in each country, as well as the likely impacts of climate change and opportunities to mitigate greenhouse gas emissions under projected future climate conditions. The teams therefore need evidence of the impact of climate change on the tree species currently on the PFE in each country.

Summary: Strategic decisions, spatial with no neighbourhood interrelations, regional/national level, multiple stakeholders, multiple objectives, for market wood products and market and non-market services.

12.1.13 Problem types 6 - ensuring successful establishment

Description: Forest operations managers are required to ensure that newly planted trees are successfully established. Often the forest operations manager for a given area will not have sufficient silvicultural knowledge or experience to be able to do this with confidence, especially if they are new to the job. This type of problem is tactical since there are multiple operations that must be planned over several years for successful establishment to occur. The problem is non-spatial and is focused at the stand level with potential multiple objectives, since the plan for this stand could be for timber, recreation, species diversity, climate change adaptation, etc.

Summary: Tactical decisions, spatial no neighbourhood interrelations, stand level, single decision-maker, single objective, for market wood products.

12.1.14 Problem type 7 – priority and protected species

Description: Rare and threatened species and habitats are important in the public perception of forest management and its adherence to EU, UK and country legislation and policy. There are also economic reasons for protecting and enhancing the cultural services that woodland biodiversity and rare species provide. The rare woodland species, particularly birds and butterflies, draw the public to the forests (e.g. osprey – *Pandion haliaetus* L., red squirrel – *Sciurus vulgaris* L., chequered skipper - *Carterocephalus palaemon* Pallas), and feature view points and exhibition/viewing centres have been developed to raise the profile of rare species management. This has helped stimulate a 'Wildlife Tourism' industry (Bryden 2003; Martin 2003), and as a result, more people are choosing to visit forests as part of a recreational-learning experience. This is likely to benefit rural economies in terms of services, products and employment. In recent years the level of legal protection at the European and national levels which has been given to European Protected Species (EPS) and their habitats has also increased. It is now an offence to damage the habitat or disturb or damage any EPS. This has important consequences for land managers, particularly woodland and forest managers who need to fell trees and manage woodland to maintain habitat conditions for various species without causing damage to those species. A series of guidance notes has been published to do this in each of the devolved countries in Britain. However, it can be difficult for woodland managers to efficiently interpret the guidelines.

Summary: Tactical decisions, non-spatial, stand level, multiple stakeholders, multiple objectives, for non-market services.

12.1.15 Problem type 8 – Hylobius pine weevil

Description: Newly planted pine and spruce trees on recently felled conifer sites are particularly vulnerable to damage by the large pine weevil (*Hylobius abietis*). The fell-restock silvicultural practice exacerbates the weevil problem (see Heritage and Moore 2001; Moore 2004). Restock sites leave a large harvesting residue providing food for adults, and the remaining stumps and roots are ideal for insect larvae development, as the insect does not breed in live plants. Insect populations are affected by the time of year of felling, and stands felled in the late winter and early spring hold larger numbers of adult insects – attracted by the volatile chemicals from the cut stumps. The greatest amount of damage occurs to newly planted trees following the second summer after felling the previous stand. Research has shown that up to 50% of untreated newly planted stock is lost in the early establishment period through weevil damage. In the past, newly planted trees were protected by dipping plants from the nursery in insecticide. However, there is an urgent need to adopt a new approach to the management of this pest as public concern about the use of chemicals in the environment has increased and legislation concerning the use of chemical pesticides is increasingly stringent.

Summary: Tactical decisions, spatial with neighbourhood interrelations, stand level, single decision-makers, single objective, for market wood products.

12.1.16 Problem type 9 – wind damage

Description: Wind damage is a serious problem in forests; it is believed to cost the countries of the EU more than €15 million per year, and in extreme cases substantially more. Britain has one of the windiest climates of Europe, and five 'catastrophic' storms have affected British forests in the 50 years since 1945, emphasising the frequency and scale of the problem – these include the storms of 1998 in south Scotland, 1990 in south-west England and south Wales, 1987 in the south-east of England, 1968 in the central belt of Scotland, and 1953 in north-east Scotland. In each case over 1 million m^3 of timber was damaged, and up to five times the normal annual cut in the affected region required harvesting. Lesser storms cause endemic wind damage in most years, and their combined effect is a serious constraint in upland forests. Wind-throw has been the main form of damage, but wind snap can be locally important when trees are particularly well anchored or the crowns are loaded with wet snow.

As discussed in other sections, in the devolved countries of Great Britain, the PFE is managed mainly with the use of FDPs. In the western parts of England, Scotland and Wales, wind damage is a key feature of forests, and this is frequently endemic damage in pole stage to mature crops and occasionally catastrophic damage as a result of severe storms. FDPs take account of the endemic damage by prematurely felling stands in which more than 15% or so of the trees have been windblown. However, in developing FDPs it is important that forest planners take account of the effect of 'opening up' contiguous forest stands to damage through felling a neighbouring stand and leaving an exposed 'brown' edge. This type of wind damage occurs frequently as trees on a newly exposed edge are not wind firm.

Summary: Tactical decisions, spatial with neighbourhood interrelations, stand and forest level, multiple stakeholders, single objective, for market wood products, market services and non-market services

12.2 Materials and methods

Nearly all of the DSS tools developed for forestry in Britain have been developed by the FC or with FC involvement. Consequently the method for researching this chapter involved reviewing internal systems, largely developed within the last 10 years, where the people involved in the development, testing and implementation of the systems still work for FC. There is a mixture of information about the DSS systems described. This information has been taken from peer-reviewed papers, FC reviewed publications and grey literature. This information has also been substantially supplemented by the personal knowledge and experience of the authors of this chapter, both of whom work within Forest Research (the research agency of the FC) and have either been involved in the development of forest DSS or have been involved in analysis of their practical application, development, implementation, usefulness and uptake.

12.3 Results

The nine problem types described above are addressed by six DSS systems (Forester GIS, EMIS, ESC, HaRPPS, HylobiusMSS, and ForestGALES). Four of the DSS tools described have been included in the FORSYS Wiki (http://fp0804.emu.ee.wiki/index.php/Category:Decision_support_system).

Table 8. Summary of results

Problem type	Computerized tool/DSS	Models and methods	Knowledge management techniques (if applicable)	Methods for participatory planning (if applicable)
1 – timber production target setting	Forester GIS Spatial planning, information and forecasting system	Empirical classical methods, heuristic methods (used to map species with insufficient empirical data to other similar species with adequate empirical data)	None	None
2 – design planning to meet multiple objectives	Forester GIS Spatial planning information and forecasting system	Empirical classical methods, heuristic methods	None	Stakeholders and statutory consultees provide comments on plans. Local public and community group meetings are held to enable members to discuss and comment on plans
3 – species selection based on site conditions for forest	ESC (Ecological Site Classification) Predict species-site suitability for the baseline and future	Empirical classical methods	Knowledge-based methods	None

Problem type	Computerized tool/DSS	Models and methods	Knowledge management techniques (if applicable)	Methods for participatory planning (if applicable)
design planning	climate projections			
4 - species selection based on site conditions at an operational level	ESC (Ecological Site Classification) Predict species-site suitability for the baseline and future climate projections	Empirical classical methods	Knowledge-based methods	None
5 – species selection for climate change adaptation	ESC (Ecological Site Classification) Predict species-site suitability for the baseline and future climate projections	Empirical classical methods	Knowledge-based methods	None
6 – ensuring successful establishment	EMIS (Establishment Management Information System) Ground preparation, tree species choice and establishment information	Empirical classical methods	Knowledge-based methods	None
7 – protected species	HaRPPS (Habitats and Rare, Priority and Protected Species) Protection of UK Biodiversity Action Plan (UKBAP) priority woodland species, and woodland species listed on the European Protected Species List	Empirical classical methods	Knowledge-based methods, Evidence-based methods	None

Problem type	Computerized tool/DSS	Models and methods	Knowledge management techniques (if applicable)	Methods for participatory planning (if applicable)
8 – Hylobius pine weevil	HMSS (Hylobius Management Support System) Management to predict occurrence and reduce the impacts of the large pine weevil (*Hylobius abietis)*	Empirical classical methods	None	None
9 – wind damage	ForestGALES Predict damage to forest stands from breakage or overturning by extreme gusts during high wind speeds	Empirical classical methods	None	None

12.3.1 Addressing the problem types with DSS tools

12.3.2 Problem type 1 – timber production target setting

In order to answer problem type 1, planning teams in each country use the Forester GIS system. Forester GIS maintains all geo-database records supporting FDPs at a sub-compartment level. Details of tree species, age, management type etc. are held in a vector geo-database. On the PFE, coupe planning within FDPs form the most detailed level of forest planning. Design plans record vector information about proposed future coupes (e.g. felling, thinning), including species, planting year, management system and other attributes. Coupes can be formed from one or more existing sub-compartments – the existing spatial components of the forest, and so provide the approach of changing the spatial structure of the forest into the future. Spatial data is held in a geo-database and separate modules in the Forester GIS system are used to hold information about forest sub-compartments and forecast the product assortment that will be harvested from spatial components in the future.

The production forecast module calculates future production levels and assortments from the spatial mosaic of sub-compartments associated with management coupes – their age and planned thinning/felling dates. The production forecast is a calculation of the annual assortment of timber products for the forest district, based on the estimated yield class by species of each of the managed sub-compartments. The calculation is possible because: the FDPs in each district describe the position and size of management coupes for the 10-year period; the species and age of trees in sub-compartments which make up management coupes are attributes of the Forester GIS database; and the yield class of the components (species and structure) within each sub-compartment have been measured or estimated and are attributed in Forester GIS. Thus production targets can be projected into the future 10 years from the design plan information in Forester.

The methods incorporated into the production forecast are empirical yield models, empirical relationships between the tree diameter and height distribution of species of known age in stands, and empirical assortment predictions. These are all classical statistical methods.

12.3.3 Problem type 2 – design planning to meet multiple objectives.

Various other modules in Forester GIS provide information to guide the timing of operations. For example, a conservation module documents the occurrence of rare and protected species. Information about the forest infrastructure (roads, quarries, drainage etc) and future habitat development is documented. Plans for the restoration of plantations on ancient woodland sites (PAWS) are included and deer management plans are also described. A recreation management module is also included which helps to support the management of assets and services as well as objective decision-making around community, recreation and tourism activities on the PFE.

When a new FDP is being developed, the conservation module in Forester GIS helps identify constraints on the FDP, such as the existence of protected species within sub-compartments which will require the acquisition of special licences for felling out of the breeding season to reduce disturbance. The recreation module can help planners to identify where felling may have an impact on a busy recreation forest trail or feature, for example. Planners can also query Forester GIS by species, age and estimated top height to identify stands at or beyond the maximum mean annual increment (MMAI). A separate plan can then be developed for a survey team to measure the height and diameter distribution in temporary sample plots in the potential sub-compartments to confirm the volume estimate from the GIS. The spatial wind risk layer (calculated from ForestGALES) helps to ensure that new forest edges will be relatively wind firm.

Assuming the mensuration survey team report that the production estimates for the planned coupes are within tolerance for the agreed production forecast for the district, the plan can then be further developed for consultation. For the consultation, Forester GIS can create 3D views of the visual impact of planned operations.

12.3.4 Problem types 3 and 4 – species selection based on current site conditions

Ecological Site Classification (ESC) is a tool which was designed to help foresters assess tree species options based on an assessment of site conditions. The ESC development followed an approach, in which the variability of climate was defined in four climatic factors: warmth (accumulated temperature - AT), droughtiness (moisture deficit - MD), wind exposure (DAMS), and continentality (see Pyatt et al. 2001 for definitions). The suitability class (Very Suitable, Suitable, or Unsuitable) of different tree species and semi-natural woodland communities was linked to each of the climatic factors, and to two soil quality factors representing soil wetness (soil moisture regime - SMR) and soil fertility (soil nutrient regime - SNR) following a similar method to those described for BEC (Pojar et al. 1987), Ecosites (Beckingham and Archibald 1996) and FFF (Rameau et al. 1993). The ESC suitability models assess which factor is likely to limit suitability and growth on any particular site by calculating a suitability score from response functions (Ray 2001). The method assumes that suitable or very suitable factors cannot compensate for an unsuitable factor, thus following a precautionary principle. The approach also offers a sensitivity analysis to assess the effect on results, of varying one or more factors.

At the FDP stage, ESC-GIS can be used to solve the problem of matching tree species to site conditions using spatial soil (and/or plant) data from previous surveys. Indeed, since ESC has been deployed as a GIS application (Clare and Ray 2001; Ray and Broome 2003; Ray et al. 2003) it can be used to provide forest coupe/sub-compartment analyses from high resolution forest soil maps, and regional and national analyses of species suitability from low resolution digital national soil maps. Many forest districts have access to high quality soil maps, ranging between information mapped at a scale of between 1:10000 and 1:25000. The higher resolution digital mapping provides soil information at approximately a 1 ha resolution on the ground. This soil data is converted to soil quality (soil moisture regime and soil nutrient regime – water availability and fertility) and then combined in an assessment of site-species suitability with downscaled high resolution climate maps of warmth, moisture deficit, windiness etc to inform the forest planner of the range of possible species choice for restocking. The process provides indicative species restocking maps for consultation with stakeholders. Importantly, although the process does not provide a precise species - site type match (as this can only be done by a site survey) it does help increase the species options for restocking coupes, and so operations staff that are familiar with reading site conditions to plant suitable species will have a wider range of species on site to make detailed amendments to the plan.

At the operational stage, the ESC species suitability analyses can also use soil and plant indicator information collected by operational managers at a site or stand scale. The stand version of ESC enables the mix of site types within woodland to be carefully assessed. A survey is needed to evaluate the soil type and the mix of vascular plants occurring within a stand. Information from the soil and vegetation combine in the ESC stand-based DSS to reveal the detailed site quality. This includes information about soil water availability and the fertility of the site. The DSS provides a list of suitable tree species or NVC (Rodwell 1991) woodland communities. The ESC also provides information about the potential growth of the stand (yield class – $m^3ha^{-1}yr^{-1}$) and a summary of the projections for alternative species for the changing climate – based on IPCC climate projections. The ESC suitability analysis carried out by operational managers can then be used to discuss and agree changes to the FDP with the planning foresters and the forest authority.

12.3.5 Problem type 5 - species choice for climate change adaptation

To compile a climate change impact assessment for the UK government, a country forestry policy team can find out the species composition of the PFE through the Forester GIS geo-database. This can then be exported into shape files. The shape file layer shows the distribution of each individual species along with many other attributes. Using ESC-GIS in which national scale datasets of soil type and climate have been developed for the baseline climate, and for climate projections A1FI (High) and B1 (Low) scenarios for 2050 and 2080, the change in suitability from the baseline to the future climate is calculated for each species. For example, Figure 1 shows the summary of the output for the region of South East England. This illustrates declining suitability for the six species selected in the driest and warmest part of England. An overlay operation is performed on the GIS to calculate the area of changing suitability class as a percentage of the forest area on which the species currently occurs.

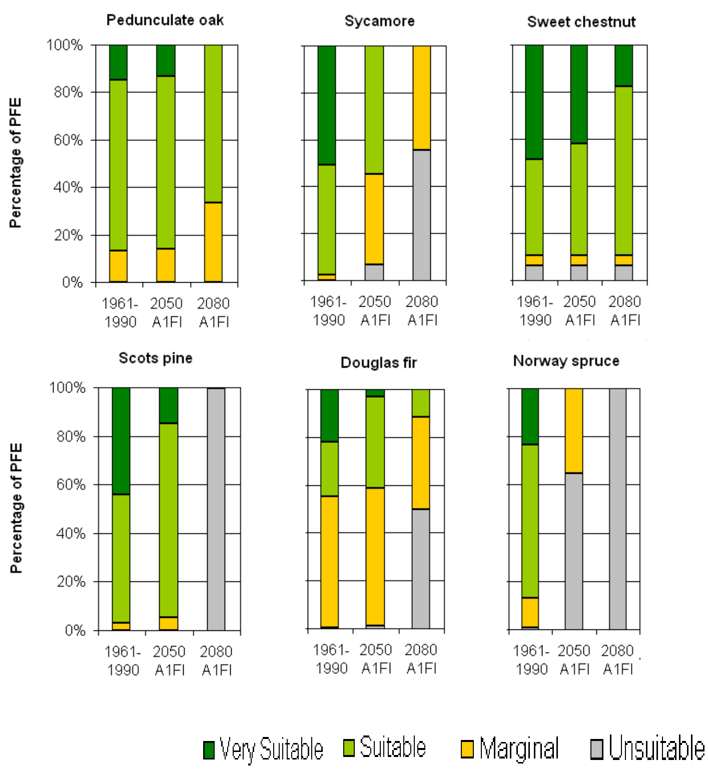

Figure 1. Summary of current and projected future suitability of six tree species growing on forest sites on the public forest estate (PFE) in South East England. This analysis was conducted using the ESC GIS DSS for the UK 2012 Climate Change Risk Assessment: Forestry Sector Report (Moffat et al. 2012).

12.3.6 Problem type 6 - ensuring successful establishment

The Establishment Management Information System (EMIS) links the species suitability outputs from ESC with information on best practice from published sources e.g. (Paterson and Mason 1999). The tool has been deployed as a web application (Perks et al. 2007) to provide easily accessible guidance on the forest operations and techniques particularly suited to the species and site combinations described by the user. Having used ESC to identify potentially suitable species for restocking a site, a forest operations manager who has to draw up the operations schedule for the restocking may find that they are not familiar with the silviculture of the chosen species and/or they may be aware that the species is known to be difficult to establish successfully. Where this is the case they can use EMIS to assess the options for successful establishment. EMIS prompts for the soil type, slope and tree species to restock. EMIS is a rule-based DSS providing site preparation advice for different species and site characteristics. The rules have been developed from the results of 60 years of experimental work on establishment.

12.3.7 Problem type 7 – priority and protected species

Habitats and Rare Priority and Protected Species (HaRPPS – www.harpps.org.uk) (Ray and Broome 2007) is web-based DSS and information system. HaRPPS was designed to aid forest managers in maintaining high standards of sustainable forest management while minimizing disturbance to protected species and reducing damage to their habitats. HaRPPS structures, simplifies and delivers complex information on the protection of existing species and their habitats and in addition it offers opportunities where careful habitat management might provide potential for colonising species. The system takes information about the type of woodland to be managed and where it is located, and shows the manager the most likely Priority Species (designated under the UK Biodiversity Action Plan) and Protected Species (EPS) that may occur in the area. The DSS provides guidance on how to manage to prevent disturbance, when to carry out the management, and who to contact to get authority (in the case of EPS). Autecological information on each species provides a summary of the signs to look for to confirm presence in a woodland. The application of HaRPPS is for operational management, as the DSS recommends operations (type, degree, and timing).

The system relies on a knowledge-base that develops linkage between the attributes in different feature groups from a systematic review of literature and other knowledge, e.g. the experiences and expert opinion of practitioners within forest management. Figure 2 identifies how the data quality and a citation table operate as core features within the system. These tables offer the transparency required when mixing evidence and experience-based information presented to a user or reviewer of the database. The data quality table provides a means of classifying the type and quality of information used in the database. Information is tagged in the acquisition process to identify the source and its quality. Information gained from the results of scientific research published in peer reviewed papers and books are given a classification value of 5, whereas observations from rangers and managers are given a classification value of 1. Intermediate sources are allocated values 2, 3 and 4. This allows the reliability and some of the uncertainty associated with the information to be considered in using the system to help in habitat management planning.

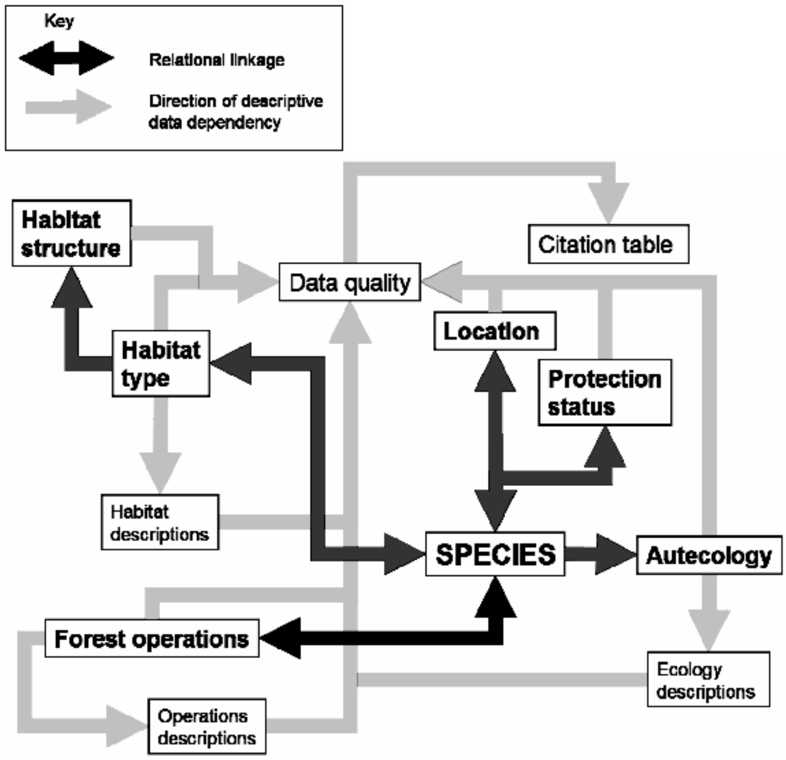

Figure 2. Information flow model – linkages between species and associated factors within HaRPPS.

HaRPPS not only provides information on the priority woodland species which the FC has a legal obligation or a duty of care to protect. The novel and powerful aspect of using HaRPPS comes from the inclusion of information relating those species to their habitats, distribution, and sensitivity to forest operations, as well as the implication of this to their continued viability. The database is structured to allow queries to be constructed from knowledge of any one or more of these factors and provide information on any of the others. Existing information on the autecology of species is dispersed throughout the literature in scientific papers, books, magazines and specialist web sites. The data acquisition process searches the literature and selects information that is relevant and reliable. The key data requirements of the acquisition process, by a team of experienced ecologists, cascade naturally from the pre-determined knowledge-base structure. Although the relevance of information is often based on the judgment of the ecologist undertaking the data search, the acquisition process always sources information to supply the same suite of facts for each species.

For many species, little is known on aspects of their ecology or their response to interactions with habitat or operations. In this case HaRPPS is dependent upon the experience of wildlife rangers, land managers and ecologists for information, again with the proviso that all information is classified in terms of quality and contains the source reference. The approach used in HaRPPS, to grade and reference all information, allows multi-sourced data to be held on species, and presented in a transparent form to users. This contrasts with a purely evidence-based approach extracted by a systematic review process (Pullin and Knight 2001; Pullin and Knight 2003; Stewart et al. 2005) initially developed within the field of medicine. Evidence-based knowledge is rigorously tested in review, and so provides a robust knowledge-base. However, the acquisition process would take time and considerable resources to complete for the 130 species and their interaction with forest operations, included within HaRPPS. It is important that the systematic review continues, but in the meantime HaRPPS provides qualified best evidence, and a system of identifying where both the research and review effort might be focused

12.3.8 Problem type 8 – Hylobius pine weevil

Following extensive research into the autecology of the weevil and the impacts of forest management on populations and resulting damage to trees (Heritage and Moore 2001; Moore 2004), the Hylobius Management Support System (HMSS) was developed to help forest practitioners manage restock sites in a way that might reduce the damage to newly planted trees.

The HMSS was developed using classical statistical approaches to analyse data from empirical research. HMSS is a stand-based tool, but the impact of weevil damage is highly dependent on interaction with neighbouring stands. The HMSS tool is deployed as a web-based application. It requires the user to provide basic site information, details of the stand to be managed and the local costs of different operations associated with ground preparation and restocking. HMSS designs an insect monitoring protocol for the user, and trained forest district staff or other trained contractors undertake the field monitoring to assess the size of the weevil population and its phenological stage. Following each felling or thinning intervention, the size of the weevil population is sampled. This involves placing billet traps (short pieces of freshly cut Sitka spruce) systematically through the stand. The billet traps are inspected each week for one month, and the results are entered into the HMSS.

The HMSS then produces a schedule of robust, cost-efficient measures to suppress weevil damage. The recommendations consider the relative costs of operations, including beating-up (replacing plants which fail to establish) in the form of a cost-benefit analysis. Most important of all is the analysis of the field monitoring to establish the extent of a resident population of weevil. This information is vitally important in understanding damage level projections, the management option of the length of the fallow period prior to replanting with trees and the extent and scale of remedial operations necessary to reduce damage or replace damaged trees.
The system also estimates the cost of the restocking operations including the treatment of plants with nematodes, the size of the plants, cultivation type, and the stocking density required.

12.3.9 Problem type 9 – wind damage

ForestGALES was developed (Gardiner and Quine 2000; Quine 2000) to replace an earlier wind-throw hazard classification (Miller 1985) and bring forest management and interventions into a system that considers wind risk management. The DSS calculates the probability of average trees being damaged within a stand, meaning by implication that the stand as a whole will be substantially damaged by wind-throw or stem breakage, rather than stating a precise height at which damage will occur as in the WHC. Probabilistic predictions are more realistic than precise heights since the occurrence of damaging winds varies from year to year, which has a powerful influence on the occurrence and spread of damage. The risk of damage is extremely dependent on the windiness of the site, and ForestGALES is able to discriminate several levels of risk for trees in the same wind-throw hazard class.

ForestGALES uses a set of mathematical models which describe storms and their impacts on trees from field experiments, past data sources, and wind tunnel research findings. ForestGALES is based upon a better understanding of forest climatology and wind-throw, and explicitly links the wind profile and mechanical forces exerted across the forest stand as a function of tree characteristics. The system estimates the threshold wind speeds that are predicted to overturn and break stems within the canopy, based on a function of tree height, diameter, current spacing, soil type, cultivation, drainage and choice of species (Dunham et al. 2000; Gardiner and Quine 2000; Stacey et al. 1994). The extreme wind climate of the site is described in terms of the extreme value (Weibull) distribution, and this allows the return period probabilities to be calculated and used to assess the risk of damage to a stand through overturning or stem breakage as the stand grows through time, based on outputs from a yield model (Edwards and Christie 1981).

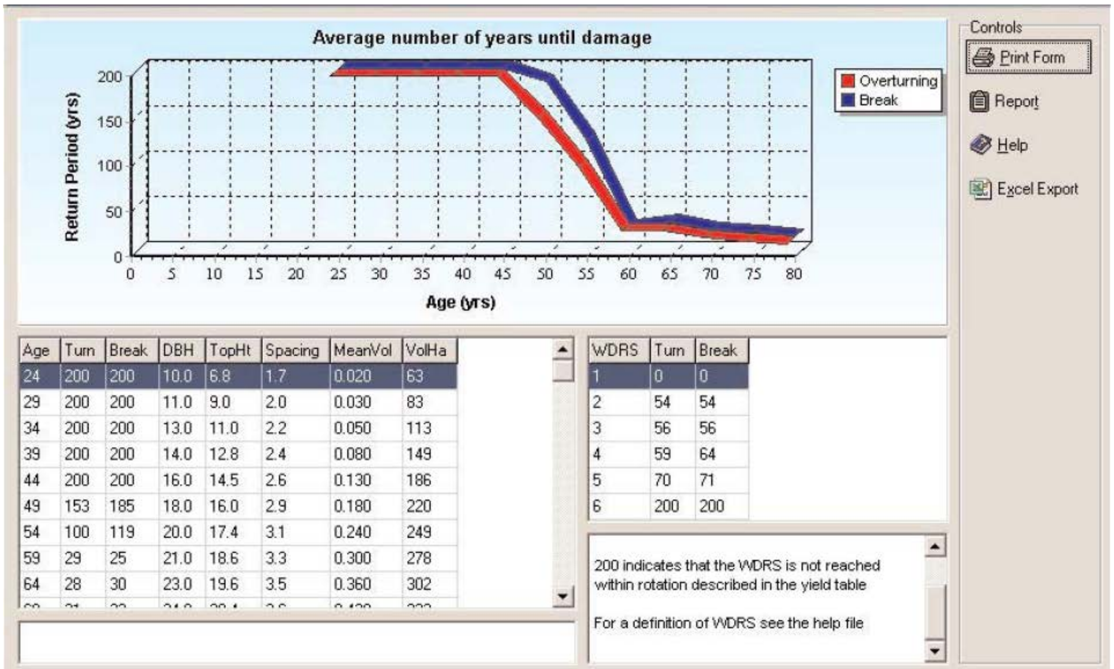

Figure 3. ForestGALES results of an analysis of the probability of damage to a single stand through time.

The probability of the critical windspeed occurring at a particular site is estimated by the DAMS (Detailed Aspect Method of Scoring) index (Quine and White 1994). DAMS is a function of elevation, topographic exposure, aspect, funnelling effects, modified through wind zone classes across Britain (Bell et al. 1995). DAMS is related to parameters of the extreme value distribution in order to link the mean and strong wind climatologies (Quine 2000) to topographic position.

The program estimates the annual probability of damage at different time steps. The temporal dimension of the model is very important for the estimation of risk during the life of the crop and for testing alternate silvicultural practices that may affect the stability of a crop. Initial validation of the model with data from wind tunnels and field experiments (Gardiner et al. 2000) has shown how sensitive the model is to silvicultural that alters the height-spacing ratios, drainage, stem taper and distance to new edges, representing changing stand conditions. Spatial functionality provides forest managers with an excellent tool for decision-making at the forest landscape scale. It allows a visual analysis of the implications of silvicultural strategies in terms of wind risk such as thinning, retentions, design of felling coupes, new forest roads or the effect of felling neighbouring stands resulting in edge effects.

To apply the DSS at the forest level, forest planners run a spatial analysis of the sub-compartment database in ForestGALES. ForestGALES then processes the sub-compartment polygons in batch mode within ForestGALES. This analysis assesses the impact of exposing the forest edge by felling neighbouring polygons, using the soil type, drainage type, stand age, spacing and species composition of the stand as parameters of the aerodynamic and anchorage models within ForestGALES. The planners can then use the output to design new felling coupes with green edges (more wind-firm) over areas of the design plan area that are most at risk.

12.4 Discussion and conclusions

Forestry sector decision support tools have been developed in Britain and the UK over many years in the form of guidance published as hard copy. This system continues in the form of guidelines which provide the rules by which the UK Forestry Standard is maintained in order to deliver sustainable forest management standards acceptable to the Forestry Stewardship Council. However more recently, computer-based decision support system developments beginning in 2000 and 2001 with the publication of ForestGALES and Ecological Site Classification, respectively, have made some impacts on UK forestry, although their adoption has by no means been consistent across the forest sector, or within the Forestry Commission itself. Management of the PFE has followed a trend towards the incorporation of the forest inventory and forest design planning roles within the spatial system Forester GIS, released in 2001. However, the adoption of other DSS has been less uniform. A scoping study (Stewart et al. 2010) exploring the uptake of DSS in the Forestry Sector in Great Britain suggests a number of reasons for this. These are summarised below.

The adoption of DSS has met with considerable cultural resistance among some potential users. Their attempted delivery has highlighted that a lack of trust exists between many foresters and scientists and there is also a sense that DSS may challenge values that underpin the practice of decision-making, impose solutions, suppress creativity, or threaten professional judgement and site-specific ‘real world’ knowledge and experience. For some users, DSS appear to provide misleadingly accurate results, stripped of uncertainty, and for others, they do not provide enough certainty and their inconclusiveness and lack of absolutes diminishes their value.

It is therefore clear that there is a need for improved communication between developers and other key stakeholders on how DSS fit into decision-making processes, and this is arguably more important than detailed discussions around the science that underpins models. There is also a need for discussion to clarify roles and responsibilities regarding DSS delivery, a role that developers may not feel comfortable with. The role of 'champions' may be important in this context and getting support and 'buy-in' from influential stakeholders at an early stage may prove key.

An issue affecting uptake of DSS within the public sector in the Great Britain has been in relation to their lack of integration into corporate IT systems used across the Forestry Commission. This problem has been, in part, caused by a lack of communication between developers and those responsible for the corporate systems at the beginning of DSS development, which has resulted in software incompatibility issues. However, there are also issues around a lack of expertise within the personnel responsible for corporate systems to enable them to be able to support the provision of many DSS to their customer base on a daily basis. There has also been a degree of disagreement and uncertainty over whether all forestry DSS should be incorporated into Forester GIS, which enjoys universal use within the public forest sector but is not widely used in the private sphere. Very recently, since 2010, work to incorporate ESC into Forester GIS has been initiated, and we can report that the new Forester GIS system is being tested. The impetus comes from forest managers keen to use a wider tree species selection for climate change adaptation, and DSS tools to help identify suitable species.

At the end of the day, uptake of DSS depends largely upon the extent to which they satisfy a business need. User groups can help ensure DSS are developed to meet customer needs, but the participants in such groups need to be able to communicate effectively with scientists, and the groups must have a stable composition over the course of DSS development. User group membership also needs to reflect the full range of users and stakeholders, but experience in Britain demonstrates that this is sometimes hindered by a lack of appreciation of the exact application of the finished tool and who it might be used by. Use of DSS, for example by forest planners, may affect operations on the ground in unforeseen ways. Another concern is that volume testing and feedback mechanisms from users to developers have often not been in place which has impacted negatively upon the usefulness of the DSS delivered. Better delivery strategies may help the industry absorb new and improved DSS, including attention to training, which needs to be sufficiently long-term to address problems with staff turnover and loss of expertise among intended users. A new approach using Participatory Action research (Patiño and Gauthier 2009a; Patiño and Gauthier 2009b) is being tested in the UK to develop, with end users and forest policy representatives, relevant, understandable and easy to use vulnerability assessment tools. It is hoped that this will have more impact in the intended user community.

Some have suggested that making the use of specific DSS compulsory (such as by making their use a requirement of certification) is the only way that uptake can be guaranteed. However, there are risks that this would lead to inappropriate use. The case for compulsion needs to be accepted by users for it to work and ultimately, uptake depends on the ability of a DSS to meet demands. Indeed, the use of a DSS is only likely to be made compulsory (and even if it is made compulsory, is only likely to be used) if it is perceived on several levels to respond effectively to a business need.

12.4.1 Conclusions

There is no doubt that development of DSS for a range of problem types in the British forestry sector have seen marked progress over the last decade. The methods and models used within them, and the processes through which they are developed and delivered are growing in sophistication. However, their impact and use remains limited and their potential unfulfilled, although this is changing rapidly in the case of ESC.

It is likely, that the value of DSS to the forest industry in the UK will increase in the coming years, particularly as the need for evidence-based policy grows and the projected impacts of climate change, the uncertainty that it brings, poses forest managers with new challenges for adaptation. Indeed, the potential future impact of climate change is becoming a key problem for foresters in Britain (as elsewhere) to tackle, and this problem has by no means been fully addressed yet by existing DSS. There is a growing perception that forests will need to play a critical role in climate change mitigation and adaptation (Lawrence and Stewart 2010) and DSS could provide useful assistance in ensuring this role if fulfilled successfully if they can incorporate an acceptance of uncertainty and integrate forest management models with climate change models (Ogden and Innes 2007).

However, as the discussion above suggests, unless the identified issues, barriers and challenges to the uptake of forestry DSS in the UK are addressed, many new and existing DSS may never be widely used and may never fulfil their potential in terms of the added value they could contribute to forest planning and management.

Fundamentally, as we have learned, the quality and quantity of stakeholder engagement and participation during DSS development must be improved. In the future, it is therefore suggested that there is a need for an increased focus on the process of development, over and above a focus on the product, and for developers to work collaboratively with potential end-users to identify and understand their needs and to build trust and credibility for the DSS produced (McIntosh et al. 2009).

References

Beckingham, J.D. and Archibald, J.H. 1996. Field Guide to Ecosites of Northern Alberta. Special Report 5, Canadian Forest Service. University of British Columbia, Canada.

Bell, P.D., Quine, C.P. and Wright, J.A. 1995. The use of digital terrain models to calculate windiness scores for the windthrow hazard classification. Scottish Forestry 49 (4): 217-225.

Broadmeadow, M. and Ray, D. 2005. Climate change and British Woodland. Information Note 69. Forestry Commission, Edinburgh, Scotland.

Broadmeadow, M., Ray, D. and Samuel, C., 2005. Climate change and the future for broadleaved tree species in Britain. Forestry 78 (2): 145-167.

Bryden, D. 2003. Quality of Wildlife Tourism Survey. Highlands and Islands Enterprise, Scotland.

Clare, J. and Ray, D. 2001. A Spatial Model of Ecological Site Classification for forest management in Britain. In: Konecny, M. (ed.). Proceedings of the 4th AGILE Conference on Geographic Information Science. Brno, April 19-21 2001. Pp. 93-111.

Dunham, R., Gardiner, B.A., Quine, C.P. and Suarez, J. 2000. ForestGALES: A PC-based wind risk model for British Forests - User's Guide. Forestry Commission, Edinburgh, Scotland.

Edwards, P.N. and Christie, J.M. 1981. Yield models for forest management. Forestry Commission Booklet 48. Forestry Commission, Edinburgh, Scotland.
FCE, 2007. A strategy for England's Trees, Woods and Forests. Defra - Department for Environment Food and Rural Affairs, London, England. Pp. 43.
FCS, 2006. The Scottish Forestry Strategy. Forestry Commission Scotland, Edinburgh, Scotland.
FCS, 2009. Climate Change Action Plan 2009-2011. Forestry Commission Scotland, Edinburgh, Scotland. Pp. 52.
FCW, 2009. Woodlands for Wales - The Welsh Assembly Government's Strategy for Woodlands and Trees. Forestry Commission Wales, Cardiff. Pp. 62.
Forestry Commission, 2011. Forestry Statistics 2011. Forestry Commission, Edinburgh, Scotland. http://www.forestry.gov.uk/forestry/infd-7aqdgc
Gardiner, B.A., Peltola, H. and Kellomäki, S. 2000. Comparison of two models for predicting the critical wind speeds required to damage coniferous trees. Ecological Modelling 129: 1-23.
Gardiner, B.A. and Quine, C.P. 2000. Management of forests to reduce the risk of abiotic damage - a review with particular reference to the effects of strong winds. Forest Ecology and Management 135: 261-277.
Heritage, S. and Moore, R. 2001. The assessment of site characteristics as part of a management strategy to reduce damage by *Hylobius*. Information Note 38, Forestry Commission, Edinburgh, Scotland.
Klinka, K., Krajina, V.J., Ceska, A. and Scagel, A.M. 1989. Indicator plants of coastal British Columbia. UBC Press, Vancouver, Canada.
Krajina, V.J. 1969. Ecology of forest trees in British Columbia. In: Krajina V.J. (ed.). Ecology of Western North America. University of British Columbia Department of Botany. pp. 1-146.
Lawrence, A. and Stewart, A. 2010. Sustainable forestry decisions: on the interface between technology and participation. Mathematical and Computational Forestry & Natural-Resource Sciences 3 (1): 42-52.
Martin, S. 2003. Wildlife tourism and forests in Scotland. Forest Research, unpublished internal report, Roslin, Scotland.
McIntosh, B.S., Giupponi, C., Voinov, A.A., Smith, C., Matthews, K.B., Monticino, M., Kolkman, M.J., Crossman, N., van Ittersum, M., Haase, D., Haase, A., Mysiak, J., Groot, J.C.J., Sieber, S., Verweij, P., Quinn, N., Waeger, P., Gaber, N., Hepting, D., Scholten, H., Sulis, A., van Delden, H., Gaddis, E. and Assaf, H. 2009. Bridging the gaps between design and use: developing tools to support environmental management and policy. In: Jakeman, A.J., Voinov, A.A., Rizzoli, A.E. and Chen, S.H. (eds.). Environmental Modelling, Software and Decision Support: State of the art and new perspective. Elsevier, Amsterdam, The Netherlands. pp.33-48.
Miller, K.F. 1985. Windthrow Hazard Classification. Leaflet 85. Forestry Commission, Edinburgh, Scotland.
Moffat, A.J., Morison, J.I.L., Nicoll, B. and Bain, V., 2012. Climate Change Risk Assessment for the Forestry Sector, United Kingdom Climate Change Risk Assessment. Defra. UK Government.
Moore, R. 2004. Managing the threat to restocking posed by the large pine weevil (*Hylobius abietis*): the importance of time of felling of spruce stands. Information Note 61. Forestry Commission, Edinburgh, Scotland.

Ogden, A.E. and Innes, J.L. 2007. Incorporating climate change adaptation considerations into forest management planning in boreal forest. International Forestry Review 9 (3): 713-733.
Paterson, D.B. and Mason, W.L. 1999. Cultivation of soils for forestry. Bulletin 119. Forestry Commission, Edinburgh, Scotland.
Patiño, L. and Gauthier, D.A. 2009a. Integrating local perspectives into climate change decision making in rural areas of the Canadian prairies. International Journal of Climate Change Strategies and Management. 1 (2): 179-196.
Patiño, L. and Gauthier, D.A. 2009b. A participatory mapping approach to climate change in the South Saskatchewan River Basin. Prairie Forum, 34 (1).
Perks, M.P., Harrison, A.J. and Bathgate, S.J. 2007. Establishment Management Information System (EMIS): Delivering Good Practice Advice on Tree Establishment in the Uplands of Britain. In: K.M. Reynolds et al. (Eds.). Sustainable Forestry: from monitoring and modelling to knowledge management and policy science. CAB International, Wallingford, England. Pp. 412-424.
Pojar, J., Klinka, K. and Meidinger, D.V. 1987. Biogeoclimatic Ecosystem Classification in British Columbia. Forest Ecology and Management 22: 119-154.
Pullin, A.S. and Knight, T.M. 2001. Effectiveness in Conservation Practice: Pointers from Medicine and Public Health. Conservation Biology 15: 50-54.
Pullin, A.S. and Knight, T.M. 2003. Support for decision making in conservation practice: an evidence-based approach. Journal for Nature Conservation 11: 83-90.
Pyatt, D.G., Ray, D. and Fletcher, J. 2001. An Ecological Site Classification for Forestry in Great Britain. Bulletin 124. Forestry Commission, Edinburgh, Scotland.
Quine, C. 2000. Estimation of mean wind climate and probability of strong winds for wind risk assessment. Forestry 73(3): 247-258.
Quine, C.P. and White, I.M.S. 1994. Using the relationship between rate of tatter and topographic variables to predict site windiness in upland Britain. Forestry 67(3): 245-256.
Rameau, J.C., Mansion, D. and Dume, G. 1993. Flore Forestière Française, 2 Montagnes. Ministère de l'agriculture et de la Forêt, Paris, France.
Ray, D. 2001. Ecological Site Classification Decision Support System V1.7. Forestry Commission, Edinburgh, Scotland.
Ray, D. 2008a. Impacts of climate change on forestry in Wales. Forestry Commission Wales Research Note 301. Aberystwyth, Wales.
Ray, D. 2008b. Impacts of climate change on forests in Scotland – a preliminary synopsis of spatial modelling research. Forestry Commission Research Note 001. Forestry Commission Scotland, Edinburgh, Scotland.
Ray, D. and Broome, A. 2003. Ecological Site Classification: supporting decisions from the stand to the landscape scale, Forest Research Annual Report 2001-2002. The Stationery Office, Edinburgh, Scotland.
Ray, D. and Broome, A.C. 2007. An information retrieval system to support management of Habitats and Rare Priority and Protected Species (HaRPPS) in Britain. In: Reynolds K. et al. (ed.). Sustainable Forestry: from Monitoring and Modelling to Knowledge Management and Policy Science. CAB International, Wallingford, England.
Ray, D., Clare, J. and Purdy, K. 2003. Applying an Ecological Site Classification to woodland design at the landscape scale. In: Humphrey, A.N.J., Latham, J., Gray, H., Kirby, K., Poulsom, E. and Quine, C. (eds.). The Restoration of Wooded Landscapes. Forestry Commission, Edinburgh, Scotland.

Rodwell, J.S. 1991. British Plant Communities, 1: Woodlands and scrub. Cambridge University Press, Cambridge, England.
Stacey, G.R., Belcher, R.E., Wood, C.J. and Gardiner, B.A. 1994. Wind and wind forces in a model spruce forest. Boundary Layer Meteorology 69: 311-334.
Stewart, A., Lawrence, A. and Edwards, D. 2010. Uptake of decision support systems in the forestry sector in Great Britain: Scoping Report. Forest Research, Edinburgh, Scotland.
Stewart, G.B., Coles, C.F. and Pullin, A.S. 2005. Applying evidence-based practice in conservation management: Lessons from the first systematic review and dissemination projects. Biological Conservation 125: 270-278.

ESC:
ESC website: www.forestresearch.gov.uk/esc
Forest Research Decision Support Portal (registration required) contains ESC Version 2 for climate change: www.eforestry.gov.uk/forestdss/
Ecological Site Classification v1.7 Field Survey Pack (pdf):
www.forestresearch.gov.uk/pdf/escfsp.pdf/$FILE/escfsp.pdf

EMIS:
Forest Research Decision Support Portal (registration required):
www.eforestry.gov.uk/forestdss/

ForestGALES:
ForestGALES website: www.forestresearch.gov.uk/forestgales
Forest Research Decision Support Portal (registration required):
www.eforestry.gov.uk/forestdss/

HaRPPS:
HaRPPS website: www.harpps.org.uk

Hylobius Management Support System:
Forest Research Decision Support Portal (registration required):
www.eforestry.gov.uk/forestdss/

13 Computer-based tools for supporting forest management in Hungary

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13.1 Introduction

Hungarian forestry has several controversial features. Its contribution to GDP is hardly measurable; on the other hand forestry is still considered an important factor in employment. The forest cover is around 20%, as after the plough-land, forested land is the second largest field of cultivation in Hungary. The country can be described by various climatic conditions: yearly precipitation range between 400 and 1000 mm, altitude range 100 m – 1014 m. These two factors result in a wild span of site conditions in Hungarian forestry from semi-arid deserts to cold hills. In term of species, conifers (spruce, scotch pine, black pine) cover only 15% of forest cover and the majority of forests consist of broadleaved trees: mostly beech, oaks and turkey oak. Non-native species such as improved poplars and black locust are also important and generate conflicts with nature protection movements. Another significant factor of Hungarian forestry is that the historically low forest cover has been doubled over the last 50 years, but forests are still considered as a scare resource. Therefore forest management is strictly regulated and supervised by the state. The legal backbone of forestry is regulated by a new forest law which was accepted in 2009. Forest law considers highly nature protection issues and strictly regulates forest management, but still forest managers are attacked frequently due to even the most environmentally friendly forest removals.

The main function of Hungarian forests is wood production, with a special focus on fuel wood, while nature protection and recreation is also important (Stark 2000). The growing stock in 2010 was estimated at about 356 million m^3 solid wood, with an average (referring to the total forest area) of 186 m^3 per ha. The annual increment is estimated at 13.2 million m^3 solid wood, with an average (relative to the total forest area) of 6.8 m^3 per ha. The total harvested wood was 6.8 million m^3, 51% of the total increment. The cutting rate in Hungary has continuously decreased over the past decades.

Approximately half of Hungary’s forest is in state ownership; the other half is in private ownership, while other forms (churches, communities, etc.) are not significant. Private ownership emerged after the political changes of 1989-1990, when land privatisation started (Gál and Mészáros 1999). Private forests are affected by extremely fragmented ownership due to the problems and difficulties of ownership transformation after the political changes in 1990. The restitution process started in 1992 and finished around 1998. The process can be described mostly with the use of compensation vouchers and use of auctions where there was a great possibility to formulate joint ownership (Jáger 2008). While there are complaints about fragmented ownership status practically in every country, the Hungarian situation is still different. It is common that more than 200 owners share a single forest compartment, and smaller owners have around a few square meters of forest area only.

The economic features of forests are much more important than in Western European countries as the wood prices are almost the same in Europe due to the open markets, but the income level is significantly lower in Eastern Europe. As a comparison, it can be stated that the net minimum wage in Hungary is around 260 euros per month. It means that the economic pressure on forests is much higher than in Western Europe (Jáger 2000).

One of the most important conflicts of the Hungarian forest sector is that there are nature protection movements to restrict the use of black locust. Black locust *(Robinia pseudo-acacia)* is not native in Hungary, as it was introduced approximately 400 years ago. It has adapted to natural conditions very well and today it is accepted by the public as the 'most Hungarian tree' and widely used in forestry as it covers 20% of the total forested area. The above-described forest policy problems also lead to difficulties in forest management planning.

It is an additional problem that there is a lack of clear management policy of Natura 2000 sites. Natura 2000 forests are supervised by the state forest administration only. However the forest authority treats these forests as protected ones just to avoid any conflicts with the EU administration. Approximately 40% of forests are protected by law which is regarded as a very high percentage by most foresters (Gálos et al. 2007).

Forest management planning is highly developed and centralised in Hungary. The reasons are mostly historical. Forest management regulations have a long tradition in Central Europe. During the medieval ages, mining, especially gold mining was a core part of the economy. As the inner structure of mines demanded a huge amount of wood, a shortage of available timber forced the kings to regulate forest management as early as the 16th century. Countries like Austria, Czech Republic, Slovakia, Hungary, Slovenia, Croatia (the previous Austrian Empire) have a similar history, background and knowledge about forest management.

In Hungary, the forest law as early as 1879 contained a detailed description and regulation of the process of forest management planning. Later on, when Hungary became a communist state after the second world war, a so called 'planned economy' was established similar to other countries in the region under Russian influence. This meant that planning became the core concept of the economy, while factories and land were nationalised. The state covered all aspects of economic production with five-year plans. These plans were hardly successful apart from in forestry. Due to the long harvest periods, the forest management planning process can easily provide good short- and long-term predictions if the actual situation is known. Because of this kind of successful forestry planning, the communist state supported further improvement of centralised management planning, and this system has been kept after the political changes in 1989. As a result, a very detailed and accurate system has been applied in the Hungarian forest sector. The key features of the actual Hungarian forest management planning system are the following:

- All forest compartments are subject to forest management planning, irrespective of size, ownership, tree species or purpose.
- All forests are visited, inspected and measured by the state forest service every 10 years to measure and describe the actual forest status and decide about:
    - the interventions which are necessary in the next 10 years;
    - the time of final harvest and regeneration method;

    - the future stand type (after regeneration).
- Description of the forest means determination of all the features of the forest as height, diameter, volume, density, tree species composition, growing stock, annual growing rate, average growing rate, etc.
- The forest management plan is produced by the state forest service for the owner/manager of the forest for a nominal fee. These plans are provided at stand level, forest unit level and district level as:
  a) the 10-year district forest plan (district forest plan);
  b) the 10-year forestry operational plan (operational plan);
  c) the annual forestry plan (forestry plan).
- Aggregate data is collected and maintained centrally as the Forestry Database. This database was established in 1976 and now contains 35 years of key features of all Hungarian forests.
- In the first decades, the participation process was very limited, even the forest managers had no right to participate in the planning. Today forest law allows participation for a broad circle and the owner, NGOs, local councils, nature protection groups can affect the planning process.

As a result of this process, the so-called National Forest Database is the most important tool of DSS in Hungary. Publicity and participation is also regulated: the National forest Database is open for public access, but the forest service charges a fee for data access. Access to personal information is restricted for the forest owner only. During the planning process, all the stakeholders are encouraged to participate both at the starting and closing meeting before and after the actual planning process when forest owners, and other relevant parties are invited to express their ideas about the next 10-year forest plan.

The database is also used for regional planning, when estimation is given about the volumes to be harvested and tree species composition. Additionally, country-level information is provided every five years about the Hungarian forest sector and forest stands. This information is also available on the internet.

The objective of this report is to describe the actual situation and trends of use of decision support systems in forest management planning in Hungary. While the actual situation can be described with the dominance of National Forest Database and the related centralised, computerised forest management planning, there was an attempt to demonstrate some other DSS related to forest management.

It must be emphasised that general planning problems are addressed and solved by the National Forestry Database. Due to the long history of standardised planning, most of the problems which were common during the establishment of the system have been solved by now. On the other hand, due to the highly standardised solutions, the system does not support completely new forest management methods which were not applied as a practice during the last decades. Single tree selection systems can be mentioned as a considerable example of this problem. It must be kept in mind that some problems which are typical all over in Europe, simply do not exist in this highly centralised planning context.

Significant forest management problems are presented in Table 1. Problems are classified according to the FORSYS dimensions, considering spatial, temporal features and objectives. A core part of the research was to determine DSS systems which address solutions or better understanding of these problems. A detailed description of the problems, and related tools, programs are presented in section 3.

Table 1. Classification of forest management planning problems in Hungary according to the FORSYS dimensions

ID	Spatial scale	Temporal scale	Spatial context	Objectives	Parties involved	Goods and services
1	regional/ national	strategic	Non-spatial	multiple	single decision-maker	all
2	regional/ national	tactical	non-spatial	single objective	single decision-maker	market wood products market non-wood products
3	regional/ national	tactical	non-spatial	multiple objective	more than one decision-maker	market wood products market non-wood products market services
4	regional/ national	strategic	non-spatial	single objective	more than one decision-maker	market wood products
5	regional/ national	strategic	non-spatial	multiple objective	more than one decision-maker	all
6	regional/ national	tactical	non-spatial	single objective	single decision-maker	market wood products
7	forest level	tactical	spatial	single objective	single decision-maker	market wood products market non-wood products market services
8	forest level	operational	spatial	multiple objective	more than one decision-maker	all
9	forest level	strategic	spatial	multiple objective	more than one decision-maker	market wood products
10	forest level	tactical	non-spatial	single objective	single decision-maker	market wood products
11	forest level	tactical	spatial	multiple objective	more than one decision-maker	all
12	forest level	operational	spatial	single objective	single decision-maker	all
13	stand level	strategic	spatial	single objective	more than one decision-maker	market wood products market non-wood products
14	stand level	strategic	non-spatial	multiple objective	single decision-maker	all
15	stand level	operational	spatial	single objective	single decision-maker	market wood products
16	stand level	operational	non-spatial	single objective	single decision-maker	all

13.2 Materials and methods

For a better understanding of conflict areas and constraints and related computer-aided tools, an extensive investigation was carried out within the field of forest management planning. The following methods were used to collect the major conflicting issues:

- overview of literature available;
- evaluation of National Forest Database and related guidelines;
- stakeholder group analysis;
- internet search;
- the opinion of experts from forestry higher education and the ministry of rural development (department of forestry and natural resources);
- legal cases were also analysed and state regulations were evaluated from the point of conflict management.

As there is a long history of computer-aided forest management in Hungary, most of the information is widely available. Due to the recent changes in both forest legislation and institutional framework, the actual status of forest legislation, including related ministerial decrees, were evaluated in detail.

Another comprehensive source of information was the Hungarian National Forest Program. This program covers most of the important fields of forest policy, and is used to formulate forest policy, and therefore it is a major tool to formulate forest policy decisions. The main document of forest policy is National Forest Program, which was adopted by governmental decree 1110/2004. This program covers the timeframe 2004-2015 and includes 10 subchapters as follows:

1. Development of state forestry
2. Development of private forestry
3. Rural development, afforestation
4. Nature protection
5. Forest protection
6. Hunting and game management
7. Wood and biomass utilisation
8. Forest administration and supervision
9. Human-forestry interactions

13.3 Results

Forest management in general has several problems in Hungary. Most authors highlight the following ones:

- unsettled management rights and fragmented ownership in private forestry;
- high pressure from nature protection movements;
- recent transformation of complete forest legislation;
- divided state forest management rights in state forestry.

Most of these problems are related to forest policy and do not arise from the lack of information. Therefore the solution in these cases will not arise from any better developed decision support systems. In this chapter mostly those problems are addressed where integrated data management and computer-aided tools are available to improve the current status of forest management. Problem type analyses are based on the various dimensions and factors focusing on time, spatial context and decision-making.

Table 2. Computerized tools/DSS, KM techniques and participatory planning methods used/developed for each forest planning problem type

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning
1	National forestry database (NFD)	simple quantitative model, database not fixed unit approach	mapping is included	free access: http://erdoterkep.mgszh.gov.hu/
8	National Game Inventory	multiple database (management units, plans, execution)	master-apprentice connection with NFD	limited access
9	E-LAP MEPAR	data analysis system digital spatial database	multiple layers GIS information	access for landowners
2	EIR	complex accounting and planning software transport cost harvest optimalization	competence management	-
11	EUIR EPGM	spatial planning or road network statistical evaluation of future heuristic costs		- -
3, 13	TAKARNET MATI	digital access to land registry system integrated database	complex information system for private owners personalised help cost evaluation	limited access -
14	GAK2005 ERDOTELE TAMOP 4.2.1.B	simulation model	best practice transfer knowledge management	- -
7	EVH	future predictions and trend calculations	spatial database	-

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning
12	TUZTER	forest fire simulator heuristic modelling	digital mapping biomass models, road network	participation of local communities, fire fighters
4	CASMOFOR	database, linear programming	generalised models of forest stands	free downloadable version for public access
6, 5, 16	SOSKLIMA	climatic models, strategic analysis		-
	BUKK	simulation of multiple scenarios	decision maps	-
	D-e-METER DIGITERRA	land evaluation methods universal digital mapping software	land value database	- commercial software
15, 10	JOVOKEP	yield planning, linear programming		educational software
	F-LAP	harvest registry and approval system	interactive access	for all forest managers

Due to the given economic conditions, profitability and economic performance of state forests (problem 2) and private forests (problem 3) is one of the most commonly addressed problems of decision support systems in Hungary. State forests are covered by 22 companies, while in private forestry the average unit size is around 5 ha, therefore obviously different solutions tools are required in the state and private sector.

EIR (Forestry Geographic Information System) is a complex administration program of state forest companies. It covers all the aspects of forest activities of the companies (Lett et al. 2008). Data is originated from State Forest Database and state forest companies use EIR to provide data for the forest authority. The GIS system and maps are integrated to help spatial planning. EIR can be described as the counterpart of the National Forestry Database: data exchange between the forest service and forest companies is executed within this framework.

The core concept of EIR is a harmonised accountancy/bookkeeping system towards efficient supervision of management of state forest companies, while there are suggestions that one big company would be more efficient to cover the whole state forests. Modules of EIR offer possibilities for spatial and time planning of harvest/transportation.

In the case of private forests, fragmented ownership is considered the greatest barrier to improvement of profitability. Problems 3 and 13 address a strategic question of fragmented private land ownership. The legal basis of land ownership is the so called land registry system as the primary source of land ownership, land status and land type. Heritage models proved that the number of forest owners is doubled in every 10 years (Jáger 2008a). Huge efforts were made to increase participation and raise the interest of small private owners. The TAKARNET program was developed to provide internet access to the land registry database in order to help further land ownership improvements. Most of the related programs and efforts focus on regional or forest-level solutions (László and Nagy 2010).

Schiberna proved that improvement of economic performance would improve the land market and therefore land ownership (Schiberna 2008b). The private forestry accountancy network (MATI) was established in 2005. General and country-wide solutions are still missing, and most probably the situation will remain unsolved in the next decade (Jáger 2010).

Problem 5 is related to the growing importance of global warming risks. In Hungary several research groups were about to determine or predict future changes (Matyas 2006). The University of West Hungary has launched a project to determine the future of beech stands at the time horizon of 2050 (Berki 2007). This is a good example of data access in Hungarian forestry research that in stead of sampling, climatic, spatial and forestry data of all beech stands (approximately 120,000 ha) were included in the model. Szép (2010) presented a computer program especially designed to determine the financial possibilities of the state forest company, Szombathely Erdészeti Zrt.

In relation to global warming, the carbon accumulation of Hungarian forests has been investigated in problem 4. CASMOFOR, a computer program was developed by a Hungarian research team (Somogyi 2007). The program is intended for use by independent forest owners and demonstrates the carbon accumulation especially in afforestations.

Problem 6 and 10 is in the field of short rotation plantation, which is a rapidly growing sector at the moment and also in the future. Short rotation plantations are not considered forests in Hungary, therefore these stands are not subject of forest management planning, but still some issues are common with plantation type forests (e.g. poplar plantations) (Szabo et al. 2010). Therefore it is important to investigate the best suited plant material for different areas to find sustainable methods for planting and harvesting and improve machinery development (Horvath et al. 2010). Barkoczy developed a computing model for better use of existing biomass plantations (Barkoczy and Ivelics 2008). This model can be used to determine the optimal location for new plantations, considering the harvest and transport costs. Projections for optimal harvest time estimation are also included.

Problem 8 addresses the conflicts related to the increased game damage in reforestations. In Hungary both game and game damage level has been permanently increased in the recent decades both within forestry and agricultural areas (Stark et al. 2010). In some regions, it is not possible to carry out forest regeneration without fences. Hunting rights belongs to owners, but the minimum size of hunting area is 3,000 ha. Land owners therefore are obliged to rent out hunting rights for hunting clubs in 10-year periods. Hunting clubs often refuse to recover the game damages and land owners are obliged to pursue long-term legal litigation processes. As the conflict becomes increasingly important, several efforts are made to find balanced solutions between contrasting interests. Following the example of the

National Forestry Database, a National Game Inventory was also established in 1996, and serves as a general source of game-related information.

Farago introduced spatial planning and GIS-based tools to determine the risk levels of game damage as a part of the TAMOP research program. GIS-based programs are also used by the hunting authority to determine the borders of hunting areas. Several computerised solutions exist to help the estimation of game damages (Náhlik et al. 2009).

Similar risk assessment is addressed in problem 12, where interactions of forest fires and forest management planning are described. Although Hungary is moderately affected by forest fires, due to the dense population level forest fires potentially can cause severe damages. Several authors pointed out the importance of proper forest management in order to reduce fire risks (Debreczeni et al. 2006). A computerised regional fire prevention system was set up in 2006 to prove the efficiency of improved fire prevention (Nagy 2004). The model includes digitalised land surface, biomass models, road network and digital mapping. Based on the collected data, an estimation can be given to determine the occurrence and dispersion of future fires. The new forest law also specifies the increasing importance of fire prevention but the transformation of large conifer monocultures in the lowlands will take several decades. A further increase in fire risk due to global warming was discussed several times.

Problem 7 proves that there has been a growing concern about biotic and abiotic damages in Hungarian forests from the 1990s (Standovar and Somogyi 1998). Computer programs were applied to determine gradation, dispersal and damage level of the gypsy moth *(Limantria dispar)* and other species. As a universal tool of measurement of forest health, the EVH system has been maintained by the forest service. The National Forest Health Database is also maintained to collect and store data in relation to forest health. One regional example is the TAEG state forest company which was seriously affected by gradation of bark beetle *(Ips typographus)* between 1995-1998 (Lakatos 2011). Schiberna calculated various scenarios to determine and reduce foreseen economic losses due to the damage and salvage harvests (Schiberna 2008b). The program proved that state forestry puts a higher emphasis on the reduction of reforestation (short-term) costs than value of the next stands (long-term return).

Management planning in a single tree selection system is addressed in problem 14. In the last centuries, the general concept of forest management was based on clear cuts and shelterwood systems, both defined areas to harvest in a specific time (e.g. next 10 years). New movements put an emphasis towards permanent forest cover and single tree selection systems. The new forest law of 2009 expresses an obligation on state forest companies to manage 20% of their area in such a method in the next 10-year cycle. On the other hand, from the point of forest management it is difficult to describe and plan these stands as all the existing methods are based in clear cuts and shelterwood systems. New methods must be developed: how to describe single tree harvest forests, how to measure the volume, the increment and the level removals. It is an additional problem that single tree selection system will be transformed from existing even aged forest and the planning, regulation and supervision of the transformation process will be even more complicated. GAK2005 ERDOTELE is the first program developed by the University of West Hungary to provide standardised solutions and management rules in case of permanent forest cover (Schiberna 2008b).

The complexity and accuracy of planning and determination of the future level of afforestation is addressed in problem 9. Long-term plans indicate 25% forest cover compared to the actual level of 20%, but afforestation activities have been reduced significantly due to lower subsidies and increasing agricultural prices (Schiberna 2008a). This is a good example of the difficulties of long-term planning when circumstances change rapidly. In relation to long-term planning there are examples of both bottom-up and top-bottom approaches. In the DELALFOLD program as a part of regional planning, efforts were made to determine the future use of each agricultural fields (Mészáros et al. 2000). This solution simply cannot accommodate owners' future interests and aims. Newer methods try to determine future afforestations based on the past activities of a specified area using heuristic models and probability estimations (Lett et al. 2007).

The Agricultural Authority maintains MEPAR (Agricultural Land Unit Identification System): an administration system of all arable land. It is not primarily intended for use in forestry, but the agricultural authority is involved in the establishment of new forest, and therefore this system plays a role in the definition of long-term forest cover in Hungary.

Problem 16 focuses on the proper determination of forest value in relation to forest management planning. While there is an increasing interest in this field from private forestry, most of the research activities are focusing on state forest assets (Héjj 2008). The theoretical framework of forest valuation was established more than a century ago, but the first computing algorithm was presented by Mészáros in 1998. While calculation is usually simple and in most cases it is based on the use of simple excel sheets, difficulties emerge from the accurate evaluation of non-timber services and land value (Lett and Schiberna 2010) and (Nagy and Héjj 2011). Puskás presented a calculation method to determine recreational values, based on the well known representation costs and travel costs methods (Puskás 2009).

As transport is a costly part of forest management, in various countries programs are available to optimise transport costs (problem 11). The Hungarian situation is partly different as approximately 50% of the total harvest is utilised as fuel wood, mostly locally. On the other hand, some large power plants were converted partly from coal to wood in the last decade. One example is PANNONPOWER, in Pecs, south-west Hungary. In this power plant the total consumed wood volume is 300,000 m^3 per year and various computer programs were applied to determine optimal transport distances and related costs from forests to the power plant.
Some other computer programs relate to the establishment of the new forestry road network. The Road Planning Department of the University of West Hungary produced a program, EPGM, to determine the optimal solution in various conditions, while the main aim of EUIR is to forecast the maintenance costs of the road network of forest companies.

The determination of optimal harvest time is a crucial question of practically any forest management plans and this method is addressed in problem 15. As the Hungarian system works with legally settled (shortest) harvest periods (e.g. in the case of noble oak, 120 years), computerised tools hardly can be found in the field of optimalization of the harvest period. All the harvest-related data exchange is executed with the program F-LAP.

While the whole concept of forest management planning is based on harvest periods and cut forests, the new forest law introduced the obligation of permanent forest cover in the state forest. This obligation seems difficult to fit into the traditional concept of forest management planning. The JOVOKEP computer program was produced mostly for educational purposes, but it can be used in real life. The core concept of the program is to determine the optimal harvest time in case of several forest compartments - in that way the yield is kept at the same level.

13.4 Discussion and conclusions

As was seen in the first section, the Hungarian forest management planning system is a comprehensive, fully computerized instrument, covering practically all aspects of decision-making, forest management and related issues. Moreover, the Hungarian Forestry Database is used not only for planning the future status of a forest compartment, but all forest-related activities such as commercial, non-commercial thinnings, final harvests, afforestations, etc. are also registered. Therefore the database can be considered as a complex, up-to-date register of Hungarian forests. The results of such highly centralised planning system are the following:

- There is a lack of additional standalone programs and computerized tools dealing with various issues of forest management planning.
- Plenty of data is available of all forest compartments.
- Traditional forest management is more or less a simple execution of forest management plans as major decisions are determined during the planning period. On the other hand, the state forest management planning process is a purely biological planning process based on natural factors, while economic features, income, costs, expenses are not considered.
- Forest management activities are highly harmonised within the whole country irrespective of ownership status or forest unit size.

This paper proved that the actual situation of decision support systems in forest management planning can be described with the dominance of the National Forestry Database. This tool provides the luxury of data access in time (back 40 years) and detail (all the forest sub compartments are included). While the forest authority has an unlimited access for its data, obligatory management planning provides forest managers with the possibility to know all the data of their forest in detail.

The benefits of this system are obvious:

- a country scale inventory can be provided for each year;
- forest regulation is powerful and based on realistic figures;
- it is easy to provide future estimations, yield calculations;
- risks, damages are easy to evaluate.

The shortcomings of the system are also easy to perceive:

- The planning system is very expensive; it can be said that the state spends more on administration than the total economic benefits of forests, as approximately 300 forest engineers are employed by the state as the planning department of the state forest service. There are worries in the forestry sector that state will not finance this system any more, and planning will be a task of the forest manager, and the forest authority will only supervise the planning and execution.
- Accuracy is always a question.
- In the private sector, state planning puts significant restrictions on forest owners.

Additional computer programs were also presented in this paper. Although it was not emphasised, the data of these programs in each case originated from the National Forest Database, acting as a general standard of Hungarian forest management planning.

Practically none of these programs deals with the core part of forest management planning, as it is fully covered by the system organised by the state forest service.

These programs:

- address some technical parts of forest management such as road construction, game protection;
- focus on economic questions as the state forest service is based only on biological features;
- or deal with scientific/research questions such as carbon accumulation.

Most of the programs described are used by researchers. State forestry maintains its activity more or less within business confidence, while private forestry is fragmented and interested in simplest solutions.

Public participation had been always very weak in post-communist countries, but today some significant improvements can be seen in relation to this field, due to the renewal of the Forestry Act in 2009. Hungarian forest law describes in detail the methods of participation in both regional forest management and single unit forest management planning. In general terms, the potential for participation is wide for general public bodies and private persons.
Regional planning is more open to the public. During this process, all the NGOs and private persons are invited through the homepage of the forest authority to express their opinions about forest management. Additional measures are provided in case of protected and Natura 2000 forests where the forest authority puts a special focus on the improvement of natural factors. The participation of land neighbours is based on civil law regulations. Administrative law describes the participation of other authorities like fire protection, agricultural authority, land registry authority and first of all, nature protection. In the case of important forest issues, the forest authority may organise a public hearing in any forestry-related topic.

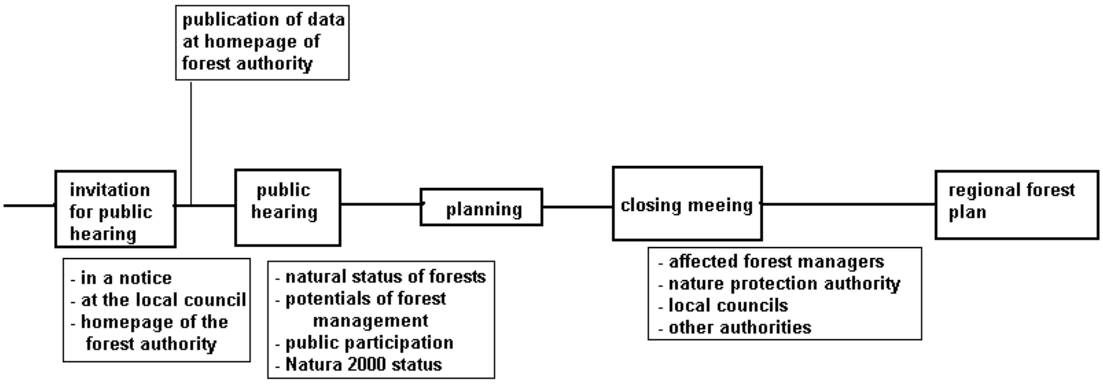

Figure 1. Structure of participation in regional planning

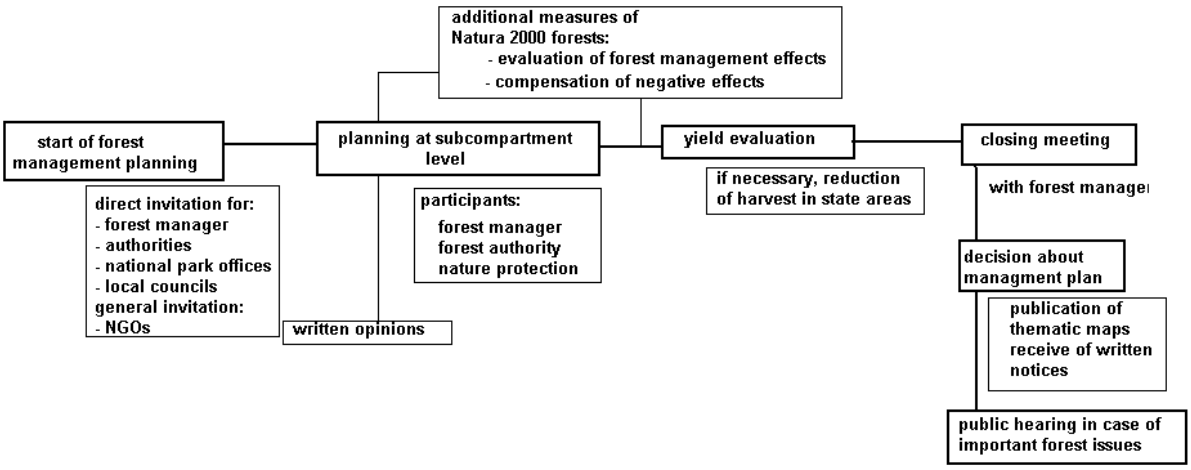

Figure 2. Structure of participation in management planning process

Another direction of forestry DSS improvement is the aim to develop a general forestry DSS. One of the most critical issues is to develop a new application for each new analysis problem by implementing the appropriate mathematical background. The purpose of the research team at the University of West Hungary is to build up a general database where the data from different applications are uniformly stored, and that provides a possibility to perform the analysis process in a single software frame even in case of very different application domains. The basic components of the system are: (1) data integration component, (2) general database structure, (3) data preparation and transformation module, (4) analysis module and (5) presentation module (presentation layer). The relationships of the components are illustrated in Figure 3.

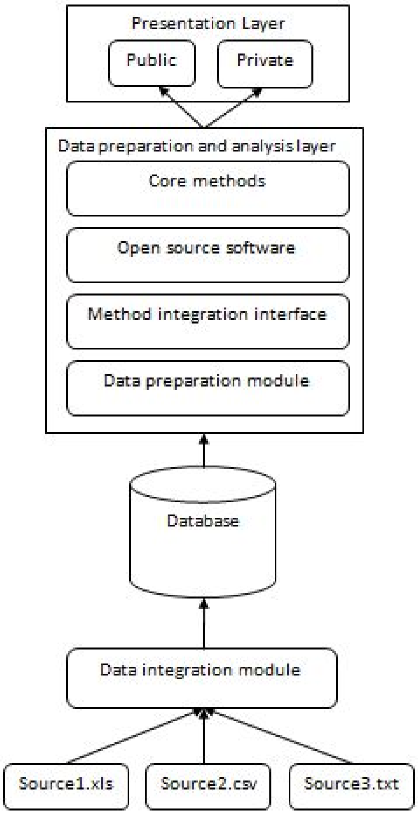

Figure 3. Relationships of the components of a general forestry DSS.

In this framework, a workflow called a 'session' is defined. A session starts from loading data into the relation database and ends with providing and interpreting results. Previous experiences show that forestry data usually stored in Excel files. The formulation of the database is carried out in two steps. The first step is the transformation of Excel data structures to the database conformation, while the second is to upload the data. These two steps are included in the data integration module. In some cases data query procedure (SQL commands) can be complicated; so the framework has a data query component to help the researchers to get the desired data from the database. This module is a graphical form and the corresponding SQL commands are generated in the background. In this view, this SQL translation appears as a black box to the users.

If raw data is analysed, there is little chance to find correlations between variables. Therefore data should be transformed before further examination. The result of the transformation is a matrix, in which rows are data items and columns are the attributes. Pivot operations can be applied to change rows and columns.

This result matrix is the input of the methods. Mathematical, statistical and data mining techniques are also included in this framework. Statistical tests are applied in most cases. It is possible to get methods from other open source analytical frameworks, such as WEKA, which is data mining software mainly and R, which is a statistical program mostly.

Natural sciences methods can calculate only with numbers, they cannot expound the results. Therefore communication with users like forest specialists is a crucial part of proper results. The presentation layer provides results to view and to get feedback of throughputs. The framework is developed in .NET and programmed in C# language. The database type is SQLite, as it contains data in one single file, which can be moved easily. Additionally, there is no need to install complicated database management systems.

The framework is still in the development phase, but the first results could have been proved by investigation of the relationship between tree growth and environmental factors by transformation procedure and correlation (Manninger et al. 2011). The DSS will be tested with further investigation during the development and testing phase.

The paper proved that the importance of DSS in forestry cannot be neglected, but the core part of forest management planning will remain the National Forest Database. The major improvement directions of the Hungarian forest management planning system should be the following:

- The planning should consider economic features and data instead of pure biological planning.
- In stands where wood production is the primary aim of forest management, more freedom should be given for the owner/manager to determine the time of final harvest, etc.
- Efforts should be focused on the better economic performance of state forests, as in comparison with other Middle-European countries, the Hungarian forestry sector represents a very low rate of GDP.
- State intervention is needed to improve the ownership structure of private forests. There are lots of questions related to private forests as the privatisation process in Hungary resulted in an extremely fragmented ownership structure in the field of forestry.
- The flexibility of the management planning system should be improved: a good example is that there is a general rule that grazing is absolutely forbidden. As a result it is impossible to establish agro-forestry methods in Hungarian forests.

References

Barkóczy, Zs., Ivelics, R. 2008. Energetikai célú ültetvények. [Biomass plantations for energy production] NYME –MATI. .Sopron. p. 1-88.

Berki, I., Móricz, N., Rasztovits, E., and Vig, P. 2007. Determination of the drought tolerance limit of beech. In: Mátyás, Cs. and Vig, P. (eds.) Forests and Climate West Hungarian University, Sopron, Vol. V: 229-239.

Debreczeni, P., Held A. C. , Nagy, D. 2006. Implementation of the new Regulation Forest Focus – Forest Fire. in Twinning project.: Hungary- Germany. Mission report Nr 3. AESZ- CFCU, Budapest.

Gál, J. and Mészáros, K. 1999. Hungary. In: Pelkonen, P., Pitkänen, A., Schmidt, P., Oesten, G., Piussi. P. and Rojas, E. (eds.). Forestry in Changing Societies in Europe. p. 155-166.

Gálos B., Lorenz Ph., Jacob D. 2007. Will dry events occur more often in Hungary in the future? Env. Res. Letters doi: 10.1088/1748-9326/2/3/034006

Héjj B. 2008. Erdőérték-számítási irányelvek erdőterületek értékének megállapításához. [Forest evaluation guidelines for proper evaluation in practice] In: I. Mészáros Károly Memorial Publication. NYME EVGI, Sopron: 110-119.

Horváth, S. et al. 2010. Energetic utilization of production areas becoming extreme due to climate change with new Hungarian tree varieties producing high yields – SOSKLIMA Project. Forest Bioenergy 2010 Conference / Poster Session, Tampere, Finland, 01.09.2010.

Jáger, L. 2000. Role of forestry in rural development in Hungary. In: Magda, S. (ed.). Agricultural and rural development for regions. vol 4. p. 115-119.

Jáger L. 2008. A magánerdők tulajdonviszonyainak statisztikai elemzése. [Statistical evaluation of private ownership in Hungary] – In: MEGOSZ Országos Nap. , NYME EVGI, Sopron: 7-22.

Jáger L. 2010. Az osztatlan közös tulajdon a magánerdőkben. [Undivided private ownership in forests] In: Dömsödi J. (ed.): Birtokpolitika, földkérdés, vidékfejlesztés. Székesfehérvár. 2010.

Lakatos F. 2011. Present situation of bark and wood boring insects in the Hungarian forests. IUFRO WP.7.03.05 – Ecology and Management of Bark and Wood Boring Insects: Novel risks with bark and wood boring insects in broadleaved and conifer forests. 7-9 September 2011, Sopron, Hungary.

László, R., and Nagy, G. M. 2010. A birtokrendezés lehetőségei és támogatottsága Barcs térségében. [Possibilities of improvements of ownerships system in region Barcs] VIII. tájtörténeti konferencia, Kalocsa.

Lett, B., Schiberna, E., Horváth, S., Szabó, G. 2007. Erdőtelepítések és szabályozás-változás az európai uniós csatlakozást követően. [Afforestations and its regulation after the Eu accession process], Sopron.

Lett B. et al. 2008. Az erdőtelepítések szervezeti és pénzügyi háttere, motivációi és akadályozó tényezői.[Organisational and structural framework, hindering and fostering factors of afforestations] n: MEGOSZ Országos Nap, NYME EVGI, Sopron: 46-90

Lett, B. and Schiberna E. 2010. Az erdővagyon számbavételének helyzete és jövőben alkalmazandó eljárásai. [New methods of evaluation of forest assets] Termőföldpiac és földértékelés WORKSHOP . Székesfehérvár, 2010.

Manninger, M et al. 2011. The effect of temperature and precipitation on growth of beech *(Fagus sylvatica L.)* in Mátra Mountains, Hungary. „Applied Forestry Research in the 21st Century" Conference, Prague (Praha), Průhonice, 2011.

Matyas, CS. 2006. Migratory, Genetic and Phenetic Response Potential of Forest Tree Populations Facing Climate Change, Mátyás Cs. (ed.): Acta Silvatica & Lignaria Hungarica Vol 2. Sopron, p 33-46.

Mészáros, K. et al. 2000. Importance of new afforestation as alternative land use in Hungary. In: Dahiya, S. B. (ed.). The current State of Business Disciplines. vol 2. p. 947-958.

Nagy D. 2004. Az erdőtűzoltás feljesztési lehetőségei a nemzetközi tapasztalatok tükrében. [Improvement possibilities of fire protection development in the context of international experiences.] Védelem XI/4. Budapest 2004.

Nagy G. M. – Héjj B. 2011. Multiple forest use: Impact of forest tourism on students' behaviour in Sopron-mountain of Hungary. Multiple Forest Outputs: Silviculture, Accounting and Managerial Economics, International Symposium IUFRO, Viterbo, 2011.

Náhlik, A., Sándor, Gy., Tari, T. and Király, G. 2009. Space use and activity patterns of red deer in a high forest cover and in a patchy forest-agricultural habitat. Acta silvatica & Lignaria Hungarica. 2009 (5): 109-118.

Puskas, L. 2009. Speciális értékelési eljárások az erdészetben, különös tekintettel az erdők rekreációs értékének meghatározására. [Special evaluation methods in forestry with a special focus on recreational values]. PhD thesis, Sopron, 2009.

Schiberna E. 2008a. A rendezetlen erdőgazdálkodás. [Unsettled forest management rights in private forests] – In: MEGOSZ Országos Nap, NYME EVGI, Sopron: p 23-45.

Schiberna E. 2008b. Az Erdővagyon-gazdálkodási Intézet erdőgazdálkodói rendezetlenséggel kapcsolatos kutatásai a GAK2005-ERDOTELE program keretében. [Research activities related to the unsettled private forests in program GAK2005-ERDOTELE] Alföldi Erdőkért Egyesület Kutatói Napja, Szeged, 2008. AEE Kecskemét, p. 132-137.

Somogyi, Z. 2007. A klíma, a klímaváltozás és a fanövekedés néhány összefüggéséről. [Interactions between climate, climate change and growth rate] In: Mátyás Cs. - Vig P. (eds.): Erdő és klíma V., NYME Sopron, p 281-293.

Stark, M. 2000. Timber trade and marketing in Hungary during the transformation period. – In: Dahiya, S. B. (ed.). The current State of Business Disciplines. vol 6: 2984-3000.

Stark M., Schiberna E., Lett B. and Román J. 2010. A vadgazdálkodás ökonómiai kérdései. [Economic questions of game management] In: Faragó S. (ed.): Vadgazdálkodás. [Game management], Sopron. p. 232-254. ISBN 978-963-7287-22-0.

Standovar T. –Somogyi Z. 1998. Corresponding patterns of site quality, decline and tree growth in a sessile oak stand. European Journal of Forest Pathology 28: 133-144.

Szabó, M., Holl, K. and Horváth, S. 2010. Fásszárú energetikai ültetvények fa termésének vizsgálata a SOSKLÍMA projektben. [Evaluation of biomass plantations in project SOSKLIMA] Mészáros Károly Emlékülés, MTA VEAB, Sopron, 25. June 2010. Nyugat-magyarországi Egyetem Kiadó, ISBN 978-963-9883-74-1 94 p.

Szép, T. 2010. A klímaváltozás hatása az erdőgazdálkodás jövedelmezőségére. [Effects of global warming on forest income and profit] Mészáros Károly Memorial, MTA VEAB, Sopron, 2010.

14 The structure and use of computer-based tools for forest management in Ireland

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14.1 Introduction

Ireland has a forest cover of 11% (approximately 740,000 ha) of the land area. While this compares poorly with the European average of 42% (Eurostat 2009), it represents a rapid expansion of forestry from the early 1900s when the forest cover was estimated at 1%. When state forestry began in the 1920s, government policy was that only land classified as marginal for agricultural production was considered for afforestation. This resulted in the creation of single species plantations of exotic softwood species, namely lodgepole pine (*Pinus contorta* var. *latifolia*) and Sitka spruce (*Picea sitchensis*).

The management of state forests was restructured in the late 1980s – the semi-natural forests are since managed by the National Parks and Wildlife Service for nature conservation purposes and the forests with a primarily commercial function are managed by a state-owned company with a commercial remit, Coillte Teoranta. Coillte currently manage 445,421 ha of land (7% of the land area), over 397,000 ha of which is forested. Over the years, Coillte has expanded its enterprise to include operations in renewable energy (biomass and windfarms), panel board production and land development.

It was not until the 1980s that private forestry began to expand in Ireland, this was as a direct result of the introduction of financial incentives from the EU. In the early years, landowners continued to afforest marginal agricultural land. However, it was recognized that the reliance on a limited number of softwood species was not desirable from an economic or environmental perspective, and a re-structuring of the financial incentives system led to the diversification of the species base and an improvement in the quality of land being planted. There are now approximately 18,000 private owners who own 46% of the forested land. The average size of private forests is under 10 ha, the majority are under 30 years in age, and a significant proportion is considered somewhat inaccessible for many forestry operations.

In 1996, the government launched an ambitious strategic plan for forestry which aimed to increase forest cover to 30% by the year 2030 (DAFF 1996). This target was to be achieved through planting rates of 25,000 ha per annum from 1996-2000 and 20,000 ha per annum from 2001-2030. The planting rates achieved fall far lower than these targets. In recent years, planting rates have fallen to approximately 6,500 ha per annum, although a slight increase occurred in 2010. The vast majority of recent afforestation is private forestry (Figure 1) as public planting has all but ceased since a European Commission ruling in 1999 which excluded Coillte from the premium payments scheme.

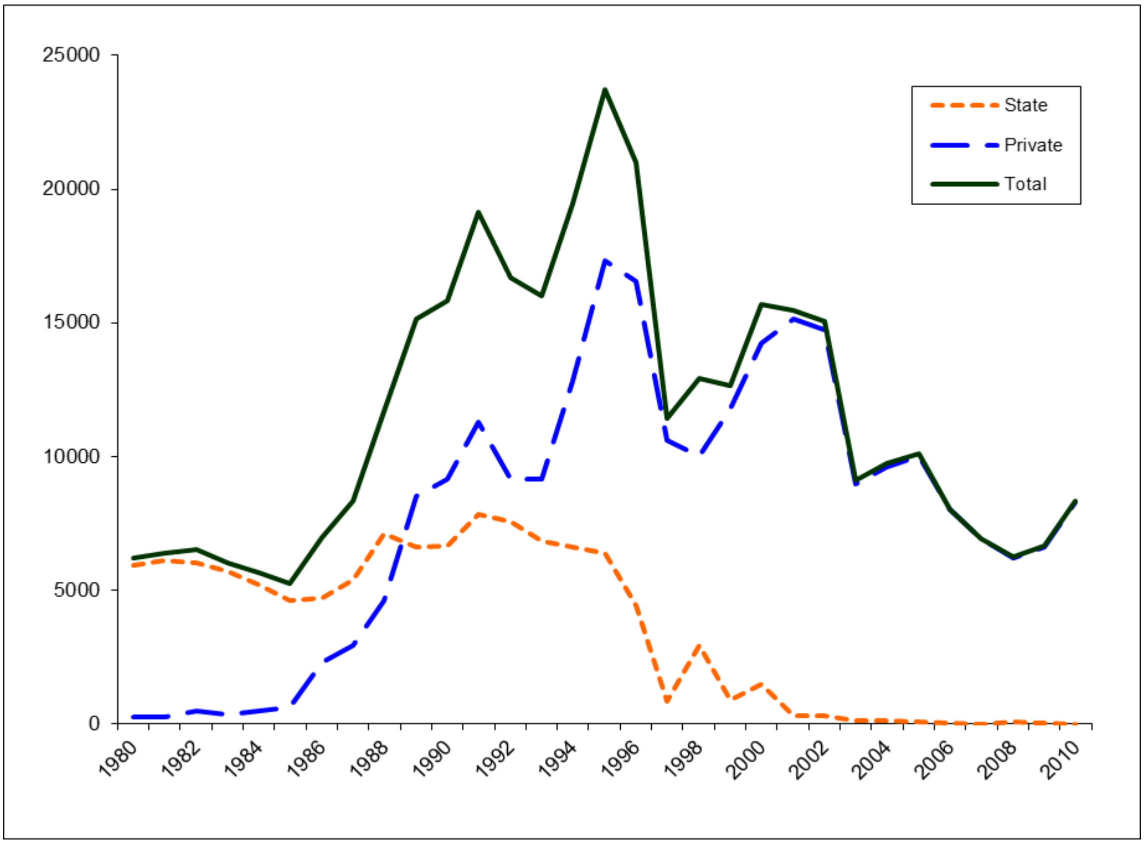

Figure 1. Private and public afforestation since 1980 (Irish Forest Service)

The state agency with responsibility for forestry is the Irish Forest Service; its functions include policy development and implementation and the development of the forestry sector. The Forest Service has been very effective in promoting the active management of private forests (largely through the efforts of state agencies such as Teagasc, the Agriculture and Food Development Authority) to ensure that the state-funded resource can reach full productive potential. Efforts have been made to encourage appropriate thinning regimes, formative shaping of broadleaves and coordinated marketing of small timber lots. It is not yet clear how much impact these activities will have on private growers, despite the fact that one of the conditions of grant aid is that the forest plantation is managed with timber production as an objective (DAFF 1996).

The National Strategic Plan for Forestry was based around achieving critical mass in timber production to sustain industry (DAFF 1996). An accurate inventory of the total forest estate, both public and private, is essential for policy development and planning for the sector. The data that exist for the Coillte-managed public forest are accurate and up-to-date. However, with the rapid expansion in the private estate, the Forest Service acknowledged that there was a gap in information on the total area under forest, species composition and potential productivity. This was addressed through the completion of the National Forest Inventory in 2007 (www.agriculture.gov.ie/nfi/).

The continued management and protection of old woodland or semi-natural woodland is of prime importance for the conservation of biodiversity. There are relatively few such areas in Ireland, and the majority of these woodlands are managed by the National Parks and Wildlife Service. Coillte also manage numerous ‘old woodland sites’ and approximately 4,500 ha of ‘native woodlands’ are owned and managed by the private sector under the Forest Service Native Woodland Scheme. There are some GIS-based tools in place to support the management and protection of these forest types but these systems were considered outside the scope of standard ‘forest management’.

Economic output for the forest sector can be divided into the growing and processing sub-sectors. In 2010, direct output of the growing sub-sector was €379.8 million (Ní Dhubháin et al. 2012). When the indirect and induced effects are taken into account using the multiplier, the overall value of the sub-sector to the Irish economy was €673.0 million in 2010. Direct employment was 3,125. Accounting for the induced and indirect effects, the total employment supported by the growing sub-sector was estimated to be 5,531.

Direct output in the processing sub-sector (panel board mills, sawmills and other wood products) was €1,330.9 million. Direct employment was 3,907. Accounting for the induced and indirect effects, the total employment supported was estimated to be 6,408. The total value to the economy of the processing sub-sector was €2.20 billion, nearly 3.3 times the growing sector figure of €673.0 million (Ní Dhubháin et al. 2012).

Due in part to the rapid development of forestry in Ireland over the past 50 years, the current forest management planning problems are many and varied. The significant changes in the balance of ownership of the Irish forest resource over the past 30 years has also created a series of opportunities and challenges for the successful management of the forest estate. The following section outlines some of the main issues facing Irish forestry today and delineates them according to the dimensions agreed for FORSYS reporting; these dimensions are explained elsewhere in the publication.

Irish private forest owners, while recognising the long-term nature of forestry, are more concerned with tactical planning decisions. While a significant proportion of private forests consist of only one stand, tactical management planning is at a forest level and spatial in nature. Decisions are made by the forest owner who has often multiple objectives and a focus on the production of market wood products and non-market services. This is classified as **Problem Type 1**.

Private owners also have to address operational level problems on an individual stand basis. The single objective of this problem is wood production and decisions are again made by the individual forest owner and are considered non-spatial in nature. This is **Problem Type 2**.

To achieve economies of scale, and to make the harvesting and sale of small volumes of timber attractive to the market, owners are encouraged to take into account other nearby private forest areas and to cooperate with other local owners. Under such circumstances, decision-making will be by multiple forest owners, the issue is spatial in nature but without neighbourhood interrelations and decisions are made at a stand level. This is an operational level problem and while the primary objective is generating income from timber sales, current research suggests that many farm forest owners have multiple objectives that include issues such as enhancing biodiversity, thus there are multiple objectives concerned with market wood products and non-market services. This level of problem is classified as **Problem Type 3**.

Most private owners engage the services of a private forestry consultant or private management company for the establishment and management of their forests. These companies are another link in the chain in Irish forestry and face their own set of problems that are largely tactical and non-spatial in nature. They largely operate at a forest level (client), decisions are made by an individual and the single objective focuses on the delivery of market wood products. We assign this as **Problem Type 4**.

Other companies in the forest industry chain include sawmills and board mills. These were not included in full in this report as this sector falls outside the area of 'forest management' but as major players in the forest industry chain, a mention is warranted. One of the key issues faced by this sector is to maximise the efficiency of timber processing. This can be characterised as operational, non-spatial, stand level with decisions made by a single decision-maker with the single objective of producing market wood products. This is referred to as **Problem Type 5**.

Management planning issues faced by Coillte have different dimensions. The forests owned are more extensive and, as a public resource, there are a wider set of expectations as to the goods and services demanded. Management planning is strategic in nature, non-spatial, and operates at a national level. Decisions appear to be made by a single decision-maker but the management of the public forest estate is subject to consultation with other bodies and members of the general public who have no formal decision-making power. Coillte has a commercial mandate and therefore aims to market wood products; however, in recent years, significant investment has been made in the provision of non-market services such as aesthetics, biodiversity and the provision of non-marketed recreational services. Management planning addresses multiple objectives and this is defined as **Problem Type 6**.

Tactical level plans are necessary to deliver the strategic aims outlined at a national level for the public forest estate. These issues are addressed at forest level and are again considered non-spatial in nature. Single decision-makers have multiple objectives and operate to produce market wood products and non-market services. This is **Problem Type 7**.

To date, Coillte supplies the majority of timber to processors in the Irish market. The issue of managing the timber flow in an efficient and cost-effective way is constantly under scrutiny. This is **Problem Type 8** and is tactical in nature, has a spatial dimension but without neighbourhood relations and operates at stand level. The single objective is timber production and decisions are made by an individual decision-maker.

To address some of the concerns surrounding past forestry practices, for example, the afforestation of sensitive sites and loss of biodiversity, strategic-level plans are necessary. The public require that the management of the national forest resource does not only apply holistic management practices to new forest areas but that appropriate measures are also taken to minimise any potential negative impacts that might arise from existing forest areas. This problem requires plans that are spatial with neighbourhood relations that operate at stand level. Plans will have multiple objectives and focus on the delivery of market wood products and non-market services. Addressing this type of issue will necessitate the involvement of stakeholders in the decision-making process, most likely on an informal basis. This is classified as **Problem Type 9**.

Policy-related management planning problems are generally strategic in nature and operate at national level. Examples of this included the necessity to have detailed and accurate inventory information for future planning, reporting purposes, and as indicators to measure whether policy is being implemented. Most decisions are made by one decision-maker but with significant levels of input from other parties, including the EU, which may influence the decision. These problems often have a single main objective and can be either non-spatial or spatial in nature. The goods and services dimension often concerns the provision of non-market services while acknowledging the importance of market wood products. This has been assigned **Problem Type 10**.

The implementation of strategic policies requires that plans are developed, at an operational scale, which addresses stand-level decisions. Ideally, they are spatial with neighbourhood interactions and input, formal or informal, should be sought from stakeholders. Such issues have multiple objectives and are concerned with the provision of market wood products and non-market services. This is **Problem Type 11**.

In many cases, the same issues exist for the owners of small private holdings and the public state company – examples include the need for accurate and reliable growth predictions for the forests, accurate and up-to-date inventory information on which to base management decisions. This can be categorised as strategic, non-spatial, relevant at stand level, and where decisions are made by single decision-makers with the single objective of market wood production. This is classified as **Problem Type 12**.

The need to protect forests from the threats posed by wind, fire, deer and disease are also issues that affect public and private forest holdings. These problems can be classified as strategic with a spatial context and stand level implications. In most cases, problems are of single objective dimensions and decisions are made by an individual. The majority of issues are primarily concerned with the delivery of market wood products. This is defined as **Problem Type 13**.

The use of fully developed DSS in forest management in Ireland has been limited to date. However, the need for dynamic systems to support the management and development of the expanding forest resource has been recognized and there are several computer-based tools and a number of DSS in use in Irish forestry.

The objectives of this report include compiling an inventory of decision support tools that have been developed for use in Irish forestry in recent years, and investigating the adoption of such tools across the forest sector. It is also envisaged that this examination of problem types may also lead to the identification of areas that could benefit from such tools.

14.2 Materials and methods

As new systems are developed for use in Irish forestry, information is made available to the sector in forestry research reports, conferences and scientific papers, through professional organisations and associated field days and in trade journals. Moreover, due to the relatively small nature of the forestry sector, information on these systems is relatively easily accessed.

For several years, COFORD (Council for Forestry Research and Development) has been the major driving force of forestry-related research in Ireland. COFORD controlled significant levels of research funding and was extremely active in the dissemination of research findings. Coillte, as the largest forest owner in the country, was also very active in research and systems development and continues to cooperate widely with other elements of the sector. Teagasc has a Forestry Development Department which specialises in the provision of advice, training and research related to farm forestry. Several third-level educational institutes are also very active in the development of tools required to address the range of management issues in Irish forestry.

The information in this report was sourced initially from literature searches. In most instances, contact was then established with someone who was directly involved in the development of the system or its application. In the majority of cases, it was possible to review the system and its details with the users. It was hoped to assign the problem type with the input of the user but it was not always clear which dimensions applied to the system under review.

14.3 Results

The DSS identified during the search, together with information on models, methods and KM techniques used as well as participatory planning methodology, are listed by problem type in Table 1.

Table 1. Problem types and DSS in the Irish forestry sector

Problem type	DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
1	PRACTI-SFM	Simulation	Database	
4	CRMS-FEL	NA	Relational database	
5	Optival	Variance and regression analysis	Spreadsheet	NA
7	MIPS-SFM	Simulation, Optimization		NA
8	HSS	Simulation, Optimization (LP, MIP)	GIS, Database	NA
9	WESTFOREST	Optimization, Cellular Automata	Decision rules, GIS-based tools	(informally)
10	CARBWARE	Growth simulation	Database	(informally)
11	iFORIS	NA	GIS , Database	(informally through the statutory-based approvals process)
12	GROWFOR	Growth simulation,	Database	NA

		García's multivariate Bertalanffy-Richards model		
12	TRC	Simulation, yield modelling	Database	NA
13	WINDTHROW RISK MODEL	Stepwise logistic regression;	Database	NA
13	FORECAST	Simulation	GIS, MS Access database	NA

Problem type 1: Practi-SFM

This tool was designed to support tactical level planning at forest level by a single decision-maker. It is designed to address multiple objectives including the delivery of wood products and non-market services and has a spatial context, without neighbourhood relations.

As a result of the third Ministerial Conference on the Protection of Forests in Europe in 1998 and the subsequent development of the Irish National Forest Standard (INFS) in 2000 (Irish Forest Service 2000), private and public forests in Ireland are managed under the principles of sustainable forest management. The application of SFM requires that forest owners become aware of interactions between the social, environmental and economic aspects of their forests and reflect this in their management plans. By extension, inventory practices must be expanded beyond the traditional timber-focused data to include those that will aptly reflect all productive functions of the forest. At the same time, it is vital that any extra demands are reasonable in terms of cost, time and expertise. It is envisaged that such developments will also facilitate third-party certification for forest management and timber production. The Practi-SFM tool was developed as a first step in addressing the perceived gap that existed for local level information on private sector forests (Barrett et al. 2009) and is intended for use by the owners/managers of private forests.

This tool was developed as part of a COFORD-funded research project based in UCD. The tool consists of two components; a multi-resource inventory protocol and a decision support system. The inventory protocol component is based on criteria and indicators detailed in the INFS, best practice methodologies and extensive field testing. The collection and management of this data can, over time, enable monitoring of progress towards or movement away from sustainable forest management (Barrett et al. 2007).

The DSS component of the Practi-SFM system is Microsoft Excel-based. It includes a growth simulation model to forecast growth at stand level and facilitates the production of management plans for a 10-year period (Barrett and Nieuwenhuis 2009). Based on the stand management options selected by the user, maps, tables and graphs are produced which detail forecasted timber production, cash flow, scheduled operation hours, biodiversity, landscape sensitivity and several other factors. The program has an interactive map interface that allows the user to interact with the program, visualise spatially the impact of particular management scenarios and to refine and reselect management options for different stands. The system also includes a module which produces a graphic display of sliders, where the user can visualise the current, the minimum and the maximum possible values of a number of timber and non-timber variables. This goal analysis module of the program allows the user to set specific goals and monitor how far the current timber and non-timber results deviate from these goals at the end of the 10-year planning horizon. Changing the selected options will produce a different scenario and these can be compared across a range of factors giving the user insight into how the various components of the plan interact and where compromise can best be made to achieve an acceptable balance in management objectives (Barrett and Nieuwenhuis 2009).

Future development of this system will introduce an element of optimization to simplify the selection of management options on a stand by stand basis. It is also planned to integrate the data compiled in the Practi-SFM DSS with the Irish Forest Services' IFORIS.

Problem type 4: CRMS-FEL

This system has a tactical scale, is non-spatial, operates at forest level, has a single objective, concerned with market wood products and has a single decision-maker.

Individual forestry management companies have, in recent years, experienced changes in the nature of the work they do. Many forests that they established on behalf of clients are now due for thinning. However, the contracts between these companies and private owners most often lapse following the second instalment of the afforestation grant at Year 4. Managing the work flow of the company foresters under these circumstances often means that they are required to 'cold call' forest owners to suggest that their properties are due for thinning and again offer the professional services of the management company.

This tool is a customized customer relationship management system (CRMS) and is based on Maximizer software (maximizer.com). This is a commercially available tool that is customized to a client's specific requirements. It is not a forestry-specific tool but is representative of the type of tool favoured by the larger forestry management companies in Ireland. The advantage of such a system is that it allows all elements of the business to be kept aware of relevant developments (sales, accounts, forest managers) and prevents the loss of potential business through controlled reporting. Regional forest managers are required to update the status of their work regularly so that a weekly review of progress can be made. Such a system also prevents loss of continuity with changes in personnel. Full engagement of all staff is required to optimise its potential benefits to the company.

Some of the larger companies have a separate GIS-based database of sites that they manage but depend mostly on some form of standalone CRMS database for day-to-day operations.

Problem type 5: Optival

This tool was designed to support short-term decision-making at stand level, it does not have a spatial context, is focused solely on timber production and decisions are made unilaterally.

This tool was developed to address the issue of maximising the potential value/volume of logs from a processing perspective. The OPTIVAL system is a "sawmill stand evaluation and production chain analysis tool set". It consists of a pre-harvest inventory and value maximization decision-support system (Nieuwenhuis et al. 1999), a machine calibration analysis tool (Nieuwenhuis and Dooley 2006), and a sawmill input-output analysis tool (Browne et al. 2007). It was developed in a research project funded by COFORD and the work was carried out in conjunction with Palfab Ltd. and UCD.

The data used in the development of the system was from Sitka spruce clearfell sites in the south of Ireland. The results achieved were considered reasonably accurate if data is based on large enough sample sites. The tool was developed for use by timber processors but is not in everyday use.

Problem type 7: MIPS-SFM

This model operates at forest level, producing medium term plans, it is non-spatial in nature, has a single decision-maker with multiple objectives seeking to produce wood and non-market services.

The TRC system was developed before the need for holistic forest management was recognized. However, more recent work has resulted in the development of a system to include the issues of SFM in harvest scheduling (Nieuwenhuis and Tiernan 2005).

This work was undertaken to address the potential benefits of introducing optimization to the Coillte TRC system and also to attempt to incorporate the constraints that SFM brings to forest management. This tool was developed by a Coillte staff member working in conjunction with UCD on a COFORD and Coillte-funded research project.
Optimization-based economic models were developed for harvest scheduling on a forest level within the context of a hierarchical approach. The development of the optimization models involved the evaluation of: different management options strategies, optimization techniques, model types and constraint strategies (Tiernan and Nieuwenhuis 2005).

These financial models were further developed to produce a Mixed Integer Programming - Sustainable Forest Management (MIP-SFM) model, in which principles of sustainable forest management were incorporated into the harvest scheduling process (Nieuwenhuis and Tiernan 2005). Overall, it was found that the inclusion of SFM standards for a range of factors did not adversely impact productivity and in the case study actually resulted in an increase in net present value. This tool was developed for use by forest managers and while it was not adopted for general use, has prompted further developments of the TRC.

Problem type 8: Harvest Scheduling System (HSS)

This tool has medium-term focus with a spatial dimension; operates at stand level and focuses solely on timber production; one decision-maker.

Research on the inclusion of operations research techniques focused on the area of timber transportation and indicated that significant efficiencies could be introduced (Nieuwenhuis and Williamson 1993). This is a prototype tool and was developed to optimise the harvest scheduling and the allocation and transportation of Coillte's timber supply (Nieuwenhuis and Williamson 1993). It was funded by a research grant from Coillte. Linear programming and mixed integer programming were used in this system, while the programme successfully demonstrated the benefits of optimizing timber allocation. The tool was used in the planning process for some strategic-level decisions within Coillte but solution times were considered excessive.

This system was further refined in a later study to include the following issues: a change in emphasis from a production-driven approach to that of a demand-driven approach; the spatial distribution of market demand, haulage costs, and the economic impact of selecting a particular year for production from a particular stand (Nieuwenhuis and Nugent 2000).

Problem type 9: WESTFOREST

This tool will be strategic in nature; will operate at stand level, will have a spatial with neighbourhood interrelations context; will have multiple objectives, market wood products and non-market services dimension with a single decision-maker, with informal input from stakeholders.

In the early years of state afforestation, large blocks of forestry were established on blanket peatlands in western counties, predominately with Sitka spruce and lodgepole pine. Many of these areas are still under the management of Coillte as a part of the public forest estate. At the time of planting, there was little awareness of the significant ecological value and landscape sensitivity of such areas. In many cases, these forests are economically unsustainable and standard management is hampered by poor soil conditions and high probability of windthrow. These sites are now considered highly sensitive for biodiversity, water quality and amenity. The challenge now is to balance timber production with other non-timber goals and redesign the forests in a manner that optimises their environmental, social and economic contributions to society.

This DSS is currently under construction as part of a COFORD-funded project in UCD. The objective is to develop a nationally acceptable DSS for the redesign of western peatland forests, which is economically, environmentally and socially acceptable with due regard for the unique sensitivity of the surrounding landscape and stakeholders' requirements.

The DSS will combine GIS constraint information and analysis capabilities with the matrix of constraint. The user (forest manger) can select specific management practices for the range of stands under consideration, and the system will identify the overall results in terms of environmental, social and economic outputs and costs. Some management options may not be allowed in certain areas based on weightings of the constraint set. The user will be able to change the selected management practices in individual stands or management units and the system will identify the costs and benefits of this change for each of the environmental, social and economic parameters considered. On a trial-and-error basis, it will be possible to reach an 'optimal' solution as long as the number of management practice options, the number of constraints, and the number of management units is not too great. This 'optimal' solution will also be dependent on the subjective weighting by the user of the costs and benefits associated with each of the constraints. The uncertainty level associated with the derived solutions will form an integral part of the output. It is envisaged that this tool will be used by local forest managers and will address issues raised by local stakeholders.

Problem type 10: CARBWARE

The CARBWARE system has a long-term planning dimension; a spatial context without neighbourhood interrelations; it operates at a national scale; decision-making is unilateral and there is a single objective (carbon accounting) and the focus is on non-market services (this may in time be reclassified as a market service once carbon trading markets develop).

As a signatory of the Kyoto Protocol, Ireland has an obligation to account for the carbon levels in Irish forests and to report these to the United Nations Framework Convention on Climate Change (UNFCCC). The CARBWARE tool was developed in 2002 to support this accounting process and provides information on the level of carbon stored in Irish forests, and projected impacts of afforestation, deforestation and timber harvesting on carbon stocks (McGettigan et al. 2010).

The tool was initially developed with data inputs from the Forest Service and the Coillte permanent plot database and reported on biomass levels. It has been significantly expanded in recent years and now provides estimates on above- and below-ground biomass, deadwood, litter, soil carbon, emissions from fires, deforestation, and fertiliser applications (Black et al. 2012). One of the most significant steps in the expansion of the system was the development and incorporation of single-tree growth models which use the NFI data (the NFI data is not directly compatible for use with the stand-based GROWFOR system). This allows for growth modelling across a range of parameters (semi-natural, mixed species, uneven aged stands). The model also accounts for harvest, competition and mortality.
The CARBWARE system consists of several modules including pre-processing of the data, growth simulation and biomass allocation. It is linked with the Forest Service felling licence records, and various other Forest Service databases which provide spatial information for the model (Black et al. 2012). The system supports the calculation of carbon stocks into the future, and thus facilitates scenario analysis and supports national forest policy development whereby policies and management objectives can be assessed in terms of carbon sequestration potential under different management decisions, planting rates, species selected etc.

This system is in use by government reporting agencies, for example, the Environmental Protection Agency and the Forest Service and also by researchers seeking to evaluate multiple aspects of Ireland’s forested areas. While its primary function is carbon accounting, CARBWARE can be applied to timber forecasting; outputs include timber volumes and assortments at the single tree, stand and regional level, as defined by the user.

Problem type 11: iFORIS

This tool has a short-term planning dimension; a spatial context with neighbourhood relations; operates at stand-level scale; one decision-maker (though consultation exists); multiple objectives; focused predominately on market wood products and non-market services.

Applications for grant approval for forestry development are submitted to the Forest Service. There is a well-established approvals process in place to ensure that forestry development, whether grant-aided or not, is allowed only where it is appropriate from a production, landscape, amenity and environmental perspective. All applications were paper-based and the process was considered somewhat cumbersome until the development of the ‘integrated Forest Information System’ (iFORIS) to support the Forest Service in processing pre-approval applications and grant and premium applications. It also facilitates the management of a number of other forestry related schemes. iFORIS contains a number of spatial datasets including Special Areas of Conservation, Acid and Fisheries Sensitive zones, Landscape Sensitive zones, National Parks and Monuments, the existing forest cover, an indicative forest strategy as well as colour ortho-photography and the administrative boundaries.

Using the iFORIS system, approved foresters and forestry companies, on behalf of their clients, can complete and submit applications for the approval for forestry development online. Users are provided with the tools to digitise the plantation boundaries, and access to the range of environmental datasets helps to ensure that even at pre-approval stage, applications are credible and likely to be approved (www.epractice.eu/en/cases/iforisip). Users can access the system at any time and can also track the process of applications through the system.

Applications are received in an accurate and standardised format and Forest Service Inspectors can view the proposed forestry development and run a query that will provide information on spatial and temporal scales in relation to the proposed development (Barrett, pers. comm.). This tool is in everyday use by both Forest Service staff and approved forestry professionals.

Problem type 12: GROWFOR

This tool facilitates non-spatial long-term planning at stand level; there is a single objective (forecasting growth); single decision-maker; the focus is on market wood products.

Irish forests were traditionally managed using long established British Forestry Commission Yield Models (Edwards and Christie 1981). The accuracy of these static models relies on the imposition of a predefined management regime and thus a major limitation is that no deviations in forest management can be accounted for. In modern forestry, dynamic yield models are considered a more appropriate tool as these do not assume a prescribed regime and can therefore be used to forecast the outcome of a wide range of management practices (Broad and Lynch 2006).

The modelling of Sitka spruce growth under Irish conditions has resulted in the generation of dynamic yield models based on actual data from Irish forests. The stand-level growth models utilises García’s state-space modelling methodology (Broad and Lynch 2006). Models were also developed for other major forest species including lodgepole pine, Norway spruce, Douglas fir and Scots pine. Work is ongoing to develop models for Japanese larch and common ash and mixtures (Nieuwenhuis and Purser 2007).

A user interface was subsequently developed and further features added which render this a valuable and user-friendly management tool. It allows user-defined assortment specifications for some species and thinning cycles; net present values for different management options, current annual increments, mean annual increments and yield classes can all be generated. This tool was developed with funding from COFORD and is available for use under licence through the Council for Forest Research and Development (COFORD). This tool is in wide use by foresters operating privately, within Coillte and for research purposes.

Problem type 12: Thinning and Rotation Classification (TRC)

This tool produces long-term, non-spatial, stand level forecasts for timber production.

Managing the output from the public forest estate is a complex issue given its scale and distribution. For more than 20 years, Coillte has used a 'Thinning and Rotation Classification' (TRC) system to assign rotation lengths and thinning regimes to all its forest stands. The system is used as an input to the generation of long-term timber production forecasts. A silvicultural prescription is generated for each stand indicating a proposed thinning and rotation schedule (Quinn 1996). The information relating to thinning specifies the year of first thinning, the number of thinnings expected, the interval between thinnings and an explanation section where deviations from the standard are expected, for example, in a stand where thinning is not recommended.

The information generated in relation to rotations specifies the proposed year of felling, and whether the rotation is considered standard (age of MMAI) or otherwise. An explanation section is included to allow the forest manager to indicate why changes were made to the system's proposed rotation, for example, in the case of avoiding or addressing windthrow.

It is possible to modify the timing of harvesting operations but such changes are made on a somewhat trial-and-error basis without the benefit of any formal decision support. Coillte are currently investigating the potential of building in a form of optimization to the TRC system. This system was developed to support Coillte's in-company planning and is in everyday use within the company.

Problem type 13: Windthrow Risk Model

This tool addresses a long-term scale, with a spatial context (without neighbourhood interrelations), it addresses stand level decisions made unilaterally it has one objective and is aimed solely at market wood products.

In Ireland, wind has serious implications for the management of forests. This is due in part to how and where forests were established in the early years – often in exposed areas considered marginal for agricultural production and employing agricultural ground preparation techniques. Many even-aged stands in exposed areas are left unthinned to reduce the risk of windthrow (Ní Dhubháin *et al.*, 2001). The result is crops that do not achieve their full productive potential. Economic losses are also encountered when harvesting from windblown sites or if sites are harvested before financial maturity due to the perceived risk of windthrow.

A prototype windthrow risk model was developed to examine the key factors in windthrow risk in Irish forests. This tool was developed in COFORD-funded research work which was executed by teams in Coillte, Teagasc and UCD. The model was based on pure stands of Sitka spruce and in total 15 factors were examined. Stepwise logistic regression was used to generate a windthrow risk model. The final model included top height, top height squared, soil type, ground preparation bearing, wind zone and thinning status (Ní Dhubháin et al.

2001). Validation of this work resulted in the further development of the model and the factors used in the final model are top height, top height squared, soil type, thinning, wind zone, altitude and the interaction between top height and soil type (Ní Dhubháin et al. 2009).

A user-friendly GUI was added and the added functionality of examining the levels of windthrow probability along a range of yield class values. The model is available for download on www.coford.ie. This tool was developed to support decision-making by forestry professionals and is in use.

Problem Type 13: FORECAST

This tool has a long-term planning dimension; a spatial context without neighbourhood interrelations; operates at stand-level scale; decision-making is unilateral and there is a single objective (timber forecasting); focused on market wood products.

Early forecasts of the potential timber output of the private forest resource assumed that standard forestry practices would be followed (Gallagher and O'Carroll 2001). In many cases, this has not happened and private forests have not been managed in silviculturally appropriate ways. The reasons for this include the fragmented nature of the private estate, and a lack of expertise on the part of owners. Given the significant resource that these forests represent, it was necessary that methods be identified to quantity the actual levels of available marketable material. FORECAST operates at national and catchment level to facilitate planning for harvesting operations and processing capacity. This tool was developed in research work funded by COFORD and carried out between UCD, the Forest Service and Forest Solutions.

This is a GIS-based tool for forecasting timber supply from private sector forests in the years 2009-2028. A number of existing spatial datasets were used, including the National Forest Inventory, and a series of forecasting rules developed to provide a robust forecast of potential output. To facilitate access by users, a set of free web-enabled GIS tools, accessed through a MS Excel interface, were developed. These tools allow private sector forecasts to be downloaded at different spatial scales (national, regional, county and at 60 and 80 km radii from 42 locations) and also provide information on volumes by timber assortment, harvest areas, production years, species group, ownership category and harvest type (Phillips et al. 2009). The system is compatible with the existing iFORIS system. This tool was developed to support planning at government and industry level and it is envisaged that it will be used, particularly by the processing sector.

In time, the FORECAST tool will include the facility for forest owners/managers to upload accurate stand data thus making the information available to the industry and planners.

14.4 Discussion and conclusions

This section aims to examine how the problem types identified in Irish forestry were addressed through the development of computer-based tools and also to consider where gaps still exist in problems types currently not addressed through the existence or application of such tools.

Ireland's forest resource is relatively young and the application of computer-based tools to support the dynamic management of the resource is at an early stage. From an Irish perspective, this has allowed the development of such tools to benefit from the extensive experience gained in other countries, however, the range and complexity of tools in commonplace use is currently quite restricted.

Many of the problem types identified are very local in nature and operate at stand level. This is perhaps as a result of the relatively 'small' area of forestry in Ireland and an inclination to address problems at this level. This focus of many of these problem types is also on market wood products only and this is perhaps also worth considering given the extensive commitment that the Irish government has made to implementing SFM across all forest types. It is also interesting to note that although informal input from stakeholders is sought for some tools, the tendency generally is that decisions are made by a single decision-maker.

It is clear that many of the problem types identified in Irish forest management have benefitted from the use of some level of computer-based tools. It is also clear that some tools (for example Practi-SFM and the TRC) can be improved through integration with other systems or the addition of some other elements, for example, optimization. This appears to be happening to some extent in several of the systems reviewed, including the TRC where optimization is currently being integrated. The forestry management companies readily acknowledge the benefits to be gained from fully developed DSS but the outlay in terms of cost and expertise is not feasible due to the short-term nature of the standard client-company contract which extends for the first four years of plantation establishment.

As Ireland has a small open economy, continuing access to markets (particularly the UK markets for timber and other wood products) is of vital importance. In the 1990s independent verification of forest management practices became a driver for change and market access for uncertified timber became more difficult. The Irish public forest estate, as managed by Coillte, became Forest Stewardship Council certified in 2001. It is interesting to note however, that although consultation with stakeholders is a major component of third-party forest management certification, none of the computer-based tools have an explicit method of participatory planning. This is perhaps an area that will be more fully developed in coming times.

Some of the systems in existence appear to be applied across a range of dimensions – the iFORIS system is used for short-term approvals of applications for forestry development but the tool is also considered important as an aid in the long-term development of the Irish forest estate. This is also a system where although there is no explicit participatory planning, the referrals process means that a wide array of relevant stakeholders do have an input to the decision-making process.

There are problem types identified which are not currently addressed by formal computer-based tools. These include problem types 2, 3 and 6. The lack of a computer-based tool for problem type 2 is understandable to some extent – if an owner has an overall tactical plan for a small forest area, they are unlikely to require a sophisticated tool to facilitate operational planning. Problem type 3 is another area that is currently under investigation and significant efforts are underway to support individual owners in forming networks for the purposes of marketing their timber. The CLUSTER project operates at a local level to support private forest owners in realising the potential of their resource (Farrelly et al. 2008) but was considered by its developer not as a computer-based tool but rather as an application of GIS. Problem type 6 is probably supported to a large extent by the information available through the TRC system and other in-house systems feed into the development of planning at a national scale for Coillte.

The escalating deer population also poses a significant threat to Irish forestry as it restricts attempts to expand the tree species base, encourage natural regeneration and move from clearfell systems to continuous cover management. A confounding element to achieving a solution to the deer problem is the existence of two separate legal jurisdictions on the island and to date, the lack of a coherent national policy on managing deer and forestry (Purser et al. 2009). This issue is currently being addressed through the development of a deer policy by the Forest Service. It is envisaged that this will, in time, lead to the development of a computer-based tool to aid in understanding, tracking and managing deer interactions with forest areas.

Despite our temperate maritime climate, fire is a risk to Irish forests. The controlled burning of vegetation (usually furze (*Ulex* spp.) on lands adjoining forests is most often the cause of forest fires. Arson has also been suspected as a cause of some of the recent fires in May 2011 when over €7.5 million worth of forest was damaged. This obviously has significant implications for the management of the resource, whether publicly or privately owned and owners are strongly encouraged to have full insurance cover for their plantations. The development of a computer-based tool that would, at least, record the occurrence of forest fires and subsequent damage could be a useful first step towards addressing the problem posed by fire.

A risk that has recently emerged is the threat to the forest estate by the plant pathogen *Phytophthora ramorum*. During forest inspections since 2003, this pathogen was detected on rhododendron in Irish forests but since 2010 it has been found on several Japanese larch (*Larix kaempferi*) stands. Noble fir (*Abies procera*), common beech (*Fagus sylvatica*), and Spanish chestnut (*Castanea sativa*) trees close to infected Japanese larch were also infected as was one young Sitka spruce tree. As Japanese larch comprises approximately 3.5% of the forest estate, the risk to Irish forestry is considerable. Should widespread infection spread to Sitka spruce, the effects on Irish forestry could be devastating. The infection sites are, by necessity, mapped and monitored closely but due to the relative 'newness' of the problem, no tool has yet been developed to aid in its management.

Many of the tools that have been developed have been the result of academic research work. While several of them are being used to some extent, it is apparent that the most actively used tools are those that have been developed following a demand from end-users. Examples of this include the TRC, iFORIS, CARBWARE and the CRMS-FEL.

The iFORIS offers the most potential benefit in terms of the array of tools and level of access to a variety of potential users. It is possible that with further development, this tool could meet the requirements of many of the forest management issues in Irish forestry that are either not being addressed fully or at all through a computer-based tool.

References

Barrett, F., Somers, M., Nieuwenhuis, M. 2007. PractiSFM - an operational multi-resource inventory protocol for sustainable forest management. In: Reynolds, K.M., Thomson, A.J., Kohl, M., Shannon, M.A., Ray, D. and Rennolls, K. (Ed.), Sustainable Forestry: from Monitoring and Modelling to Knowledge Management and Policy Science, CABI, UK, pp 224-237.

Barrett, F., Nieuwenhuis, M. 2009. A decision support system linking forest policy with sustainable forest management planning in private forests in Ireland. In: Grossberg, S.P. (Ed.), Forest Management, Nova Science Publishers, New York, pp 61-84.

Barrett, F., Nieuwenhuis, M., Doyle, M. 2009. The PractiSFM multi-resource inventory protocol and Decision Support System. A model to address the private forest resource information gap in Ireland. Irish Forestry 66: 5-20.

Black, K., Hendrick, E., Gallagher, G., Farrington, P. 2012. Establishment of Irelands projected reference level for Forest Management for the period 2013-2020 under Article 3.4 of the Kyoto Protocol. Irish Forestry 69.

Broad, L.R., Lynch, T. 2006. Growth models for Sitka spruce in Ireland. Irish Forestry 63: 53-79.

Browne, I., Layton, T., Nieuwenhuis, M. 2007. The impact of Sitka spruce log dimensions on recovery in an Irish sawmill. Irish Forestry 64: 61-71.

DAFF. 1996. Growing for the future. A strategic plan for the development of the forestry sector in Ireland. Department of Agriculture and Food. The Stationery Office Dublin.
Edwards, P.N., Christie, J.M. 1981. Yield models for forest management. Forestry Commission, Edinburgh.

Eurostat. 2009. Forestry statistics. Publications Office of the European Union, Luxembourg, p 172.

Farrelly, N., Clifford, B., and Green, S. 2008. Using GIS cluster analysis to quantify timber production from farm forestry plantations. Irish Timber and Forestry 17: 30-33.

Gallagher, G., O'Carroll, J. 2001. Forecast of roundwood production from the forests of Ireland 2001-2015. COFORD, Dublin.

IFFPA. 2010. An overview of the Irish forestry and forest products sector. Irish Forestry and Forest Products Association, Dublin, 52 p.

Irish Forest Service. 2000. Irish national forest standard. Forest Service, Department of the Marine and Natural Resources, Dublin, Ireland.

McGettigan, M., Duffy, P., Hyde, B., Hanley, E., O'Brien, P., Ponzi, J., Black, K., 2010. National Inventory Report 2010. Greenhouse gas emissions 1990 – 2008. Reported to the United Nations Framework Convention on Climate Change. EPA, Wexford, Ireland.

Ní Dhubháin, Á., Walshe, J., Bulfin, M., Keane, M., Mills, P. 2001. The initial development of a windthrow risk model for Sitka spruce in Ireland. Forestry 74: 161-170.

Ní Dhubháin, Á., Bulfin, M., Keane, M., Mills, P., Walshe, J. 2009. The development and validation of a windthrow probability model for Sitka spruce in Ireland. Irish Forestry 66: 74-84.

Ní Dhubháin, Á., Bullock, G., Moloney, R., Upton, V. 2012. An economic evaluation of the market and non-market functions of forestry. Unpublished final report of Econtrib project. COFORD, Department of Agriculture, Food and the Marine, Dublin.

Nieuwenhuis, M., Williamson, G. 1993. Harvesting Coillte's forests: the right tree at the right time. Irish Forestry 50: 123-133.

Nieuwenhuis, M., McHugh, F., Malone, L. and Layton, T. 1999. Development and evaluation of pre-harvest inventory and cross-cutting simulation procedures to maximise value recovery. Irish Forestry 56: 29-38.

Nieuwenhuis, M., Nugent, C. 2000. The evaluation of a national forest harvest scheduling system for Ireland - two case studies. International Journal of Forest Engineering 11: 23 - 32.

Nieuwenhuis, M., Tiernan, D., 2005. The impact of the introduction of sustainable forest management objectives on the optimization of PC-based forest-level harvest schedules. Forest Policy and Economics 7: 689-701.

Nieuwenhuis, M., Dooley, T. 2006. The effect of calibration on the accuracy of harvester measurements. International Journal of Forest Engineering, 17: 25-33.

Nieuwenhuis, M., Purser, P. 2007. STANDMODEL: dynamic yield models for larch, ash and mixtures. Irish Timber and Forestry 16: 22-23.

Phillips, H., Redmond, J., MacSiúrtáin, M., Nemesova, A. 2009. Roundwood production from private sector forests 2009-2028: a geospatial forecast. COFORD, Dublin.

Purser, P., Wilson, F., Carden, D.R. 2009. Deer and forestry in Ireland: A review of current status and management requirements. Woodlands of Ireland.

Quinn, L. 1996. An overview of Coillte's resource inventory and timber production forecasting. Irish Forestry :62-68.

Tiernan, D., Nieuwenhuis, M. 2005. Financial optimization of forest-level harvest scheduling in Ireland – a case study. Journal of Forest Economics 11: 21-43.

Additional supporting material

Barrett, F., Nieuwenhuis, M. and Somers, M. 2004. PractiSFM - multi-purpose inventory and decision support for sustainable forest management. Forest R&D Ireland 2004 Underpinning Industry Development Tullamore, Ireland, September 20-21 2004, pp.73-76.

Barrett, F. and Nieuwenhuis, M. 2005. PractiSFM - Estate Management Decision Support System. e-Business for Forestry, November 24 2005.

Barrett, F., Nieuwenhuis, M. and Somers, M. 2005. PractiSFM - an operational multi-resource inventory protocol for sustainable forest management in private woodlands in Ireland. [Published Abstract], IUFRO conference on Sustainable Forestry in Theory and Practice, Edinburgh, April 6-7 2005.

Barrett, F., Nieuwenhuis, M. and Somers, M. 2005. PractiSFM - an inventory and decision support system linking forest policy with the sustainable forest management of private forests in Ireland. International Conference on Bridging the Gap Policies and Science as Tools in Implementing Sustainable Forest Management, Alnarp, Sweden, October 17-21 2005.

Barrett, F., Nieuwenhuis, M. and Somers, M. 2005. SFM in Practice - PractiSFM. Sustainable forestry in theory and practice: recent advances in inventory and monitoring, statistics and modelling, information and knowledge management and policy science, Edinburgh, April 6-8 2005.

Clifford, B., Nieuwenhuis, M. 2010. A GIS-based multi-objective decision support system for the optimal management of forests on peatlands in Ireland. Association of American Geographers Annual Meeting, Washington D.C, April 14-18 2010.

Nieuwenhuis, M. 2008. PractiSFM II - a link between the inventory and management needs of the private forestry sector and the need for production forecasts. COFORD technical workshop - Forest growth modelling and wood production forecasting, Portlaoise, Ireland, May 12 2008.

Nieuwenhuis, M. and Nugent, C. 1999. Country-wide and regional wood volume regulation with a harvest scheduling decision-support system. Irish Forestry 56: 28 - 42.

15 Computer-based tools to support decisions in forest planning in Italy

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15.1 Introduction

15.1.1 Description of the forest sector in Italy

15.1.2 Extension of forests and general features

In Italy, forests cover 29% of the total country area and other wooded lands (OWL) cover a further 6% (INFC 2007; Table 1).

Table 9. The surface of forest and other wooded land in Italy.

Land use	Area (ha)	Percentage
Total country area	30 132 845	100%
Forests	8 759 200	29%
Other wooded lands	1 708 333	6%
Forest + other wooded lands	10 467 533	35%

High forests cover nearly 55% of the forest area and coppices are extended on the remaining 45%, with a wide prevalence of the former silvicultural system in North-Central areas. Dividing the Italian territory in the main geographical zones (Alps, Northern and Central Apennines, Southern Apennines and Islands) we can see, as expected, that most of the forests are located in the Alpine area and in the Northern-Central Apennines (3,600,000 ha) and that most of the OWL is located in the Southern Apennines and Islands. The relative forest cover per administrative region varies between 62% (Liguria, North-West of the country) and 8% (Puglia, South-East of the peninsula).

In the last 20 years, the annual increment of total wooded area has been 0.30%: the land cover changes are mostly due to the abandonment of farming and breeding practice (especially in mountainous areas) and natural recolonisation of pastures and crops by shrubs and young trees.

The forest type was classified during the INFC field surveys on the basis of the prevalent tree species in the sample plots: coniferous forests cover 20% of high forest surface, deciduous broadleaved forests are 70% and evergreen broadleaved forests are 10%. Temperate oak forests, beech forests and Mediterranean oak forests, exceeding 1 million ha each, are the most common forest categories. Among the coniferous forests, Norway spruce forests are the largest with an area of 586,082 ha (7% of the total Italian forests).

The total growing stock of Italian forests is 1,269 million m^3 and the average growing stock is about 145 m^3 ha^{-1}, distributed as following:

- Alps: 663 million m^3 (197.9 m^3 ha^{-1});
- Northern-Central Apennines: 366 million m^3 (115.1 m^3 ha^{-1});
- Southern Apennines and Islands: 241 million m^3 (107.9 m^3 ha^{-1}).

Aboveground dry biomass is 874 million Mg in total, and 100 Mg ha^1 on average. The total annual gross increment of Italian forests is 35,862 million m^3 (4.1 m^3 ha^{-1}); depending on the main geographical areas, the distribution of this variable is the following:

- 5.1 m^3 ha^{-1} in the Alps;
- 3.5 m^3 ha^{-1} in Northern-Central Apennines;
- 3.4 m^3 ha^{-1} in Southern Apennines and Islands.

15.1.3 Main uses of the forests and main stakeholders

Since the foundation of the Italian state, the major use of forests in Italy has been the provision of timber and wood. The other functions have been gradually gaining importance, especially during the last 30 years, and forest management is increasingly oriented towards multifunctionality. Forests play an important role in the protection of settlements, railways, main roads and socio-economic infrastructures and have an important recreational use as they offer an ideal venue for such activities and the access is free and open to all. About 3.5 million ha of forests and other woodlands are included in national and regional protected areas or Natura 2000 sites where management aims at habitat conservation.

As a consequence of multifunctionality, wood harvesting is affected by many constraints so that only one third of the annual increment of volume, on average, is exploited. Furthermore, the production of timber is too fragmented and primary industries of wood processing are too small and scattered on the territory.

Non-wood products *de facto* represent a significant, but inestimable, economic value, because products are often collected and used directly from the gatherers and are rarely sold in the market.

According to this multiplicity of uses, there are many stakeholders involved in the forest management processes: both public and private forest owners, the timber and wood processing industry, direct users (hunters, gatherers, excursionists), public opinion both as individuals and as associations.

15.1.4 Ownership structure and legal framework

Concerning the ownership structure, private ownership prevails both in forests (66.2%) and in other wooded areas (49.7%); only in Trentino Province (72.2%) and the Abruzzo Region (60%) is the area of public forests greater than that of private forests.

The presence of forest management plans in Italy is rather limited, although the law makes forest management plans compulsory for public forests.

As for the public sector, the diffusion of single forest property plans is very different: in the North-East area of the Alps, 94.1% of public forests are managed by a plan, but this value is not representative of the national situation.

Only in some alpine regions private forests are managed by a plan under control of the local forest administration. The very small size of most private properties would require a much greater diffusion of owner associations to make forest planning management feasible and efficient. The creation of cooperatives among the private forest owners could also facilitate the match of demand with such a dispersed wood supply.

15.1.5 Description of forest management planning problems in Italy

Today in Italy, from the administrative point of view, it is possible to distinguish three hierarchical levels of forest management planning:

- Region: at this level, planning provides guidelines for forest protection and sustainable forest management at regional scale for the long term (usually 10 years) either for public or private forests.
- District: at this level, planning is conceived as a tool for managing forest areas characterized by similar operational contexts on a landscape level without distinction between public and private forests; it is a suited scale to address connections between forest management and other planning tools like urban development and nature conservation plans.
- Single forest property: at this level, planning has to translate guidelines and constraints coming from higher planning levels and laws into operational prescriptions to implement in the forest compartments. This level also allows both gaining a more detailed knowledge of stands and dictating the rules on how to operate in the forests.

Considering the levels of forest management planning in Italy and the FORSYS suggested dimensions, four prevalent forest management problem types are reported in this document. Each of them represents a sort of macro box for the various specific forest management problems of Italian forests, which are sometimes characterized by the same dimensions. According to this approach, a description of the four general problem types is given, and the main forest problems (10 in total) which refer to each problem type are listed and characterized in the present paper.

The problem types were distinguished by the codes “RI” (Region, Italy), “DI” (District, Italy), “SIFOPI” (SIngle Forest Property, Italy) and “SI” (Stand, Italy), and they are described in Table

2.

Table 10. ***Prevalent problem types in Italy according to FORSYS dimension categories.***

Dimensions		Problem types			
		RI	DI	SIFOPI	SI
Temporal scale	Long-term (strategic)	x	x		
	Medium-term (tactical)			x	
	Short-term (operational)				x
Spatial context	Non-spatial	x	x	x	
	Spatial with neighbourhood interrelations				x
	Spatial with no neighbourhood interrelations				
Spatial scale	Stand level				x
	Forest level		x	x	
	Regional/national level	x			
Parties involved	Single decision-maker			x	x
	More than one decision-makers	x	x		
Objectives	Single				
	Multiple	x	x	x	x
Goods and services	Market non-wood products	x			
	Market wood products	x	x	x	x
	Market services	x			
	Non-market services	x	x	x	x

The **problem type called "RI"** is characterized by a strategic temporal scale, by a non-spatial context, in the sense that there is no concern with locational specificity and with neighbourhood interrelations, and by a regional level as spatial scale. More than one decision-maker has the power to decide and often other parties (stakeholders) with no formal decision-making power may influence the decision. The management planning problem addresses more than one objective and it addresses all products and services.

One example of the "RI" problem in Italy is forest fires prevention and fighting. Local authorities (Regions, Districts, Municipalities, Park Services) have to evaluate forest fire risk and to prescribe measures of prevention and of intervention, and therefore to elaborate the forest fire protection. There are many people involved both in fire prevention and fire management (Department of Civil Protection, State Forestry Corps and many volunteers), therefore the availability of tools to make decisions on managing resources and people, and coordinating field operations is essential.

Another sort of problem that pertains to the problem type "RI" is the control of natural expansion of forest over grassland. Forest managers working at regional scale, often have to assess the factors characterising farmland sites prone to natural conversion from crop growing and pasture to forests and other wooded land, and for predicting the probability of such a land-use change (Corona et al. 2008).

The **problem type "DI"** is characterized by a strategic temporal scale, by a non-spatial context, and by a forest level as spatial scale; the problems concerning the DI problem type, in fact, regard forest landscape with several stands grouped together for a common purpose. More than one decision-maker has the authority to decide and often other parties (e.g. Mountain Community, Forest District) may influence the decision. The management planning problem addresses more than one objective and it addresses market wood products and non-market services.

An example of problem type “DI” in Italy is the assessment, ranking and mapping of forest functions with involvement of stakeholders. The process of forest classification according to their prevailing functions has consequences at social, economic and political levels and it has to take into consideration the interests of various stakeholders. In fact, on the one side there are the forest owners interested in the productive function of forests, but on the other side there are environmental associations lobbying for the preservation of forests and furthermore there are owners of tourist activities interested in recreational functions.

Another problem sharing the dimensions of problem type “DI” is the evaluation of potential wood supply for a specific use (Frombo et al. 2009). Forest managers are called to determine the quantity of biomass that is convenient to collect, to determine its position on the territory, and to control forest biomass exploitation to maintain a sustainable production (Freppaz et al. 2004).

A further problem framed in problem type “DI” that forest managers have to face is the optimization of forest roads network for multipurpose objectives, taking into account that road effects and uses may be beneficial and detrimental.

The **problem type “SIFOPI”** is characterized by a tactical temporal scale, by a non-spatial context, and by a forest level as spatial scale. A single decision-maker has the authority to decide. The management planning problem addresses multiple objectives and it addresses market wood products and non-market services.

A major pattern of problem type “SIFOPI”, in the public forests, is the high cost of inventory operations, aggravated by the drop of timber prices. Research is developing procedures to implement more expeditious surveys, making extensive use of sampling, GIS, Remote Sensing and GPS technologies, while respecting the accuracy of the estimates. In this respect, the use of airborne LiDAR data seems to be particularly promising.

Another kind of issue faced by the planner to mark as problem type “SIFOPI” is the estimation of the amount of the allowable cut in forest compartments. In the current context of multifunctionality, the forest manager is required to estimate allowable cut integrating many variables concerning site condition, stand attributes, needs of the owner and stakeholders, legislative constraints, and ecological and social functions overlapping the productive one. The simple algorithms referring to normal forest models are of little help to solve a semi-structured problem usually addressed in an empirical or heuristic way according to the manager's ability.

The regulation of grazing rights in public forests is another kind of "SIFOPI" problem. Many types of woodland owned by municipalities and communities are affected by grazing rights. Local breeders can graze their livestock in the forest. Depending on loading cattle and site condition, grazing can damage soil characteristics and regeneration of tree species. Therefore it should be carefully regulated through a multifunctional approach. However, breeders do not often accept rules and constraints and this fact generates conflicts between stakeholders whereas funds for compensation are very scarce.

The **problem type "SI"** is characterized by an operational temporal scale (planning horizon usually extending throughout one year), by a spatial with neighbourhood interrelations context, and by a stand level as spatial scale. A single decision-maker has the power to decide. The management planning problem addresses multiple objectives and it addresses market wood products and non-market services.

A kind of problem with the profile "SI" faced by the forest manager is the identification of the typology of felling: the forest manager has to propose the location of the extraction path, the principal skid road and the stream and wetland crossings as well as the general location of appropriate erosion control measures.

Another problem type "SI" is the identification of the most suitable harvesting system for timber extraction. Silviculture and forest mechanization usually have opposite needs: silviculture takes care of the ecological aspects and aims to reduce cuttings according to new functions and utilities assigned to forests. On the other hand, work and machine investment costs increased so that small cuttings are not sustainable because high mechanization requires high productivity. The choice of the most suitable harvesting system has become crucial to reduce the cost of logging operations, as well as the negative environmental impacts and skidding damages.

To tackle problem types "RI" and "DI", participatory planning could be applied. In fact:

- participatory planning is spread particularly at medium and long-term;
- from a spatial point of view, participatory planning is mostly required at forest level and sometimes at regional/national level.

In Italy the participatory approach in forest planning has quickly gained attention in the last decade. As there is still a lack of experience, there is uncertainty concerning both participation within forest planning and methodological aspects. As a consequence of this situation, various experiences of participatory planning in Italy have been aimed at performing, through case studies, a procedure capable of integrating participation into the tactical level of forest planning and at developing a method suitable to all different situations present in Italy.

15.1.6 Use of participatory techniques to deal with forest management planning problems in Italy

Referring to the problem type regarding the definition of forest functions, Table 3 describes the different methods and tools used to involve the parties in the participatory process to face this kind of forest management planning problem.

The definition of forest functions was the only issue for which reliable literature and case studies were found.

We can only present the data relating to methods and tools used in the participatory process for the solution of this problem, because it is the only issue for which we found documentation in the literature. Different participatory strategies can be used to address the same problem, as shown in the table.

Table 11. ***Description of the phases of forest planning process in which participants are involved, and the participatory techniques most frequently used.***

Problem type	Phases	Participation	Methods/Tools used
RI	Intelligence	Restricted and Public	Interviews Questionnaires Ranking techniques Multiple criteria decision analysis Group work Focus group
	Design	Restricted and Public	Group work Focus group
	Decision-making	Restricted	-
DI	Intelligence	Public	Information/consultation Interviews Questionnaires
	Design	Restricted	Consultation/involvement Focus-group Workshops Brainstorming
	Decision-making	Restricted	-

From the information collected in the above table, it is clear that participation in Italy, in solving both problem types RI and DI, occurs mostly in the intelligence and design phases, so that it can be defined as participatory planning with information exchange.

According to the simplified version of Arnstein's ladder of participation - published by the International Association of Public Participation (IAP2 2007) - the level of public participation between consultation and involvement in forest planning in Italy can be classed as intermediate. The first level aims to obtain public feedback on analysis, alternatives, and/or decisions; the second level works directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.

The methods mentioned above in some cases are integrated in the forestry decision support system (DSS), but they are frequently used independently.

15.1.7 The objectives of the country report

DSS are not widely used in Italy in forest management planning routines. DSS applications are more frequently addressed to other fields or meant for more extensive uses than forest planning (land planning, natural hazard evaluation, environmental impact assessment).

However, for some years there has been an attempt to introduce computerized procedures in forest decision-making processes both in strategical and tactical planning, but a state-of-the-art procedure has not yet been produced.

The objectives of the country report were:

a) to provide information about computerized systems, which can be DSS, spreadsheets, etc. created to address the relevant problem types in Italy;
b) to describe briefly the key features of each computerized system;
c) to analyse the main weaknesses of the framework where computerized systems are contained, with some suggestions on how to overcome these limits (lessons learned).

15.2 Materials and methods

15.2.1 Data and information available about management planning in Italy

The primary sources used to obtain a general framework about forest management situations in Italy were the results of the Italian National Forest Inventory 2005 (INFC 2007; INFC 2009). Information presented in the review of forest computerized tools was collected through bibliographical search and by some target interviews with tool developers and experts. Bibliographical search was carried out mainly on scientific and technical websites. In some cases the tool developers were contacted in order to obtain clarifications or additional information about their products.

15.2.2 Data analysis and data processing

Data regarding forest management situations in Italy collected from the Italian National Forest Inventory 2005 was processed to obtain data in percentages. At times, it was necessary to aggregate the data regarding regions to provide a sub-national framework.

A comprehensive search was carried out to find all kinds of DSS used in the Italian forest sector and, eventually, only the DSS linked to the problem types relevant in Italy were selected.

The general structure of the FORSYS Wiki page (http://fp0804.emu.ee/wiki/index.php/DSS_Template) dedicated to forest DSS was used to describe each system. In particular the following issues have been addressed:

1. what is the function of the tool;
2. the idea that inspired the development of the tool;
3. information about the designers and developers;
4. architecture of the tool;
5. models used in the tool (if available);
6. software used in the tool;
7. application of KM techniques;
8. methods for participatory planning;
9. context of usage and users of the tool.

An acronym was assigned to each tool, even if missing in the original literature.

The Wiki page has not been updated in a satisfactory manner for most of the Italian forest DSS; only two DSS, in fact, are discussed on the Wiki (June 2011). Regarding participatory planning, two case studies, concerning experiences realized in the framework of district plans, can be found.

15.3 Results

In this section, we describe the characteristics of computerized tools that have been developed and are used to address some of the kinds of problem types described in the first paragraph.

Table 4 gives an overview of the computerized tools that address specific problem types.

For each of the four problem types, at least one DSS/computerized tool is reported, but not all the 10 forest problems that are described here have a DSS which addresses them. The reasons for this fact can be explained as follows:

- the problem, although important, has only recently arisen and it is still in its "individuation" phase (e.g. control of natural expansion of forest over grassland);
- the Italian timber market has so far been mostly based upon imports from abroad, but Italian timber will most likely become more important in the near future because of the increasing prices of imported products (e.g. estimation of the amount of the allowable cuts in forest compartments, identification of the typology of felling);

- the fragmentation of the legal framework among a number of geographic levels (national, regional, district and municipal) and local administrations discourages the development of widely usable tools (e.g. regulation of grazing rights in public forests);
- the problems related to natural hazards and risks for humans (e.g. fire fighting) depend greatly on others and have a tremendous impact on decision-making.

It is handy to note, that little information is available on KM techniques used for the identification, analysis and solution of the problem types.

The KM tool most frequently used is the database. A database is one of the three fundamental components of a DSS architecture. Databases are integrated data files organized and stored electronically in a uniform file structure that allows data elements to be manipulated, correlated, or extracted to satisfy diverse analytical and reporting needs. A database file is managed independently on the software necessary to perform the manipulations. In spite of that, a database itself doesn't help in the phases of problem identification, problem modelling and problem solving: in fact, raw data will not become knowledge unless extracted and processed into information.

Just one among the examined computerized tools shows methods for a real participatory planning.

Table 12. ***Overview of the main features of computerized tools.***

Problem type	Dimensions	Kind of problem type	Computerized tool/DSS	Models and methods	KM techniques	Methods for participatory planning in development	Methods for participatory planning in application	References
RI	Long-term Non-spatial Regional level More than one decision-maker Multiple Market non-wood products Market wood products Market services Non-market services	Evaluation of forest fire risk and prescription of measures for prevention	CHARADE	Mathematical fire spreading model, task oriented method	Database	-	-	Avesani et al., 2000
			ManForFirE	Rothermel wildland fire spreading model, cost-path functions	Database Work flow	-	-	Mussumeci and Condorelli, 2001
		Control of natural expansion of forest over grassland	-	-	-	-	-	-
DI	Long-term Non-spatial Forest level More than one decision-maker Multiple Market wood products Non-market services	Assessing, ranking and mapping forest functions	ForFun	Multi Criteria Decision Making	Database	-	Interviews Questionnaires Focus group Workshop Brainstorming	Corona et al., 2010 Saaty, 1980 Saaty, 2008
			LEaRNForME	Artificial Neural Networks, hydro-geological protection models	Database Website	-	-	Scrinzi et al., 2005 Scrinzi et al., 2006
		Evaluation of potential wood supply for a specific use	Biomass-TA	Optimal supply models for area unit, long-term cumulative supply models and geographic cost model, decision analysis models	Database	-	-	Bernetti et al., 2008
			PoodyBLEP	Optimization model, wood supply model, biomass growth dynamics model, carbon sequestration models, strategic decision model	Database	-	-	Freppaz et al., 2004 Frombo et al., 2009

Problem type	Dimensions	Kind of problem type	Computerized tool/DSS	Models and methods	KM techniques	Methods for participatory planning		References
						in development	in application	
		Optimisation of forest roads network for multipurpose objectives	-	-	-	-	-	-

A brief description of the tools listed in the table is given below.

CHARADE ("Combining Human Assessment and Reasoning Aids for Decision-making in environmental Emergencies") is an interactive planning system embedded in an intelligent decision support system aimed at supporting firemen in the whole process of fire fighting, including situation assessment and planning activities (Avesani et al. 2000).

The problem of forest fires in the Western Mediterranean area inspired an Italian (Alenia, IRST, Italsoft), French (Alcatel and Thomson LCR) and Spanish (CESELSA) consortium to develop the system.

The design of the interactive system functions was performed following a task model of the forest fire management activities that was built upon a careful analysis of the activity conducted by a task-oriented methodology. This approach led to splitting the system into three modules: situation evolution and assessment module, intervention planning and resources allocation module, resources management module.

CHARADE is based on a database management system (Informix or Oracle), a Geographical Information System (URIAH), and an object-oriented environment ($SPOKE^{TM}$) for software application.

The KM tools used in the CHARADE DSS consists of databases and a workflow.

The users of the system are firemen working in a regional centre in charge of supporting local fire fighting. CHARADE is currently used in the French South East Inter-Regional Centre of Operational Coordination of Civil Security and the International Training Centre of Civil Security. Thus, the context of use concerns both researchers and consultants.

ManForFirE ("Management of the Forest Fire Emergency") is a spatial DSS for the management of forest fire emergency. The DSS was designed by the University of Catania to address the gap of tools in the operational headquarters of the Italian Civil Security (Mussumeci and Condorelli 2001) to be able to develop realistic scenarios, to forecast the evolution of forest fires, to plan and manage interventions.

The tool was developed in a GIS environment. The procedure consists of a spatial analysis that allows the fire to simulate spreading by the implementation of the Rothermel's model on specific raster layers and in a network analysis extended to the road network system, which allows users to define and to update the best starting locations and routes for fire fighting vehicles, evaluating also their travelling time.

The KM tools used in ManForFirE also consist of databases and a workflow both in development and application of the tool.

The developers of the tool frequently contacted entities such as the Fire Department, Forest Service, Civil Defence, etc., and they wrote the first drafts of agreements and memoranda of understanding, but because of institutional problems, these intentions have not been put into practice. For these reasons, so far no authority has used this tool, and the usage has been limited to researchers.

ForFun is a computerized tool that allows the ranking of the functions performed by a unit of forest land. The ForFun system was developed by the Department of Forest Environment and Resources, University of Tuscia, to support forest managers in the participatory process of medium-scale forest planning (Corona et al. 2010) involving a large number of stakeholders.

The forest functions are sorted by relevance based on a score derived from the data on site and stand attributes stored in the information system and from the preferences of the stakeholders involved in decision-making. The assignment of a score to each function is done through a multi-criteria algorithm. The criteria for the attribution of the score to functions are: forest type vocation, site suitability and importance attributed to each function by the stakeholders.
The values of the first two criteria are quantified through a combination of indexes, different for each function. The importance attributed by the stakeholders to each function is obtained through the elaboration of a Saaty matrix (Saaty 1980; Saaty 2008) filled by using data from a simple questionnaire where stakeholders are asked to list the functions in order of relative importance.

The results provided by ForFun can be converted into a map of the predominant functions and highlight possible conflicts which may emerge in the territorial units with very similar scores for different functions. The tool is not really an application software, it is rather a methodology which uses indexes developed by GIS analysis and other information taken from the regional and district GIS. The processing and the final results are performed in Excel. The KM tools used in ForFun are databases.

This methodology was successfully applied in the Asiago's Plateau project and it is currently used in a second pilot project for the Mountain Community of Cadore – Longaronese – Zoldo in the Veneto Region. Its range of use is therefore extended to researchers, consultants, and stakeholders.

LEaRNForME (Landslide Erosion and Runoff: Neural Forest Estimation Models) is a tool that supports forest and land planners in evaluating the protective value of forests (Scrinzi et al. 2006). The idea that inspired the development of this tool was to provide forest managers with an instrument for the medium-scale land planning able to recognise the role of the vegetation cover in controlling some hydrogeological instability phenomena. It was designed and developed within Ri.Selv.Italia National Project, funded by the Ministry of Agriculture and Forestry (Scrinzi et al. 2005).

Regarding the running of the DSS, the user describes the predisposition as instability phenomena (shallow landslides, runoff, water erosion) of a homogeneous land unit (propensity) and the vegetation cover functionality in contrasting these events (functionality), selecting specific variables proposed by the system. Then Artificial Neural Network (ANN) models are applied to evaluate the propensity and functionality which are ranked in a scale from 1 to 5. Finally the two synthetic numeric results are 'translated' into four levels (equilibrium level, protection value, management constraint level, action priority) with descriptive and planning significance which can be used by the forest manager to broadly identify the silvicultural system applicable. LEaRNForME integrates two KM tools, that is to say artificial intelligence and website.

After being applied in three case studies (Val Antrona, Val di Fassa and Acqualagna), LEaRNForME has not yet found any actual application, although a training version of the tool can be used on-line through the project website. It can be used by researchers and consultants.

BIOMASS-TA is a system for biomass and energy planning in the Tuscany Apennines designed by a group of researchers from the University of Florence (Bernetti et al. 2008). The aim of BIOMASS-TA is to quantify, with territorial detail, the potential demand for residual biomass for thermal power use. The tool was developed to cope with the increasing interest in the production of energy from renewable resources, especially forestry ones.

In developing the DSS, an approach based on Multi-Criteria Evaluation (MCE) has been used, based on the Analytic Hierarchy Process – AHP – (Saaty 1980). The DSS processes geographic data such as land use, roads, residential and productive areas, civil and administrative buildings, methane distribution network and, of course, forest biomass. All of this data was represented on a set of GIS raster layers (75x75 m resolution) and processed by means of Map Algebra algorithms and overlay functionalities. The BIOMASS-TA DSS uses the database of the GIS software as KM tool. The KM tool is fundamental in the gathering of information.

According to the information available, BIOMASS-TA has so far been applied only by researchers in a case study in the Emilia-Tuscan Apennines (Prato province) on an area of about 440 km^2, almost completely covered by woodlands (wood index 82%).

PoodyBLEP is a GIS-based Environmental DSS (EDSS) developed by a group of researchers from the Universities of Genova and Savona (Frombo et al. 2009). The EDSS should help local authorities and/or private companies in defining effective, commercially appealing and environmentally sustainable strategies for biomass use for energy production. This idea inspired the development of the tool.

The DSS, which uses vegetation growth models and carbon sequestration models, is characterized by three modules: a GIS, a data management system and an optimization module; this latter is in turn divided into three sub-modules: strategic planning, tactical planning, and operational management. Moreover, the optimization problem is structured through a set of parameters and equations able to encompass different energy conversion technologies (pyrolysis, gasification or combustion) in the system. The architecture of the DSS integrates a database as a KM tool. All data and calculations are stored in a relational database (Frombo et al. 2009).

So far PoodyBLEP has been applied in a case study on the Liguria Region (Val Bormida, Savona Province). Thus, it has mainly been utilised in the research environment.

SAMSIZE is a computerized tool used to determine the number of relascopic sample plots to be performed in each ‘stratum’ in which the managed forest had been previously divided within a stratified systematic sampling inventory design, with respect to an expected sample error (relative standard error of basal area per hectare). The tool has been designed and developed by the Forest Monitoring and Management Research Unit of the Italian Agricultural Research Council to support the newly adopted inventory system for forest management plans in Trentino Province (North East of Italy).

It was developed in Visual Basic and implemented in a Microsoft Excel environment; currently it is also available in Microsoft Access as part of the Trentino regional database of forest management plans.

Regarding the operation of the tool, SAMSIZE makes use of three weighted variables supplied by the planner at stratum level: variability, structure complexity and exploitation temporal proximity. The planner gives a score of each variable, under the principle of assigning more plots to strata having higher variability and complexity and more close to exploitation epoch. The total number of sample plots and an expected overall sample error can be imposed by the planner, as well; modifying the values of the described parameters, useful information about inventory costs under different conditions and desired precision level can be obtained.

The tool has been operatively used since 2009 by forest managers from the Forest Service in Trentino Province, and therefore its users have extended from researchers to consultants (professionals who perform forest management plans) and to stakeholders (the public forest administration of Trentino, which is responsible for 300,000 ha of public and private forests).

ProgettoBosco Assestamento (PBA) is a data-driven DSS aimed at optimising the data collection on forest and forest management by implementing a nationally standardized method and tool for monitoring and supporting forest planning and forest policy choices (Ferretti et al. 2004). The idea that inspired the designers and developers of the tool (researchers from the Italian Agricultural Research Council) was the standardization at national level of the description of forest areas under a unique technical and management perspective.

The tool organizes data input and it records all important inventories and description data. Afterwards, it processes the data, it produces standardized tables with the main dendrometric and descriptive results compiled and summarized by forest compartments which are the basic spatial units of stand level. The methodology used for the development of the DSS can be summarised as follows: cooperation, successive approximations and experimentation (Ferretti et al. 2011). PBA uses Microsoft Access as its database management system and ESRI ArcView 3.1 as software to manage the related mapping data. PBA uses a database as a KM tool integrated in the application: it strongly supports the phase of intelligence gathering and partly the phase of design and problem modelling.

At the moment, PBA is already under implementation in some Italian Regions (Bianchi et al. 2006), by both public institutions (stakeholders) and freelancers (consultants).

The **FOpP** DSS (Forest Operations Planning) defines whether a specific skidding system may be used in a forest area (according to its technical capabilities) and determines where that system should work to reduce operational costs and increase the value of wood. FOpP is the product of a PhD thesis (Lubello 2008) whose origin was inspired by the intention to help the forester make decisions about which skidding system is the most viable according to standard assessment data and geography.

ModelBuilder tool of ArcGIS 9.2 (ESRI) was chosen to build the mode'ls content in FOpP because it is a powerful tool that does not require knowledge of any programming language. The Models are Defining Skidding Systems and Systems Optimization and Costs. Defining Skidding Systems creates one feasibility map for each skidding system. Systems Optimization and Costs establishes technical and economic preferences for the skidding system.

FOpP uses a geodatabase as a KM tool: according to the author's definition, a geodatabase is a comprehensive series of application logic and tools for accessing and managing GIS data (Lubello 2008). In this case the database strongly supports the phase of intelligence gathering.

FOpP is not directly available to end users, but may be referred to the author who makes it available for free. Its usage has so far been limited, according to information available to researchers.

To evaluate the success of a computerized tool in addressing the problems, we must take into consideration the basic architecture for DSS. Structurally, a DSS has four essential components (Holsapple 2008):

(ii) a language system (LS): consisting of all messages the DSS can accept;
(iii) a presentation system (PS): consisting of all messages the DSS can emit;
(iv) a knowledge system (KS): consisting of all knowledge the DSS has stored and retained;

(v) a problem-processing system (PPS): trying to recognize and solve problems during the making of a decision; the DSS's software engine.

Regarding the DSS described above, in general we can say that strong attention is dedicated to the phase of problem-processing system development, but there is weak awareness given to the design of the knowledge system and to the participatory process.

Analysing how and why each computerized tool was (or was not) successful in addressing the problem with a focus on the impact of:

- development process;
- models and methods;
- KM techniques;
- participatory processes;

we considered, for each item, respectively, the following aspects:

- the involvement of people with different disciplinary expertise (engineers, computer scientists, communications experts, foresters, land planners, etc.) (A1);
- the amount and specificity of data required by the models and methods (A2);
- the integration of KM tools as components of the DSS architecture and the use of KM tools to support any participatory process DSS development (A3);
- the initial commitment and real involvement of stakeholders and end-users both in the DSS development process and in the usage of the tool (A4).

Based on these concepts, the success of each computerized tool in addressing the forest management planning problems in Italy is evaluated in the following table (Table 5) by a four-qualitative rating scale ranging from excellent to weak.

Table 13. ***Evaluation of computerized tools' success by four-qualitative rating scale (excellent, good, moderate, weak).***

Problem type	**DSS**	**Development process**	**Models and methods**	**KM techniques**	**Participatory processes**
		A1	A2	A3	A4
RI	CHARADE	good	moderate	weak	moderate
	ManForFirE	good	good	weak	moderate
DI	ForFun	good	good	weak	good
	LEaRNForME	excellent	good	moderate	good
	Biomass-TA	moderate	good	weak	moderate
	PoodyBLEP	moderate	good	weak	moderate
SIFOPI	SAMSIZE	good	good	weak	good
	PBA	moderate	moderate	weak	weak

SI	FOpP	weak	moderate	weak	weak

15.4 Discussion and conclusions

The analysis of information found in the literature showed that in the forest field there is sometimes an inappropriate use of the term DSS: systems are consequently classified as DSS although they should not be. According to the Johnson and Gordon definition (2003), DSS are tools which:

- are policy/management-oriented (decision);
- deal with complexity (support);
- have a clear, reproducible protocol (system);
- are computer-based.

DSSs are not:

- Habitat Suitability Indexes (HIS) alone;
- research models;
- forest certification standards;
- informal expert systems.

Reynolds (2005) states that "while geographic information, spreadsheet, and database systems may be critical components, or even the foundation, of a DSS, it stretches the definition of a DSS beyond usefulness to classify these types of applications as DSS. Numerous simulation systems have been developed to support many aspects of forest planning (Schuster et al. 1993), but most should be considered as potential tools in a DSS framework as opposed to DSS *per se*."

The bibliographical research has highlighted the fact that in Italy, in most cases, computerized tools designed for forestry are not real tools available for end users, but they are rather approaches and methodology developed in research programs described in scientific articles, conference proceedings, graduation or doctoral thesis (Cavalli 2010, personal communication).

Most of the described tools have the potential to become, with some adjustments and improvements, actual forest DSS. On the other hand, some tools carried out to support forest managers have not been classified and circulated as DSS in a former phase, although in fact they are (i.e. LEaRNForME).

Concerning DSS usage, the review highlighted a general lack of full-response applications in forest management. The main reasons for this may be the following:

- most developments are linked to research projects and/or PhD thesis, not to operative programs assigned and sponsored by public or private institutions, being therefore limited in space, time and resources;
- the Italian market of forest products, services and resources is very small and the demand of sophisticated, and expensive, software is very low;
- there is a very high fragmentation of competences and responsibilities on Italian forest heritage, shared by a number of national and local public administrations and lots of small private owners.

In addition, some other critical weaknesses may be pointed out:

- information about models, KM techniques and system architecture is often scarce and not so clear; authors sometimes do not refer to a common (and standardized) language and many definitions are not globally accepted nor unique;
- some tools seem to be static, in the sense that they are not updated, and there is not even any information available on their websites;
- most participatory methods are used independently in the frame of the planning process, only in a few cases are they integrated into computerized tools.

Based on this, some possible measures and actions to be undertaken in the years ahead may be suggested as follows:

- to involve more private professionals and public administrations in developing forest DSS, also in view of understanding their real needs;
- to establish a network of researchers and forest managers working on DSS development, to share knowledge and methods, with a particular care in standardized ontology and architectures and software platforms as well;
- to ensure medium/long-term maintenance, user assistance and updating of the DSS developed, passing from a ‘project’ logic towards more stable processes and programs. This will require adequate and definite funds and human resources which could be obtained involving more institutions as users (see previous point) and supplying many good examples on DSS usefulness in operational processes;
- to promote DSS development in those sectors which are crucial for specific Italian situations, like environmental emergencies management, tourism/recreational value of forests, new green energy sources, hydro-geologic protection and the preservation of human presence in mountain regions;
- to integrate participatory processes into the available DSS or to develop DSS which integrate participatory methods into their systems.

With reference to the described tools, we can say that, in general, they address the problems effectively and they provide helpful ideas for the forest managers. Unfortunately, they are not widely used in the forest planning sector in Italy.

Some tools, some better than others, have a hybrid architecture that satisfies the requirement to interactively involve the user in the decision process (e.g. CHARADE and ManForFirE).

The use of the Artificial Neural Network for the implementation of expert systems (as in the case of LEaRNForME) is a suitable way to interpret the 'experience' of expert people and to build tools through which the forest manager can take a decision in an objective manner.

Regarding knowledge management (KM) tools, it appears there is a widespread application of databases as integrated components of computerized tools. Vice versa, KM tools are not yet widely used to support participatory planning.

Regarding participatory planning, in Italy there are many forest planning processes that involve stakeholders, giving them the possibility to influence the planning process. Furthermore most processes have been developed since the start of the decision-making process.

On the other hand, as mentioned above, there is a lack of experience regarding methodological aspects and in the integration of participatory tools into a DSS or a computerized tool.

References

Avesani, P., Perini, A., Ricci, F. 2000. Interactive Case-Based Planning for Forest Fire Management. Applied Intelligence Journal, Vol. 13, pp. 41-57.

Bernetti, I., Fratini, R., Sacchelli, S., Fagarazzi, C., Ciampi, C. 2008. Decision support system for biomass and energy planning in mountain. IUFRO 4.05.00: Emerging needs of society from forest ecosystems; University of Ljubljana, Slovenia, May 22-24. 2008.

Bianchi, M., Bovio, G., Camia, A., Cantian,i P., Corona P., Ferretti F., Francesetti., A, Lamonaca, A., Portoghesi, L., 2006. "ProgettoBosco": un sistema di supporto alle decisioni per la stesura di piani di gestione forestale quale strumento di sussidio all'attività didattica. Forest@ 3: 91-97. [online: 2006-03-17]

Cavalli, R., Grigolato, S., Lubello, D. 2006. Planning logging systems through site analysis. In Ackerman P.A., Langin D.W., Antonides M.C. (eds) 2006. Precision Forestry in plantations, semi-natural and natural forests. Proceedings of the International Precision Forestry Symposium. Stellenbosch 5-10 March 2006. Stellenbosch University.

Corona, P., Calvani, P., Mugnozza, G.S., Pompei, E. 2008. Modelling natural forest expansion on a landscape level by multinomial logistic regression. Plant Biosystems - http://www.informaworld.com/smpp/title~db=all~content=t713737104~tab=issueslist~branches=142 - v1422008, Pages 509 – 517.

Corona, P., Carraro, G., Portoghesi, L., Bertani, R., Dissegna, M., Ferrari, B., Marchetti, M., Fincati, G., Alivernini, A. 2010. Pianificazione forestale di indirizzo territoriale. Metodologia e applicazione sperimentale all'altopiano di Asiago. Regione del Veneto. CSALP Università della Tuscia. Piccoli Giganti Edizioni, Castrovillari.

Ferretti, F., Cantiani, P., Bianchi, M. 2004. Progettobosco: un sistema di supporto alla realizzazione dei piani forestali di gestione aziendale. Sherwood, n. 105, novembre 2004, pp. 13-16.

Ferretti, F., Dibari, C., De Meo, I., Cantiani, P., Bianchi, M. 2011. ProgettoBosco, a Data-Driven Decision Support System for forest planning. Mathematical and Computational Forestry & Natural-Resource Sciences (MCFNS), Volume 3, Issue 1, Pages 27-35. ISSN 1946-7664 Available at: http://mcfns.com/index.php/Journal/article/view/MCFNS.3-27. Date accessed: 18 Oct. 2011.

Freppaz, D., Minciardi, R., Robba, M., Rovatti, M., Sacile, R., Taramasso, A. 2004. Optimizing forest biomass exploitation for energy supply. Biomass and Bioenergy 26 (2004) 15 – 25.

Frombo, F., Minciardi, R., Robba, M., Rosso, F., Sacile, R. 2009. Planning woody biomass logistics for energy production: a strategic decision model. Biomass and Bioenergy, Volume 33, Issue 3, March 2009, Pages 372-383.

Holsapple, C.W. 2008. DSS Architecture and Types. In: Burstein, F., Holsapple, C.W. (Eds.). Handbook on Decision Support System 1. Basic Themes. Springer, 2008, L, 854 p. 133 illus. Pp 163-189.

IAP2 2007. IAP2 Spectrum of Public Participation. http://www.iap2.org/associations/4748/files/spectrum.pdf.

INFC 2007. Le stime di superficie 2005 – Prima parte. Autori G. Tabacchi, F. De Natale, L. Di Cosmo, A. Floris, C. Gagliano, P. Gasparini, L. Genchi, G. Scrinzi, V. Tosi. Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio. MiPAF – Corpo Forestale dello Stato - Ispettorato Generale, CRA -ISAFA, Trento, 409 pp..

INFC 2009. I caratteri quantitativi 2005 – Parte 1, vers. 2. Autori P. Gasparini, F. De Natale, L. Di Cosmo, C. Gagliano, I. Salvadori, G. Tabacchi e V. Tosi. Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio. MiPAAF – Ispettorato Generale Corpo Forestale dello Stato, CRA-MPF, Trento.

Johnson, K.N, Gordon, S.N. 2003. Decision Support Systems for forest biodiversity management – Evaluation of current systems. Report of NCSSF Project A10. http://ncseonline.org/NCSSF/DSS/.

Lubello, D. 2008. A rule based SDSS for integrated forest harvesting planning. PhD Thesis, Università degli Studi di Padova.

Mussumeci, G., Condorelli, A. 2001. Gestione dell'emergenza incendio - Un GIS per la previsione dell’avanzamento del fronte di fuoco e la determinazione dei percorsi di avvicinamento ai fini delle operazioni di spegnimento. Documenti del Territorio, n. 48.

Reynolds, K.M. 2005. Integrated decision support for sustainable forest management in the United States: Fact or fiction? Computers and Electronics in Agriculture 49 (2005) 6–23.

Saaty, T. L. 1980. The analytic hierarchy process: Planning, priority setting, resource allocation. McGraw-Hill International Book Co. (New York and London). xiii, 287 p. ISBN 0070543712;

Saaty, T. L. 2008. Decision-making with the analytic hierarchy process. Int. J. Services Sciences, Vol. 1, No. 1, 2008.

Scrinzi, G., Tosi, V., Agatea, P., Flamminj, T. 1996. Coordinate quali-quantitative dell'utenza turistico-ricreativa delle aree forestali in Italia. Genio Rurale LIX (3). 53 - 76. n.12 - dicembre 2005, pp.30-47.

Scrinzi, G., Gregori, E., Giannetti, F., Galvagni, D., Zorn, G., Colle, G., Andrenelli, M. C. 2005. Boschi e fenomeni franosi superficiali: modello per la valutazione dell'azione protettiva. Estimo e Territorio (Edagricole - il Sole24ore), anno LXVIII.

Scrinzi, G., Gregori, E., Giannetti, F., Galvagni, D., Zorn, G., Colle, G., Andrenelli, M. C. 2006. Un modello di valutazione della funzionalità protettiva del bosco per la pianificazione forestale: la componente stabilità dei versanti rispetto ai fenomeni franosi superficiali. Forest@ 3 (1): 98-155.

Wolynski, A., Zanin, M., Scrinzi, G. 2009. Revisione della pianificazione forestale in trentino a cinquant’anni dall’adozione della selvicoltura naturalistica. Atti del Terzo Congresso Nazionale di Selvicoltura. Taormina (ME), 16-19 Ottobre 2008. Accademia Italiana di Scienze Forestali, Firenze, p. 928-932.

16 The design and use of forest decision support systems in Morocco

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16.1 Introduction

The total area of Morocco is 715,000 km^2; its geographic position with the Mediterranean sea to the north, Atlantic Ocean to the west and vast desert to the south (Sahara), as well as mountains (with peaks more than 4,000 meters), provide it with a large bioclimatic variability, ranging from saharian, arid, semi-arid, subhumid, to perhumid bioclimat and then an important biological diversity (Mounir 2002).

Public forest domain covers 9 million ha. It counts 1 million ha of saharian acacia, 3 million ha of esparto grass and 5,280,000 ha of natural forests (AEFCS 1996). The most important species are: *Quercus rotundifolia* (1.3 million ha), *Agrania spinosa* (830,000 ha), *Tetraclinis articulata* (600,000 ha), *Quercus suber* (350,000 ha), *Cedrus atlantica* (133,000 ha). Moroccan forests are public and belong to the government. The High Commissariat of Water and Forest and Fight Against Desertification (Haut Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertification: HCEFLCD) is responsible for forest resources management. Figure 1 depicts the most important forest regions in Morocco.

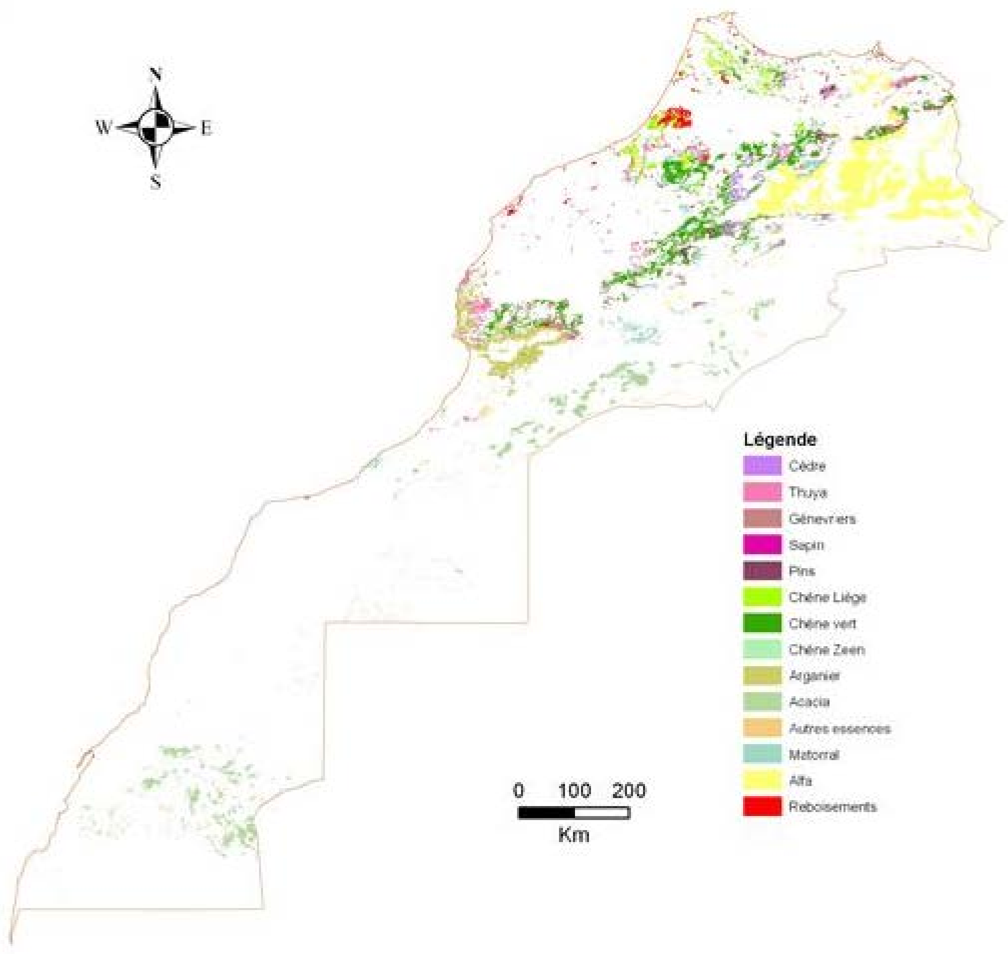

Figure 14. Moroccan forest regions

Moroccan forests are multifunctional. They produce about 130,000 m^3/year of carpentry wood, 400,000 m^3/year of fibre wood and about 10 million m^3/year of fuel wood which contribute for 30% of national energy consumption, cork is about 120,000 stere/year; forests remain the largest provider of fodder for livestock (about 1.5 billion FU (Fodder Unit) that cover 17% of herds' feed balance), a source of employment, wood and derived products to the community and industry. Also, fishing and hunting provide about 12 millions Dhs/year (M'hirit and Benchekroun 2000).

In addition to the economic and social functions, Moroccan forests, which are heavily represented, from Rif to the Anti-Atlas Mountains, host 25 to 40% of endemic plants and two-thirds of vascular plants (AEFCS 1995). Another important fact remains water supply: forest degradation reduces dam storage capacity which is evaluated to annual losses of ability to irrigate between 5,000 and 10,000 ha/year (Mouffadal 2007).

The increase of population and its needs during the last century and the social dynamics that ensued, caused imbalances that tarnished the relationship between population and forest (Mounir 2002). These are reflected for most forest goods and services by a demand far exceeding supply. For example, the fuel wood's possibilities are only between 3 and 4 million m^3/year.

In order to address forest multifunctionality, the forest administration made efforts to generalize forest management planning. Thus, 50% of forests have already their management plan (HCEFLCD 2009). Indeed, forest management falls within the policy framework established by the National Forest Program (MDCEF 1999). It concerns a diversity of ecosystems (Benabid and Fennane 1994; Benabid 2002; M'Hirit 1999) which are subjected to several constraints from the natural environment or related to human activities. As it is situated in the Mediterranean region, the dry season leads to forests' vulnerability and a rainy season leads, on fragile substrates, to an intense soil leaching. Also, according to legal dispositions, the local population uses forests to improve their incomes (fuel wood, menu products as well as feed units for feeding livestock).

Based on Moroccan forest characteristics, the problems faced by forest managers can be organized as:

- General purpose problems
  - information leaks on sylvicultural itinerary
  - data management
- Forest management problems: five typical problems are prevalent:
  - A- Related to strategic temporal scale (long-term). It concerns the forest level. This problem is spatial with no neighbourhood relations in which multiple objectives are requested including market products as well as forest services. The decision-making process is characterized by one power decision-maker, the forest department, and local communities and NGOs as stakeholders. They are considered as 'second class actors'. A participatory process could ignore, inform or involve them depending on the decision process, spatial context, and funds.

- B- like the first problem type, the second problem differs by the fact that it concerns the regional level and it involves local communities. This kind of problem is observed on ecosystem recognized as a protected area.
- C- The third problem is related to a mid- to long-term stand level planning problem with no neighbourhood interrelations in which one decision-maker has multiple objectives and tries to maximize wood production.
- D- The fourth problem addresses medium-term and stand level in which one decision-maker involves many stakeholders looking for multiple objectives: market non-wood products (esparto, Rosemarie, etc…) as well as services (e.g. protection against erosion, honey production, grazing, etc…).
- E- The fifth problem addressed is related to the short-term in which one decision-maker involves many stakeholders looking for multiple objectives: forest products as well as services.

As cited before, Moroccan forests are multifunctional. They provide many kinds of products and services. In order to improve the management process and to address the prevalent management problems, the Moroccan forest administration had changed their forest management planning methods over time (from 1940 up to now) to satisfy the evolution of awareness and social demands. Table 1 gives some information about the evolution of forest management planning in Morocco.

Table 1. Forest management planning evolution in Morocco

Period	Forest management planning type	Objectives
1940 - 1970	• Planned harvesting	• Intensive harvesting • Creation of the first logging cooperatives
1970 – 2000	• Temperate forest management planning method	This vision aims to improve: • Timber production; • Regeneration.
After 2000	• Participatory and sustainable forest management planning method	• Timber production; • Regeneration; • Involvement of local populations; • Consideration of environmental and social dimensions; • Integrated actions at the territory scale.

Taking into account the rising complexity of forest management planning according to its evolution, the Moroccan forest department has designed and implemented many computerized systems to support decision-making and to manage information related to forest resources. But all developed systems still ranked as classical information systems, and do not rise up to a full DSS.

The main objective of this report is to inventory the forest information systems (DSS) created in Morocco up to now, with a description of their key features; to see if they face correctly the problem types identified before, according to FORSYS classification and to analyze the main weakness points of this forest DSS framework.

This report will be organized, in addition to problems faced by forest managers, on the material and methods, results and discussion and conclusion. The computerized tools (DSS) used to address them will be presented in the methods part, the results refer to the way they have been developed and finally the discussion focuses on how well these tools addressed the problems.

16.2 Materials and methods

The information about forest management planning processes and computerized tools to support them in Morocco has been gathered from technical reports, general documentation and direct interview with the teams that have been involved in the development of these DSS.
Many official document and papers have been consulted in order to identify how forest management problems are faced.
In order to analyze the DSS and how they face forest management problems, the teams involved in the development, implementation or the support of each DSS have been contacted. In addition to formal interviews on the systems, user guide analysis and test cases have been tried to better understand system functionalities.

As a result of the investigations, four main DSS related to forest management have been identified:

- SIGFOR: concerns forest management monitoring (storage of management plans, support for auction and harvest);
- Chasse : web mapping solution to monitor hunting leases on forests;
- Firecol : a web GIS solution to monitor and prevent forest fires;
- FOR_SANTE: all tier application for forest health monitoring.

Each DSS has been characterized according to the spatial, temporal and objectives that are faced. Thus, the dimensions addressed are compared to those related to each prevalent problem type. Also, discussions with end users and forest managers clarified many ambiguous situations.

16.3 Results

The problems faced by forest managers and the DSS addressing these problems are presented in Table 2. They will be discussed in the next sections.

Table 2. Problem type addressed by decision support tools in national context.

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
A	- SIGFOR - Hunting lease - Health monitoring	Traditional or goal-programming approach	-Forest resource database (DB), G&Y models	Questionnaire Workshop
B	- SIGFOR - Health monitoring		Cognitive mapping	Questionnaire Workshop Cognitive mapping
C	- No formal DSS is used			
D	- SIGFOR - Health monitoring			Questionnaire
E	Fire system	-Fire risk maps	-Web GIS Portal	

16.3.1 Problems faced by forest managers and DSS used

16.3.2 Problem Type A:

The first kind of problem is related to almost all Moroccan forests. The problem is a spatial one with no neighbourhood relations that concern the long-term and forest level. According to the National Forest Program (MDCEF 1999), multiple objectives are requested including market products (wood and non-wood products) as well as forest services (recreation, soil conservation, etc.).

The HCEFLCD is the main decision-maker in the decision-making process. The local community has the right to use forests for grazing and to extract their needs of fuel wood. They are involved as stakeholders. Furthermore, the participatory process could involve, inform or simply ignore them depending on the decision process, spatial context, and funds.

The participatory process is related to the problem identification, and\or during the problem solving. Indeed, questionnaires and interviews are used in order to quantify the needs of stakeholders and to evaluate the illegal logging. Also, where actions are identified, users are informed during workshops, they also identify some kind of intervention to be scheduled (social infrastructure).

According to the process results, rational or non-rational decision-making processes could be described (Guitouni and Martel 1998). Problem-solving can be generally pointed as an irrational process. In that case, classical approaches to forest regulation are usually chosen.

Furthermore, many other works involving linear, goal programming or heuristic methods have been used for research purposes (Hlal 1988; Housni 1999; Marghadi 2009).

The knowledge management involved in this kind of problem consists of the use of stored data related to each management unit and the growth and yield models.

DSS facing partially this kind of problem are: SIGFOR, hunting lease and Health monitoring. All the DSS are used during the problem identification or modelling.

SIGFOR addresses forest management monitoring, especially wood harvesting. It consists of three subsystems: SIGFOR_CDF, SIGFOR_REGIONAL and SIGFOR_CENTRAL. Each subsystem is used by each corresponding administrative level (CCDRF, DREFLCD, CENTRAL). SIGFOR_CDF consists of a database of management units which offers many dashboards related to the management plan execution, to auctions and to wood supply. In addition to queries related to the management units to be operated each year, it offers a complete solution to harvest process monitoring: the definition of spatial logging units, marking trees to be cut, calculating timber volumes, producing selling books, organizing public tender to sale items and monitoring all related operations (harvesting, hawking and payment).

SIGFOR_REGIONAL is a regional repository of forest management plans. The subsystem is designed to store forest management plans. Also, the HCEFLCD planned to include many decision models in that system in order to facilitate forest management revision.

The hunting lease DSS is used to monitor hunting leases. Based on a web GIS solution, stored maps and data could be analysed and delivered to users in order to assist them to opt for the best decision choice.

The Health Watch DSS aims to store all kinds of pest reporting encountered in the forest to help managers develop the best strategy to fight the problem.

16.3.3 Problem Type B:

This kind of problem differs from the first problem type by the fact that it concerns the regional scale and local communities are actively involved. Managers face this problem type in protected ecosystems (national park, MAB reserve, etc.).

Multifunctional management is addressed according to functional zoning. Each zone (completely restricted zone, zone of transition and buffer zone) could be used according to special rule. Problem-solving is drawn within each functional zone.

The participatory process related to problem identification and solving is crucial. It involves local communities. Further, many funding agencies and international NGOs are generally implicated to assist or to fund actions. The most used participatory tools are the questionnaire; interview and workshops.

DSS facing this kind of problem are: SIGFOR and Health monitoring, which are used during the problem identification or modelling.

16.3.4 Problem Type C:

This kind of problem is a particular case of the first type. It differs by the spatial scale (it concerns stand level) and considers fibre wood as its primary goal. Stakeholders are not involved during the management process. This problem type is faced on stands lent to the national company producing cellulose for paper production. This problem type is faced mainly by SIGFOR because its main objective is wood production. But the National Company of cellulose is not using this system for the reason that it is considered as a private company, so then it does not use the system developed for the forest department.

Each one of the DSS developed by the HCEFLCD is used in the management process.

16.3.5 Problem Type D:

The fourth problem type is related to the medium-term and stand level. One decision-maker involving many stakeholders looking for multiple objectives: market non-wood products as well as services (e.g. protection against erosion, honey production, grazing, etc.). It is the non-wood product case (esparto, Rosemarie, etc.).

The participatory process is related to problem identification. Questionnaires are used to quantify use pressures.

SIGFOR could be used to monitor auctions, product selling and payments. The health monitoring system allows pest tracking. Also, the hunting lease system could assist managers to best deal with leases.

16.3.6 Problem Type E:

The fifth problem addresses the operational level. The decision-maker (HCEFLCD) involving many stakeholders looks for multiple objectives: forest products as well as services.

This kind of problem is partially faced by the fire system. Indeed, predicable weather conditions, forest covers, slopes, accessibility and ignition risks are used to assess fire risk and fire vulnerability. The resulting maps help managers to prevent fires, or to act as soon as fires are declared.

16.3.7 Used DSS

16.3.8 Forest Management System: SIGFOR

SIGFOR focuses on time-consuming tasks or those using or producing an enormous amount of information. The project-targeted tasks are:

1. Forest planning. The amount of information produced, and the way that managers must mobilize this information during a very long time frame in order to act with it, and also monitoring and evaluating the management plans are key elements for sustainability assessment.
2. Harvesting which wastes a lot of managers' time.
3. Database and data storage is very valuable for decision-making processes.

Thus, the system was organized on three main subsystems. Each one has its functionalities and is designed to be used by a specific administrative level:

- SIGFOR CENTRAL: designed for the national level. This subsystem holds:
    - National directory of forest ecosystems, management and administrative units;
    - Dashboard and tool for monitoring forest management;
    - Will move into a future DSS.
- SIGFOR REGIONAL: designed for the regional level. This subsystem consists of a regional forest management plan database. Its functionalities are:
    - Regional directory of forest management plans;
    - System to monitor forest management plans implementation;
    - Spatial database of regional forest stands;
    - Initial database that will evolve to a decision support system for natural resource management.
- SIGFOR CDF: designed for management unit. Its functionalities are built around harvest management (volume estimation, many dashboards related to timber harvesting and logging). Also, it allows the printing of many useful reports.

16.3.8.1 Data models

The conceptual data model according to the entity-relationship diagram is organized into three main domains: administrative and managerial units (Figure 2), forest management data, auction monitoring and financial monitoring.

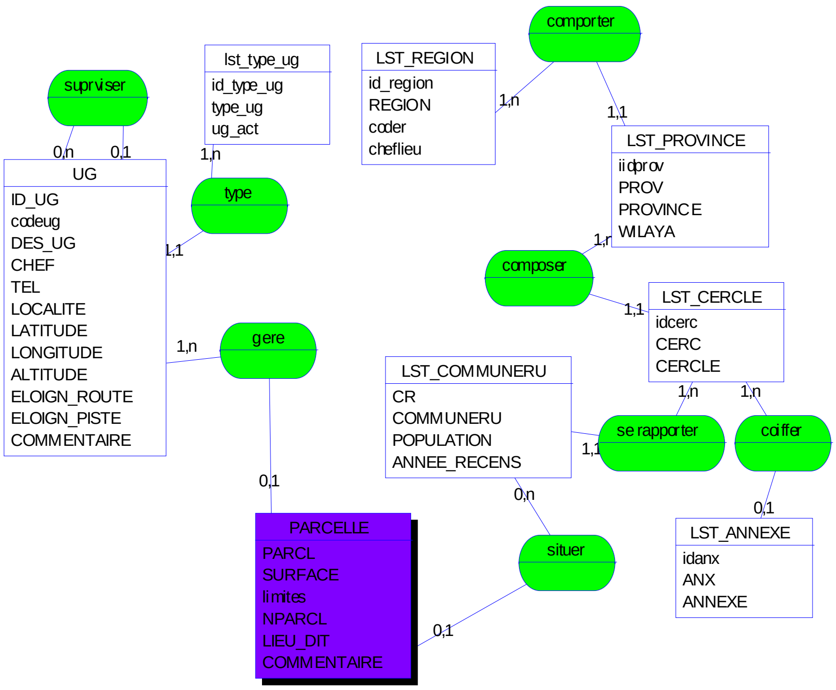

Figure 15. ER Diagram of administrative and managerial management units.

16.3.8.2 Input and output structure

Two rules are identified for each subsystem: operator and administrator. Then functionalities and GUI could differ.

The system input and output are faced using GUI or flat files according to the granted user rule. Analyzing system input and output (Tables 3 and 4) conveys the major system functionalities. Further, consulting the management units to be harvested each year or their maps, many reports and dashboards related to wood selling could be established.

Table 3. Inputs by main data domains

Domain	Data	Management unit	Provided by	Remarque
Management plan	(vi) management units data (maps, schedules, etc…)	local	Regional level	Flat file created by export utility
	- Tables or equation volume	Local	Regional or local associated with administrative rules	
Selling preparation	- Trees dimensions	Local	Fields sampling	
Selling monitoring	- Selling information	local	Public auctions	
	- Payment	local	In desk and partners requests	
	-timber logging and transportation	local		
National repositories	Forests and managerial units	Central	Administration organization	Information exported as flat files

Table 4. Sigfor's output

Domain	Output	Management unit	Delivered to	Remarque
Management plan	(vii) Management units description including maps (viii) Tables or equation volume (ix) schedules	Regional	Local level	Flat files created by export utility
Wood selling	- Many reports including: selling catalog, cutting units maps, selling synthesis, contracts, due recovery order, etc…	Local	Regional or partners loggers	Either reports, or export database used by higher level
Harvest monitoring	- logging and transportation permits - Monitor payments - harvests dashboards	Local	Regional level	

16.3.9 FIRE_SYSTEM

The fire system is a WebGIS solution designed to assess fire risk. Through a portal (web pages) managers have access to dynamic fire risk maps. The system is developed using GRASS GIS software and python scripting language.

Depending on the weather conditions, forest covers, slope, accessibility and ignition risks, two kinds of maps are produced: static and dynamic. The static map takes into account fire statistics, where dynamic maps use accurate weather conditions predictions.

The fire system consists of the following modules:

- User management module;
- Data acquisition module;
- Weather data retriever;
- GIS analysis module;
- Web mapping solution.

16.3.9.1 Input and output structure

Data used by this system includes:

(iv) Weather data: daily connection to national weather database allows downloading of predicted weather data;
(v) Maps: cover types;
(vi) Socio-economic data including village, accessibility;
(vii) Fire statistics.

Two kinds of maps are provided as an output to users:

(viii) Static maps: according to fires history, a global fire risk maps;
(ix) Dynamic maps: daily, risk maps are generated according to weather predictions.

16.3.10 HUNTING_LEASE

This system is a web mapping solution to monitor hunting leases. Managers could create a lease project or monitor an existent one. The solution is built using Mapserver, PHP and Mysql DBMS.

The main functionalities addressed by the solution are:

- User management module;
- Data acquisition module;
- Lease maps creation;
- Spatial analysis to verify whether the leases overlap or not, and is not a protected area.

16.3.10.1 Input and output structure

Data used by this system includes:

(x) Hunting leases data: data related to the owner, to the contract, and the expected facilities …etc;
(xi) Maps: leasing maps;
(xii) Hunting leases payment monitoring.

Two kinds of outputs could be provided:

(xiii) Reports related to hunting leases;
(xiv) Maps of leases.

16.3.11 Information system "Health monitoring"

The Health Watch system aims to improve processes for reporting pest problems that investigators can encounter in the forest.

Descriptive forms were produced to report any sign of pest problems. Further, a computerized application was developed to manage the collected information through a portal designed for low-speed web connections.

The applications consist of two modules:

- Management of the descriptive forms concerning the strategy "Health Watch";
- Management of the sampling units designed.

The system was developed using PHP, PostgreSQL DBMS and Apache web server.

16.3.11.1 Data model

The database consists of a set of tables containing all the information that was considered relevant to the process of health monitoring and has been the subject of extensive conceptual analysis. The physical model of this database is created in PostgreSQL (Figure 3).

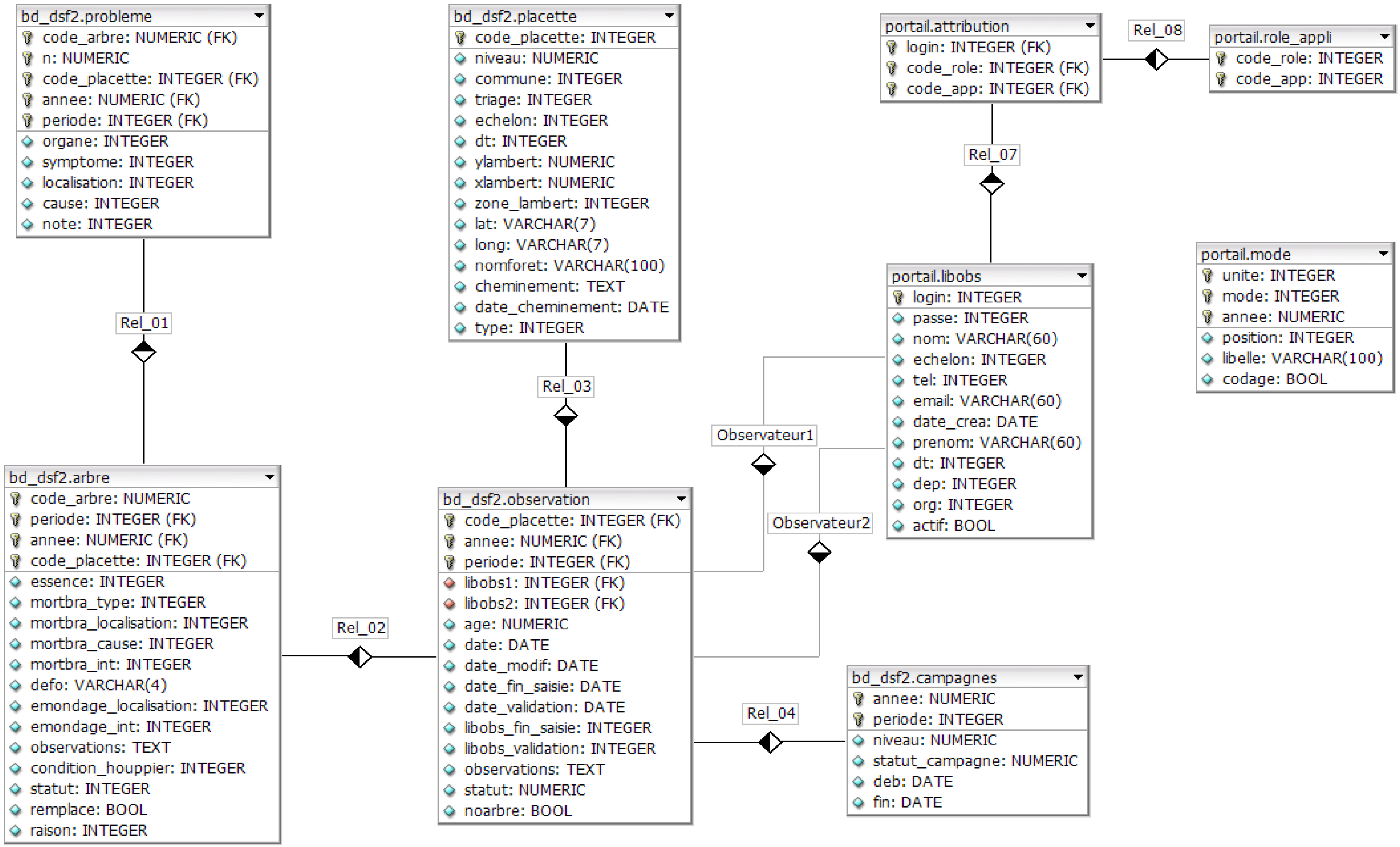

Figure 3. Data Physical Model of the BD DSF

16.3.11.2 Input and output structure

Three main connection rules are defined: investigators, animators and network administrators. Each group of users has its own access to defined functionalities.

Data used by this system includes:

(xv) Samples definition;
(xvi) Forms typing: user data, health form, pest information, etc;

Outputs could be provided as reports for infestations by pest or related to forest species, etc.

16.4 Discussions and conclusions

In the field of decision support systems (DSS), the use of information systems is necessary to store information related to a domain, which is then used to help the decision-maker in his decision-making. These systems must operate in constrained time, that is to say, they must provide answers by a specified date in order to enable decision-makers to act promptly. We classify systems of decision support in three main areas:

1. Information systems and analysis of information (documentation systems, databases, data analysis, simulations, etc.).
2. Support systems in decision-making (expert systems, support software of choice, etc.).
3. Systems of communication and cooperation (cooperative work systems remotely, trading systems, etc.).

Some systems are highly specialized, but others attempt to integrate several features of these three axes. We will not discuss thoroughly these categories of decision support systems here, but we will limit the discussion mainly to the existing systems presented in the results section, their compatibility with respect to the definition of decision support systems and their capacity to face the problem types cited before.

Based on the definition and categorization mentioned above, we find that the systems related to decision support in forest management, presented in the result section are not really dedicated systems to help decision-making, i. e. they are not full DSS for the simple reason that they do not have tools for modelling and the management capability of knowledge.

Indeed, all systems developed for the Water and Forests Department of Morocco were created in the scope of some development projects in the forestry sector, funded by foreign agencies. They were therefore created neither from a true knowledge of the capabilities of these systems to help decision-making nor from a clear identification of problems for which this kind of system can be very useful.

In addition we can say that according to a problem type identified in the introduction, we find that the systems presented in the results section do not face fully these problems because: i) all problem types identified deal with a multi-objectives purpose, but contrariwise most of the systems presented deal only with one objective, e. g. SIGFOR is concerned only with wood production; ii) all problem types cited before need a system of knowledge management to make possible decision support, but to the contrary all the systems do not have such a feature; iii) all problem types are concerned with the participatory process which is not supported by the systems presented.

But it is important to note that the systems presented constitute a significant step in introducing a computer science discipline and digital culture to the forestry sector and in assisting the decision-making process which is, without any doubt, based on the effective management of information. The systems developed provide powerful assistance to the forest manager and to the partners. The following is the example of SIGFOR:

SIGFOR has provided a solution that helps:

i) For managers:

- Reduce the time devoted to developing selling catalogue preparation and to wood selling contract monitoring;
- Enforcement of regulations;
- Better traceability of information, its processing, its sharing and dissemination;
- Reducing the risk of errors (payments, timbers logging and transportation);
- Improve and facilitate synthesis proceeding, monitoring and evaluation;
- Facilitate the revision of management plans.

ii) For partners

- Building a transparent relationship;
- Increasing the credibility of the administration;
- Accelerating the process of delivering needed documents to users;
- Reducing the risks of errors;
- Respecting the laws;
- Having a database that contains all interventions (traceability).

References

AEFCS, 1995. Plan directeur des aires protégées. Administration des Eaux et Forêts et de la Conservation des Sol. Rabat.

AEFCS, 1996. Inventaire Forestier National. Administration des Eaux et Forêts et de la Conservation des Sol. Rabat.

Benabid, A., 2002. Le rif le moyen Atlas (Maroc) : biodiversité, menaces et préservation. African Mountains High Summit. 2002. Nairoubi, Kenya.

Benabid, A., Fennane, M., 1994. Connaissances sur la végétation du Maroc: Biogéographie, phytosociologie et séries de végétation. Lazaroa 14, 21-96.

Guitouni, A., Martel, J.M., 1998. Tentative guidelines to help choosing an appropriate MCDA method. European Journal of Operational Research 109, 501-521.

HCEFLCD, 2009. Rapport d'activité du HCEFLCD. Haut Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertitifcation. Rabat.

Hlal, E., 1988. Goal programming multi-objective forest management an application to the cedar forest of Morocco. PhD Thesis. IAV Hassan II. Rabat.

Housni, Y., 1999. Utilisation de la programmation linéaire dans l'aménagement à objectifs multiples des forêts : une application à la forêt artificielle d'eucalyptus. Mémoire de 3ème cycle. ENFI, Salé.

Marghadi, S., 2009. Intégration des méthodes d'aide à la décision dans l'aménagement multifonctionnel des forêts au Maroc. Thèse de Doctorat. UCL, Belgium.

M.D.C.E.F., 1999. Programme Forestier National, Synthèse, Rabat, 93 pp.
M'Hirit O., 1999. La forêt naturelle : nécessité de la sylviculture. Le grand livre sur la forêt marocaine. Mardaga, liège, p 114-125.

M'hirit, O., Benchekroun,F. , 2000. Le rapport du millénaire pour le développement durable. Rabat.

Moufaddal, M., 2007. Les tendances en matière de propriété forestière, de mode de faire valoir des ressources forestières et des arrangements institutionnels. Cas du Maroc. Rome, FAO.

Mounir, F., 2002. Conception d'un système d'information géographique pour l'aménagement et la gestion forestière au Maroc. Intégration des critères et indicateurs du développement durable: Application à la Forêt de la Maâmora. Thèse de Doctorat. UCL, Belgium.

17 Decision support systems in the Dutch forestry sector

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17.1 Introduction

Before discussing decision support systems (DSS) in the Dutch forestry sector, I first need to place Dutch forestry in perspective. This perspective is not only related to the forest area, but also to forest policy of the different forestry actors. I will show that over the last three decades forest policy has disappeared and nature policy has become the substitute.

This of course has a major impact in the interest and role of decision support systems for forestry, as I will show in the results and discussion sections. From the interviews and literature survey carried out in the Netherlands, two information systems (Table 1) resulted which are considered as decision support systems. This table summarizes the more than 70 problem types in which these systems are used and which are listed in Appendix 1 and 2.

Table 1. The FORSYS Cost Action frame of analysis of use of DSS applied to two Dutch forestry DSS.

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
(App. 1) Temporal: tactical, operational Spatial context: all Spatial scale: all Parties involved: Single analyst Objectives: multiple Goods and services: market and non-market services	Shared Basic Information System for Nature and Landscape Management	Data query from Geographic Information System	n.a.	n.a.
(App. 2) Temporal: strategic, tactical, operational Spatial context: all Spatial scale: all Parties involved: all Objective: multiple Goods and services: all	O+BN	Web site portal	Expert teams organized by landscape types review and publish text.	n.a.

The Netherlands has a territorial area of approximately 41,000 km^2 (Figure 1). Forests make up some 12% of the land area. Almost half of the forests (42%) are mixed forests, 30% is coniferous forest, 22 % is broadleaved forest and open and young forests cover about 6% (Figure 1).

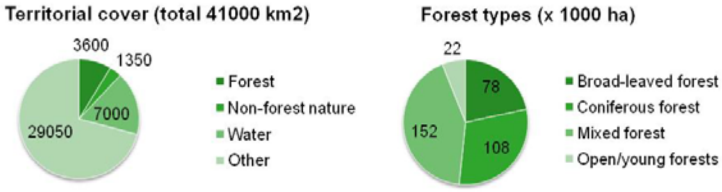

Figure 1. Area of forest types relative to territorial cover. (Bosschap 2005)

The forest and non-forest nature areas combined, are managed by four players, Staatsbosbeheer, Natuurmonumenten, the Provinciale Landschappen, and private owners. Staatsbosbeheer, which translates to State Forest Management, is a semi-autonomous government organization which manages approximately 250,000 ha. Natuurmonumenten, which translates to Foundation for the Preservation of Natural Monuments, is an association of 770,000 members (i.e. regular citizens), which manages approximately 100,000 ha. The Provinciale Landschappen, which translates to Provincial Landscapes, are 12 member-based associations with a total of 300,000 members. They manage another 100,000 ha. Finally the private owners manage 45,000 ha of nature area (Figure 2). For comparison, the Netherlands has a population of 16.5 million inhabitants.

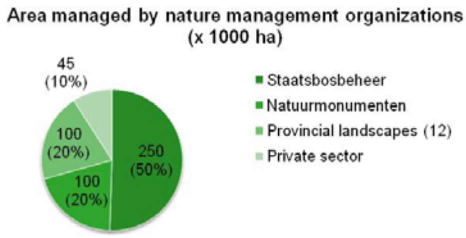

Figure 2. Distribution of different forest managers across Dutch nature areas.

For the policy change in the forestry sector over the last three decades that I need to describe, I rely on an excellent policy analysis by (Veenman et al. 2009). They explain in terms of the four dimensions (discourse, power, rules and actors) of the Policy Arrangement Approach or PAA (Van Tatenhove et al. 2000), the de-institutionalisation of Dutch forest policy. In three decades, forest policy in the Netherlands has almost entirely been integrated into nature policy. In the 1970s forest and forestry were still visible in Dutch policy, but now it has completely disappeared.

Let's first follow the discourse around government policy; until the 'Structural View on Forests and Forestry' of 1977 of the Ministry of Agriculture and Fisheries (Structuurvisie op het bos en de bosbouw, (Ministerie van L&V 1977)) timber production remained important. But in this policy document alternative functions were mentioned. The concept of multi-functionality was really introduced in the 1986 'Multi-year Plan on Forestry' (Meerjaren Plan Bosbouw, (Ministerie van L&V 1986)). The turning point was the Nature Policy Plan (Natuurbeleidsplan, (Ministerie van LNV 1990)). One of the key elements of the Nature Policy Plan was to establish a National Ecological Network (Ecologische Hoofdstructuur, EHS), consisting of core areas connected by ecological 'corridors'. Almost all forests in the Netherlands became part of the EHS. Many of those have become Natura 2000 areas.

Finally, in the year 2000, the Nature for people, people for nature' (Natuur voor mensen, mensen voor natuur, (Ministerie van LNV 2000)) policy was published. It contained a section on forest policy which gave up the goal of timber production, did not refer to multifunctionality, but focused on the nature function of forests.

Also the power of the forestry sector diminished over these decades (Veenman et al. 2009). Where the 'Multi-year plan on Forestry' still emphasized the subsidy of production of timber, the 'Nature for People, People for Nature' policy emphasized nature-oriented subsidies. Also the Ministry of Economic Affairs retreated from the forestry sector in the 1990s by ending a subsidy for fast-growing species. In parallel the expertise network changed. The specialized Forestry Research Institute (Bosbouwproefstation) was integrated into the Research Institute for Nature Management (Rijksinstituut voor Natuurbeheer), and the forestry curriculum at Wageningen Agricultural University was replaced by a more general curriculum on the management of forests and nature.

In the 1980s and 1990s, the rules of the game rapidly changed (Veenman et al. 2009). The earlier policies were still developed by a closed forestry community, i.e. the ministry together with the Forestry Board (Bosschap), which consists of representatives of employers and employees in forestry, trade and industry. In contrast, the 1993 Forest Policy Plan (Bosbeleidsplan, (Ministerie van LNV 1993)) and later the 2000 'Nature for people, people for nature' report offered several opportunities for other actors to influence the policy process. The Bosschap changed from a sectional body into a much more open representative organisation, advocating recreational and nature conservation objectives as well.

Finally, several actors, i.e. environmental and nature organizations, entered the scene and gained influence (Veenman et al. 2009). In 1977 the action group 'Critical Forest Management' (Landelijke Werkgroep Kritisch Bosbeheer) was established. The more traditional Foundation for the Preservation of Natural Monuments, focusing on the purchase and management of natural areas, not only became a key player in the policy debate due to its large membership (see above), but also as a major forest owner. Also this organization went through the same discourse of abandoning production objectives and substituting them with nature development objectives. (Dirks and Ploeg 2004). Also other organizations such as the WWF (World Wildlife Fund) became important players in the Dutch forest sector.

Even more telling were the actors that came into the government bureaucracy of forest management. In 1987, the State Forest Service was split up. The management branch became an independent agency. The policy and planning branch became the new Directorate 'Forestry and Landscape' (Bos-en Landschapsbouw) within the Ministry of Agriculture, Nature Management and Fisheries. A few years later, the Directorate for Nature, Environment and Fauna Management and the Directorate for Forestry and Landscape were merged. The new Directorate's name was 'Nature, Forestry, Landscape and Fauna' (Natuur, bosbouw, landschap en fauna) and was supposed to integrate these four aspects into one view. This re-organization signaled the abolishment of a separate focus on forests. In 1991, the Directorate was renamed to 'Nature, Environment and Fauna' (Natuur, Milieu en Fauna). Forests and nature were now fully integrated in the Dutch state bureaucracy and explicit reference to forests had disappeared.

In view of these developments, it is of course interesting to see whether this history of transformation and integration of the forestry sector into a nature development sector, has had consequence for the use of forestry decision support systems. Traditional forestry-related decisions about rotation, operation, species allocation to sites, and the like have become much less relevant in Dutch forestry. But also the major landscape ecological decisions have been made already in the 1990s when National Ecological Network (Ecologische Hoofdstructuur, EHS) was planned. The implementation will likely be delayed under current government, but where it is to be developed, remains clear.

17.2 Materials and methods

To find out current and recent use of decision support systems in the Dutch forestry sector, I approached several organizations (Table 2) by email and telephone interview. Also I reviewed scientific literature.

Table 2. Organizations approached by email and telephone.

Organization	Description	Link
Staatsbosbeheer	Semi-autonomous government forest management organization	www.staatsbosbeheer.nl/English.aspx
Natuurmonumenten	Citizen membership association for nature management	www.natuurmonumenten.nl/content/we-protect-nature
Provinciale landschappen	Twelve provincial landscape autonomous organizations	www.de12landschappen.nl/
Bosschap	Platform for everyone involved in forest and nature management. Creates conditions i.e. knowledge, labour, etc.	www.bosschap.nl/pages.aspx?id=145
Unie van Bosgroepen	Union of regional forest groups (1,200 members 434.500 ha) for collective subsidy requests & ICT, interface with national government	www.bosgroepen.nl/

In the email to the organizations I explained the purpose of the FORSYS Cost Action for which this research was done. I used Table 3 to explain the purpose of the Cost Action. It had been distributed by the Cost Action leadership. I used a graph (Figure 3) to explain what we mean by decision support systems. It had been used in a powerpoint by Cost Action chairman Ola Ljusk Eriksson, who borrowed it from Harald Vacik. Finally I requested details of whom I could contact to discuss use of DSS and methods used.

Table 3. Table shared by FORSYS Cost Action leadership defining the focus of the Cost Action

FORSYS – our FOCUS: We aim at producing decision support guidelines for forest management planning problems, where a forest management planning problem involves …

- ► the definition of the timing and location of forest management options,
- ► in order to approximate or optimize management objectives,
- ► that are single or multiple and relate to goods and services that are traded or non-traded,
- ► subject to resource constraints.

Thus the output of a decision support tool as understood in FORSYS ideally includes …

- ► an efficient set of actions,
- ► tradeoffs between management goals,
- ► impacts of changing and uncertain parameters.

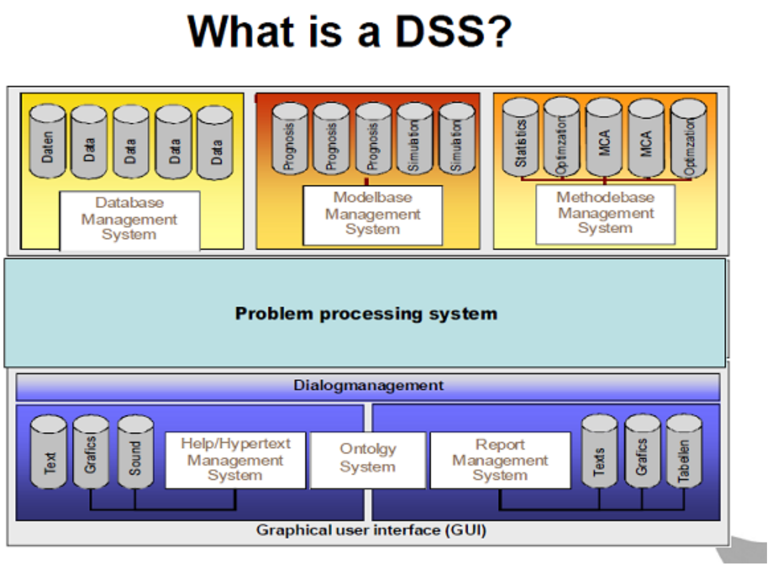

Figure 3. Diagram of decision support systems components and structure.

For the literature review I used two databases, ISI Web of Knowledge published by Thomson Reuters and CAB abstracts published by CABI. Unlike the former database which contains articles from scientific journals, the latter database also contains reports and is specialized in life sciences.

In both databases I used the following search term:

(“decision support” OR “planning support” OR “beslissingsondersteunende systemen”) AND (forest* OR tree OR silvi* OR bos* OR boom) AND (Netherlands OR Dutch OR Nederland*)

I constrained myself to the last 10 years, 2001 until 2011, since the interest is in current and recent use. In the case of the Web of Knowledge all keywords were searched in the "topic" field and all citation databases were selected. In the case of CAB Abstracts, all keywords were selected in the abstract field. Finally, I searched the site of Wageningen University and Research, WUR, (www.wur.nl/UK/) which combines the various expertise centres of landscape ecology, environment, lifesciences, economics etc.

17.3 Results

I present results separately in the next two sections. First the results of the attempt to contact organizations, then the results of the literature study.

17.3.1 Organizations

None of the organizations approached recognized the use of decision support systems as defined in the email. Responses were that every situation was considered to be unique, requiring special measures rather than "cook book" measures. The dense road infrastructure, other land uses, fixed EHS and Natura 2000 areas provide consolidation or inertia if you will.
But several organizations pointed at the fact that information and knowledge management have been well organized. At the end of the 1990s, Natuurmonumenten developed the Nature and Landscape Information System (Natuur en Landschap Informatie Systeem, NeLIS). This information system has modules on nature types, structures, buildings, subsidies, red listed species, etc. It is a management information system. It consists of an Oracle database with a Solution Development Environment (SDE) with the Arcview geographic information system. In 2011 NeLIS is to be replaced by the "Shared Basic Information System for Nature and Landscape Management" (Gezamenlijk Basissysteem Natuur- en Landschapsbeheer -GBNL). It is developed by Staatsbosbeheer, Natuurmonumenten, and Provincial Landscapes. Information about all terrains managed by the organizations is to be captured in this system to support management from purchases to evaluations, including the management reports. It is a content management system linked to the financial administrative systems (erp) a document management system (sharepoint), and geographic information systems.

I was also pointed at the knowledge management system developed by the Knowledge Network Development and Management Nature Quality (Ontwikkeling + Beheer Natuurkwaliteit, in short O+BN). The system can be found at the website www.natuurkennis.nl. Since 2010, the Knowledge Network is managed under the Bosschap, funded by the Ministry of Agriculture, Nature, and Fisheries. The knowledge is collected by expert teams grouped around the different landscape types of the Netherlands: hilly landscapes, dry sandy landscapes, wet sandy landscapes, stream valley landscapes, river landscapes, and bogland landscapes and dune and coastal landscapes.

The knowledge collected in the O+BN knowledge base covers the 17 nature types, nine landscape types, management measures, laws and regulations of the Netherlands, etc. It provides short descriptions of measures and their rationale or about problems or subsidies and the links to the sources, e.g. academic literature or websites to support the information in the knowledge base.

17.3.2 Literature

In February of 2011 the search term delivered 12 hits in the Web of Knowledge. Omitting the irrelevant hits, six publications remained (Van der Salm et al. 2006; Van den Brink et al. 2008; Palma et al. 2007; Janssen et al. 2009; BenDor et al. 2006). In CAB abstracts the search returned two of the previous documents and no additional documents. Let me briefly review each of these papers.

BenDor et al.(2006) only refer to Dutch Elm disease but they report of a study in the USA. Van der Salm et al. (2006) present the effect of afforestation (oak and spruce) on water recharge and nitrogen leaching in The Netherlands. Their paper is not about decision support. Palma et al. (2007) did a multi-criteria analysis, using the PROMETHEE outranking approach, to evaluate the integrated performance of silvoarable agroforestry on hypothetical farms in 19 landscape test sites in Spain, France, and The Netherlands. The Promethee methodology is generic in nature and not specifically geared to forestry decision support and therefore not relevant to be included in this study. Van den Brink et al. (2008) developed a negotiation support system (NSS) to solve groundwater conflicts that arose during land-use management. It was set up in cooperation with the stakeholders involved to provide information on the impact of land use, e.g., agriculture, nature (forested areas), recreation, and urban areas, on the quality of both infiltrating and extracted groundwater. Visualization of the conflicting interests of agriculture and the drinking-water extraction helped all stakeholders accept the necessary changes in land use identified by the adapted land use scenario of the NSS. These changes were included in the preferred land-use management option in the regional planning process, which has since been formalized. Although interesting, management problems were not forestry but ground water quality oriented. Finally, Janssen et al. (2009) only make reference to an article related to forestry.

Searching the publications of WUR, several policy studies emerge. But, like the earlier mentioned (Palma et al. 2007), these publications report of generic methods. For instance Bos and Vleugel (2005; 2010) apply social cost-benefit analysis to nature valuation. Or they report about landscape ecological decision support systems such as Schotman (2002), which can be used to defragment highly fragmented habitats. Finally, Lette and de Boo (2002) apply multi-criteria analysis to value forests and nature. Although they provide an interesting overview of methods, these are not computer-based systems that follow the structure of Figure 3. These methodological studies are also not included. One additional study reports on long-term effects of integrated forest management and develops scenarios applying the EFISCEN approach to Dutch forestry (Nabuurs et al. 2001).

17.3.3 In the FORSYS frame of analysis

The FORSYS Cost Action frame of analysis of use of decision support systems in forestry (Table 1) thus consists of two systems, i.e. Shared Basic Information System for Nature and Landscape Management and the O+BN. These are more information systems and knowledge organization systems than decision support systems. They are like repositories. They do not facilitate the management of knowledge with certain techniques nor do they facilitate participation. The kinds of management problems addressed in these two systems are very wide for multiple, in advance undefined, purposes. Both place forestry in a landscape management context. The kinds of problems they address are summarized from Appendices 1 and 2.

17.4 Discussion and conclusion

It is important to place the results in the context of a process of de-institutionalization of forest policy in the Netherlands over the past three decades. Organizations that manage forests still exist, and they carry the same names as 30 years ago. However, these organizations have taken up a very different mandate, one of nature management. Their organizational structure has changed accordingly and so has the power balance between the internal organizational structures as well as between the organizations.

Forests have become a vegetation type amongst others with classification codes N14 through N17 in the O+BN knowledge base. They are mostly part of the EHS. And they play a role in different landscape types. No single organization manages public forests. And many organizations get involved.

Also we should consider that there seems little room for generalization of decision rules. The intense land use, dense road infrastructure, fixed EHS and Natura 2000 areas give a lot of structure and constraints to any decision. This structure and these constraints vary from location to location. So every situation is considered to be unique, requiring special measures.

So when we look at the use of decision support systems in forestry it is not strange that we find no pointer to use, neither from practitioners involved in forest management nor from literature. The reasons are that first of all decisions are considered to be too unique so that generic methods of cost-benefit analysis or multi-criteria analysis suit better for policy studies around unique problems. Second, forests are considered as landscape elements, embedded in a green infrastructure that was designed some 20 years ago and does not require decision support any more. Third, that no organization is really concerned with forests per se.

Substantial investments are made and coordination is done for information and knowledge management. The new “Shared Basic Information System for Nature and Landscape Management” (Gezamenlijk Basissysteem Natuur- en Landschapsbeheer) and the still developing Knowledge Network Development and Management Nature Quality (Ontwikkeling + Beheer Natuurkwaliteit, in short O+BN) result. Both reflect that same landscape interest of all the parties involved in nature management, even the ones that traditionally focused on forests, i.e. Staatsbosbeheer and Het Bosschap. This information system and knowledge management system also fit well to the understanding that nature management decisions have a uniqueness about them.

Finally, I have to point at the limitations of the study. I had to assume that the people to whom I was directed for email contact and interviews had the overview of operations in the organizations and could indeed provide a comprehensive answer. My experience with some other European forest organizations is that even a knowledgeable respondent may not have the overview to know in detail which methods, tools and techniques are being used throughout the organization.

So concluding, in the Netherlands, a geo-information system and a knowledge management system are developed in coordination and shared by all major nature management organizations, and generic decision support methods are used for specific, complex and unique policy or planning problems. No specific forest decision support systems are used and as such none could be contributed to the FORSYS wiki website.

References

BenDor, T. K., Metcalf, S. S., Fontenot, L. E., Sangunett, B. and Hannon, B. 2006. Modeling the Spread of the Emerald Ash Borer. Ecological modelling, 197 (1-2) 221-236.

Bos, E. J. and Vleugel, J. M. 2005. Incorporating Nature Valuation in Cost-Benefit Analysis. In: Tiezzi, E., Brebbia, C. A., Jorgensen, S. E. and Gomar, D. A. (eds.) Ecosystems and Sustainable Development V. Southampton: Wit Press.

Bos, E. J. and Vleugel, J. M. 2010. Infrastructure and Ecology: 'Limited' Costs May Hide Substantial Impacts. In: Aravossis, K. and Brebbia, C. A. (eds.) Environmental Economics and Investment Assessment Iii.

Bosschap 2005. Toekomstverkenning Bosschap. Zeist: Het Bossschap.

Dirks, P. and Ploeg, N. V. D. 2004. Van Bomen Naar Bossen : Het Bosbeheer En -Beleid Van Natuurmonumenten Geëvalueerd. Vakblad natuur bos landschap.

Janssen, J., Hoekstra, A. Y., De Kok, J. L. and Schielen, R. M. J. 2009. Delineating the Model-Stakeholder Gap: Framing Perceptions to Analyse the Information Requirement in River Management. Water Resources Management, 23 (7) 1423-1445.

Lette, H. and De Boo, H. 2002. Economic Valuation of Forests and Nature, a Support Tool for Effective Decision-Making. Theme Studies Series 6 Forests, Forestry and Biodiversity Support Group. International Agricultural Centre (IAC), Wageningen and National Reference Centre for Agriculture, Nature Management and Fisheries (EC-LNV).

Ministerie Van L&V 1977. Structuurvisie Op Het Bos En De Bosbouw. 's Gravenhage: Ministerie van L&V.

Ministerie Van L&V 1986. Meerjaren Plan Bosbouw. Regeringsbeslissing. 's Gravenhage: Ministerie van L&V.

Ministerie Van LNV 1990. Natuurbeleidsplan. 's Gravenhage: SDU Uitgeverij.

Ministerie Van LNV 1993. Bosbeleidsplan. Regeringsbeslissing. 's Gravenhage: Ministerie van LNV.

Ministerie Van LNV 2000. Natuur Voor Mensen, Mensen Voor Natuur. Nota Natuur, Bos En Landschap in De 21ste Eeuw. ‘s Gravenhage: Ministerie van LNV.

Nabuurs, G. J., Schelhaas, M. J. and De Goede, D. 2001. Long Term Effects of Integrated Forest Management. (in Dutch). Nederlands Bosbouwtijdschrift, 73 (5) 29-32.

Palma, J., Graves, A. R., Burgess, P. J., Van Der Werf, W. and Herzog, F. 2007. Integrating Environmental and Economic Performance to Assess Modern Silvoarable Agroforestry in Europe. Ecological Economics, 63 (4) 759-767.

Schotman, A. G. M. 2002. Onderbouwing Van Het Kennissysteem Larch: Dispersievermogen, Locale Populatieafstand, En Duurzaamheid Van Locale Populaties. Alterra, Research Instituut voor de Groene Ruimte.

Van Den Brink, C., Zaadnoordijk, W. J., Van Der Grift, B., De Ruiter, P. C. and Griffioen, J. 2008. Using a Groundwater Quality Negotiation Support System to Change Land-Use Management near a Drinking-Water Abstraction in the Netherlands. Journal of Hydrology, 350 (3-4) 339-356.

Van Der Salm, C., Van Der Gon, H. D., Wieggers, R., Bleeker, A. and Van Den Toorn, A. 2006. The Effect of Afforestation on Water Recharge and Nitrogen Leaching in the Netherlands. Forest ecology and management, 221 (1-3) 170-182.

Van Tatenhove, J., Arts, B. and Leroy, P. (eds.) 2000. Political Modernization and the Environment. The Renewal of Policy Arrangements. , Dordrecht.: Kluwer Academic Publishers.

Veenman, S., Liefferink, D. and Arts, B. 2009. A Short History of Dutch Forest Policy: The [`]De-Institutionalisation' of a Policy Arrangement. Forest Policy and Economics, 11 (3) 202-208.

Appendix 1

Problem type / Dimensions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Temporal scale																		
Long-term (strategic)																		
Medium-term (tactical)	X		X		X		X		X		X		X		X		X	
Short-term (operational)		X		X		X		X		X		X		X		X		X
Spatial context																		
Non-spatial	X	X					X	X					X	X				
Spatial with neighbourhood interrelations			X	X					X	X					X	X		
Spatial with no neighbourhood interrelations					X	X					X	X					X	X
Spatial Scale																		
Stand level	X	X	X	X	X	X												
Forest level							X	X	X	X	X	X						
Regional/national level													X	X	X	X	X	X
Parties involved																		
Single decision-maker	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
More than one decision-maker / stakeholders																		
Objectives																		
Single																		
Multiple	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Goods and services																		
Market non-wood products																		
Market wood products																		
Market services	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Non-market services	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Appendix 2

Problem type / Dimensions	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Temporal scale																											
Long-term (strategic)	X			X			X			X			X			X			X			X			X		
Medium-term (tactical)		X			X			X			X			X			X			X			X			X	
Short-term (operational)			X			X			X			X			X			X			X			X			X
Spatial context																											
Non-spatial	X	X	X							X	X	X							X	X	X						
Spatial with neighbourhood interrelations				X	X	X							X	X	X							X	X	X			
Spatial with no neighbourhood interrelations							X	X	X							X	X	X							X	X	X
Spatial Scale																											
Stand level	X	X	X	X	X	X	X	X	X																		
Forest level										X	X	X	X	X	X	X	X	X									
Regional/national level																			X	X	X	X	X	X	X	X	X
Parties involved																											
Single decision-maker	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
More than one decision-maker / stakeholders																											
Objectives																											
Single																											
Multiple	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Goods and services																											
Market non-wood products	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Market wood products	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Market services	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Non-market services	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

18 Development and use of forest decision support systems in Norway

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18.1 Introduction

18.1.1 Forests and forestry in Norway

Norway is situated in the boreal coniferous vegetation zone, with mainland ranging from 57° to 71° latitude. Topography is varied: 32% of the land area is below 300 meters above sea level (asl), and 20% is situated above 900 m asl. The productive forest area (i.e. annual growth > 1 m^3/ha) in Norway is approximately 76,240 km^2 (~28% of total land area).

The National Forest Inventory (NFI) was established in 1919 and has since carried out inventories with five to 10-year cycles. A grid of permanent sample plots was established in 1986. In total there are 16,000 permanent sample plots, with about 10,500 situated on productive forest land and other wooded land below the coniferous forest limit (Larsson and Hylen 2007). The forest resources have increased substantially the last 80 years and standing stock (excluding bark) on productive forest land is estimated to 720.8 million m^3. The standing stock holds 46% Norway spruce (*Picea abies* (L.) Karst), 32% Scots pine (*Pinus silvestris* L.) and 22% deciduous trees (mainly birch species: *Betula pubescens* and *pendula*). The annual growth is estimated to 25.54 million m^3 (excl. bark and top).

Annual industrial harvest has varied between 8 and 11 million m^3 over the last decade. In addition about 1.5 million m^3 of fuelwood is harvested. Norway has a relatively strong forest industry, based on lumber, and pulp and paper production. Forest industry, including forestry, constituted approximately 0.54% of GDP in Norway in 2009. The industry is spatially scattered, and thus plays an important role for employment in many peripheral communities.

Non-industrial private ownership dominates forestry. Of the 119,614 registered forest owners in 2008, nearly 113,000 were individual owners. The average forest property is about 56 hectares. 88% of the forest area is privately owned. Some 7% of the forest land is owned by companies or cooperatives, while the rest is owned by public authorities (local or national). Due to the ownership structure and specific terrain conditions, Norwegian forestry is diversified and characterized by small-scale activity.

The Norwegian Forest Owner's Federation (NFOF) with 45,000 members is the main organization for small-scale forest owners. NFOF is a cooperative organization consisting of eight regional and 380 local associations. The federation is involved with marketing roundwood and other forest products, and working for technical progress among the members. Members had an annual harvest of industrial roundwood of approximately 5 million m^3 in 2009 - around 75% of total harvest for commercial sale in Norway. Norskog, the second major forest owner organization, has only 220 members, but represents an annual harvest of ~1 million m^3.

The current Forestry Act was authorized by Parliament in 2005. Its main objectives are to ensure sustainable management of the forest resources with prospects for promotion of local and national economic development, and to secure biological diversity, landscape, outdoor recreation and cultural values. The Forestry Act applies to all categories of ownerships. There are three levels of public governance in Norway: state, county and municipal. Public forestry administration exists at all levels. The highest public authority is the Ministry of Agriculture & Food. Each county administration has a department of agriculture including a forestry section. In addition, there is a politically elected Board of Agriculture at the county level. The Municipality Administration has responsibilities regarding both forestry and the environment in general.

The Forestry Act states that "forest management planning includes forest inventories, listing forest and environmental resources on the property and a plan for management of these. Forest inventories may be undertaken in an area even if a forest management plan has not been ordered by all forest owners. All forest owners shall be notified that such an inventory is being made. […] The Ministry may issue regulations concerning forest inventories and forest management planning including, inter alia, requirements regarding the content of the plan and provisions concerning how the data that is collected shall be managed."

A forest owner is not required to buy a forest management plan. However, to carry out silvicultural treatments the environmental consequences have to be documented. In Norway, environmental inventories in forest ("MIS") are incorporated in the forest management planning process. Management planning is mostly organized as large projects covering, for example, a municipality comprising many properties. Some of the forest owners associations at regional level have their own professional planning sections but there are also private companies that perform forest inventories and management planning. Forest inventories are close to 100% carried out by means of airborne laser scanning (cf. Næsset 2004).

The content of a Norwegian forest management plan may be divided into four main parts: i) a forest map with delineated stands, ii) a description of the present resources, iii) suggestions for treatments, and iv) a map and description of MIS registrations. The description of present resources is provided at the property level (area, development class, site quality, age, species specific volume, etc.). Suggestions for treatments may have two parts. At the property level, an overall annual harvest level is suggested. Previously this was based on compulsory computations with a large-scale scenario model. Such computations are now less frequently performed, and a large share of plans is today produced without any suggested harvest schedules. Treatment suggestions (silviculture, thinning, final harvest) for individual stands may also be part of the plan. These suggestions have mainly been based on field assessments. Since field control is no longer compulsory, an increasing part of the plans are produced without suggestions for stand level treatments. As a result, present Norwegian forest plans are becoming more like a forest resource inventory rather than a management plan.

An increasing proportion of plans is now delivered in digital format and/or distributed via internet. Forest owners are provided with software including GIS tools, and may produce summary tables and maps on different themes. In addition, the software may be used for updating according to treatments and state of stands.

Stakeholders, their need for decision-support and problem types

There are several "layers" of stakeholders in forestry, from forest owners up to governmental bodies. They have differing focus and needs related to decision support, and will for planning purposes focus on different temporal and spatial scales, as well as different objectives and services. Different "problem areas" may also be given attention, such as stand level decisions (regeneration, thinning and final harvest options), economical forest level decisions (harvest level, regeneration and thinning strategies, profitability, etc.), forest level environmental considerations (key habitats, near-nature forestry, bio-diversity), or new products like biomass for energy or carbon sequestration. In the following we describe stakeholders and their potential need for decision support, and relevant problem types according to this (Table 1). Stakeholders may belong to two distinct groups; those that need a management plan and those that need consequence analyses. Forest owners constitute the first group, while organizations and public institutions make up the other.

Table 1. Stakeholders and their need for decision-support, and corresponding relevant problem types

Stakeholder	Need for decision-support	Problem type
Small-scale forest owners	Standard calculations for forest management planning	1, 2
Large-scale forest owners	Calculations for forest management planning and consequence analyses, operational planning	1, 2, 3, 4, 5
Public forest owners	Calculations related to forest management planning and consequence analyses	1, 2, 3, 4, 5
Forestry organizations	Consequence analyses related to reports etc.	6
NGOs related to forestry	Consequence analyses related to reports etc.	6
Public institutions	Consequence analyses related to reports etc., land valuation	6
Public administration	Consequence analyses related to reports etc.	6
Forest industry	Consequence analyses related to reports etc.	6
R&D and education sector	Research, teaching, consequence analyses related to reports, teaching, etc.	1, 2, 3, 4, 5, 6

18.1.2 Forest owners

As there is large variation in both the size of forest holdings and in the aims of management, it may be fruitful to group forest ownership into small-scale, large-scale and public. Public ownership is either at the municipal or state level. Municipal forests are normally medium-sized, while state forests are larger forest areas.

For small-scale forest owners, the economical importance of the property is limited. The needs related to planning are accordingly modest in most cases. Often, in a (commercial) forest management plan for a small property, more emphasis is put on the resource aspect than on the actual management plan. For small properties the spatial aspect is less important and the possibilities for spatial planning are limited. Also, the number of products is limited for small properties. Often, roundwood is in focus. The prevalent need for the owner of a typical small-scale forest property is a projection of potential future harvests, together with the silvicultural treatments that is the basis for the projections. For small-scale forest owners, a relatively simple plan may be satisfactory. The typical planning problem for small-scale forest owners is categorized as long-term planning on stand level, spatial with no neighbourhood interrelations, single decision-maker, single objective, and market wood products (problem type 1). For forest level planning, the problem is categorized by the same dimensions as problem type 1, except that the spatial scale is forest level (problem type 2).

For larger properties, both the spatial and economic dimension might be wider. As forestry becomes more important, planning also becomes more important. For larger properties, there is certainly a need for more detailed management plans both in the temporal and spatial dimensions. Both short and long-term aspects are relevant for all property sizes, but the spatial dimension is likely to be more relevant and important for large properties. The fact that also a part (although small) of the forest properties in Norway is publicly owned adds further dimensions to the planning problem. In general both owners of small public forests (e.g. church forests, municipal forests) and large-scale forests (state) are focusing on the economic aspects of forestry in the same way as private owners do. Accordingly, they face the same challenges as described for private owners. However, in addition they quite often need to be more focused on aspects related to diversity and recreation.

Problem types 1 and 2 are therefore still the most important for large-scale and public forest owners, but a number of additional problem types are relevant due to variations in objectives, spatiality and the number of stakeholders involved. The first of these problems is categorized as long-term (strategic) planning on stand level, spatial with no neighbourhood interrelations, single decision-maker, multiple objectives, and market wood products (problem type 3). There is also a problem type with the same dimensions except that both market wood products and market non wood products are important (problem type 4). Finally, for some large-scale and public forest owners dealing with long-term planning at the forest level, neighbourhood considerations and interrelations are important, and sometimes required by law. Thus, there is a planning problem categorized as long-term planning on forest level, spatial with neighbourhood interrelations, more than one decision-maker, multiple objectives, and market non-wood products as well as market wood products and both market services and non-market services (problem type 5).

18.1.3 Other forestry-related organizations and institutions

Among the forestry organizations, the forest owners associations are especially important. For many forest owners, they are the only contact point when the forest owner has questions concerning management. Regarding forest management planning and decision support, the association's primary interest is analyses of consequences of public policies like subsidies and legislation. Consequently, they will generally have a different perspective than the individual forest owner, with a focus on regional and national issues rather than the stand or property. Changes in relevant commodity markets and the effects on forest products demand is also of interest. Thus, the decision support problems that are of relevance to this organization are wide in the temporal and spatial scale, and analyses should incorporate multiple decision-makers, objectives, and goods and services. For the forest owners association, which mainly have a need for different types of consequence analyses, a problem type categorized as long-term planning on regional level, non-spatial, more than one decision-maker, multiple objectives, and market non-wood products as well as market wood products and both market services and non-market services (problem type 6) is the most important.

Several NGOs have interests of forestry-related issues. In particular, different nature conservation organizations work closely with forestry issues as forests are important for biological diversity. Lately, also carbon sequestration has received much attention. For organizations with interest in such issues, it would be of great interest to demonstrate the effects of different forest management strategies, different policy options, nature conservation measures, etc. Such analyses are relevant and interesting at various temporal and spatial scales, and could be performed both at the stand level and at the regional/national level. Analyses with multi-objective decision-making and other goods and services than wood would be of special interest. Also here problem type 6 is the most important.

In Norway, we have public institutions that may have interests in doing analyses for different projects and purposes. Examples of such institutions could be research institutions where forestry is not the main activity; schools/colleges, public agencies or national authorities. Typical use could be consequence analysis of policy measures and forest management options, for instance the effects of subsidies or the availability of biomass for energy production.

Public administration of forestry takes place at various levels in Norway. There is governmental administration of forestry both at the national (Ministry of Agriculture & Food), county and municipality level. In addition, there are governmental bodies taking care of such diverse topics as allocating financial policy measures and carry out forest conservation. All these units would be interested in consequence analysis for policy-making, like public subsidies, and how public involvement in the sector affects forest management and relevant product markets. Their emphasis would be on long-term effects at large spatial scale. Both wood and non-wood products are of interest, i.e. problem type 6 is the most important.

Forest industry in Norway is mainly divided into sawmilling on one side and pulp and paper production on the other. Their dominant interest concerning forestry is procurement of roundwood. Thus, they would surely have the same needs and interest as most of the groups mentioned above with regards to consequence analysis for policy making and market changes. The relevant spatial scale would be regional or national level and long-term temporal scale, which means that also for this stakeholder group problem type 6 is most important.

The R&D and educational sector related to forestry is rather small and fairly well integrated in Norway. It is mainly placed at the Norwegian University of Life Sciences and the Norwegian Institute for Forest and Landscape, both located in Ås municipality. In addition, some research is taking place at different colleges and the Norwegian Agricultural Economics Research Institute. Activities related to forest management planning however, mostly take place at the university. These institutions will have a need to perform analyses of forest management at various temporal and spatial scales, as well as for both wood and non-wood products. It can be anything from teaching undergraduate students the intricacies of optimal timing of harvests to national scale bioenergy supply analyses. Studies both for single and multiple decision-makers and objectives are relevant. This means that all the problem types relevant for the other groups are also relevant for the R&D/education sector.

18.1.4 The objective

The main objective of the Norwegian country report is to give an inventory of computerized tools, i.e. decision support systems (DSS), that may support forest management planning and forestry related challenges and problems in Norway. We first give a description of the DSS including a summary description of the key features of them. Then, stakeholders, DSS and problem types are related to each other and the information is synthesized to identify knowledge and model 'gaps' in order to facilitate future development and use of DSS.

18.2 Materials and methods

18.2.1 Information on management planning and DSS

Eid (2007, in Norwegian) gives an overview of the development and use of DSS in Norway. This is one of very few such works in Norway, trying to describe different available tools and their use and development. Other than this, decision support systems in Norway are mainly described in peer-reviewed papers or in technical reports, the latter mainly in Norwegian. We have used a collection of scientific papers to evaluate different DSS. Further details on the literature are found in the section describing each DSS.

In addition to the scientific literature, we have consulted relevant websites and communicated with relevant experts. These are people involved both in work with DSS and people working with forest management planning in different ways. The descriptions and the analysis are of course also affected by the authors' own knowledge and experiences with different stakeholders and DSS.

18.2.2 Information analyses and synthesis

In order to compile the information and knowledge that we have collected, the following approach has been applied:

1. We have identified and described Norwegian stakeholders and their need for decision support (Table 1).
2. We have identified relevant problem types for the different stakeholders (Table 1).
3. We have identified and described the main features of different Norwegian DSS.
4. We have identified the DSS potential for covering the problem types indentified as relevant for Norwegian conditions (Table 2).

5. Finally, we have synthesized information on stakeholders, problem types and DSS in order to identify the most important problem types covered by present DSS, and maybe more important; we searched for knowledge gaps regarding problem types and DSS as a measure for guiding us in future development and use of DSS in Norway (Table 3).

In the same way as for the information we have collected, the analysis and synthesis is flavored by the authors' knowledge and subjective opinions. The authors have either been central in the development of or have been central in the use of one or more of the DSS reviewed in this text. Thus, they are not unbiased in the assessment of the DSS.

Information about some of the DSS we describe in this chapter has been introduced to the FORSYS Wiki (http://fp0804.emu.ee/wiki/index.php/Category:Decision_support_system). These are Avvirk-2000 and Gaya-SGIS. The DSS were originally introduced by the FORSYS Wiki-page organizers, but some adjustments have later been made by Tron Eid and Terje Gobakken. Four of the DSS described in this country report has not been introduced to FORSYS Wiki.

18.3 Results

Table 2 summarizes to what extent the existing DSS may be used to analyze the different problem types indentified as relevant for Norwegian conditions.

Table 2. Relations between problem types and DSS

Problem type	DSS	Models	Methods	KM techniques	Methods for participatory planning
1	Gaya-SGIS	Area based growth models, Area based price and cost models	Simulation	Database, GIS	Iterative process, group work
	Avvirk-2000	Area based growth models, Area based price and cost models	Sensitivity	Database	Iterative process, group work
	T(ree)	Individual tree growth models Individual tree price and cost models	Simulation	Database	Iterative process, group work
	Bestverd	Stand yield tables Stand level land values	Sensitivity	Database Web portal	Iterative process
2	Gaya-SGIS	Area based growth models, Area based price and cost models	Simulation, linear programming	Database, GIS	Iterative process, group work
	Avvirk-2000	Area based growth models, Area based price and cost models	Sensitivity	Database	Iterative process, group work
	NorFor	Area based growth models, Area based price and cost models	Linear programming	Database	Iterative process
3	Gaya-SGIS	Area based growth models, Area based price and cost models	Simulation, linear programming	Database, GIS	Iterative process, group work
4	Gaya-SGIS	Area based growth models, Area based price and cost models	Simulation, linear programming	Database, GIS	Iterative process, group work
5	n.a.	n.a.	n.a.	n.a.	n.a.
6	NorFor	Area based growth models, Area based price and cost models	Linear programming	Database	Iterative process

18.3.1 Gaya-SGIS

Gaya-SGIS is a dynamic forest management system with a forest simulator and a linear programming (LP) module integrated in a GIS environment. The system combines the forest simulator Gaya (Hoen and Eid 1990; Hoen and Gobakken 1997; Gobakken 2003), that calculates a range of treatment schedules and corresponding net present values (NPV) for each stand (or plot) in the forest, with the LP module J (Lappi 2005), that optimizes forest management given a goal and a set of restrictions. Gaya and J are integrated in the ArcView GIS system. The system is non-spatial in the sense that it does not allow adjacency restrictions. However, the GIS linking of Gaya-SGIS (Næsset 1997; Gobakken 2003) enables the use of GIS to modify the data set for the simulator or to set restrictions for the input/output matrix that transfers data from the forest simulator to the LP solver. The simulator was originally developed at the Swedish University of Agricultural Sciences (Eriksson 1983). All adaptations of the simulator to Norwegian conditions and the integration of the optimizer and the GIS features have been done at the Norwegian University of Life Sciences.

The present simulator is developed from area-based empirical-statistical biological sub-models (growth, mortality, regeneration/recruitment) describing even-aged treatment alternatives. Some rough adaptations of the area-based biological models have also been made to facilitate selective cutting alternatives. In addition to timber production and the corresponding cash flow, the forest simulator was also at an early stage developed for studying carbon flows (Hoen and Solberg 1994, 1999). Gaya has since been substantially revised and presently comprises: (1) fixation of carbon in living trees, (2) release of carbon from dead trees, litter, harvest residues, and soil, (3) release of carbon from wood products, and (4) saved greenhouse gas emissions (CO_2, CH_4, and N_2O) from use of wood products. New elements also include annual production and mortality of needles, leaves, branches, and fine roots and a process-based soil model (Yasso, see Liski et al. 2005).

Research applications of Gaya-SGIS have followed a natural evolution, starting with cases considering timber production only (Hoen et al. 2001), and then adding environmental considerations at different levels of detail (Eid et al. 2001, 2002; Bergseng et al. 2012). Recently, different climate-related analyses have emerged, comprising carbon sequestration (Raymer et al. 2009; Raymer et al. 2011) and utilization of biomass for bioenergy (Rørstad et al. 2010).

Gaya-SGIS may be applied to problem types 1, 2, 3 and 4. Presently Gaya-SGIS is used extensively in research. A few experts, employed at large-scale forestry properties or organizations, have applied the software in practical management planning. Gaya-SGIS is used for consultancy commissions, mainly by staff at the Norwegian University of Life Sciences.

18.3.2 Avvirk-2000

AVVIRK-2000 is a deterministic simulation model (Eid and Hobbelstad 2000) without optimization. Computations comprise (i) stand simulation of silvicultural regimes and (ii) determination of potential harvest level for the forest. In harvest strategies involving constraints, e.g. a non-declining harvest path, the harvest level is determined by means of an iterative process. The model should be operated heuristically, i.e. the user should calculate different alternatives through «intelligent» manipulation of the data, and search for a few, but satisfactory solutions. Projections are made for a period of 100 years, divided into ten 10-year periods. Growth projections are based on the development of the «average tree», i.e. basal area mean diameter and mean height weighted by basal area, and the number of stems ha^{-1} for the calculation unit.

Silvicultural regimes at stand level are based on a set of treatment assumptions and empirical models describing state and development of stand dynamics and stand economics.

The development can be represented separately by the three tree species Norway spruce (*Picea abies* (L.) Karst.), Scots pine (*Pinus silvestris* L.) and Birch (*Betula pubescens*). Variables used for economic calculations like terrain transport distance, cost factors describing terrain steepness and smoothness, and timber quality are required. Harvest strategies may be (i) a non-declining harvest path or net income path for the period of 100 years; (ii) a user given harvest level or net income level for any number of 10-year periods up to 10; (iii) a harvest path according to user given final harvest ages for all stands; (iv) a harvest path according to removal of stands with relative annual value increment lower than a user-given percentage.

The program was originally developed by the Norwegian forest owners association in the late 1970s (Hobbelstad 1979). All developments from 1980 to date have been done at the Norwegian University of Life Sciences. Avvirk-2000 may be applied to problem types 1 and 2. Avvirk-2000 was previously applied routinely in practical management planning for analyzing harvests at forest level by most planning companies in Norway. Since such analyses are not compulsory any more, the use of this program has decreased significantly recent years. Today the program is applied for land (forest) valuation by the Norwegian court's administration, and for research and consultancy commissions done by the staff at the Norwegian University of Life Sciences. The program is also applied routinely by the Norwegian National Forest Inventory for harvest scheduling and consequence analyses.

18.3.3 T(ree)

T (an abbreviation for Tree, since the individual tree is the basic unit in the simulator), is a forest simulator developed from biological as well as economic sub-models for individual trees (Gobakken et al. 2008). T is designed to simulate alternative treatment schedules for all compartments in the planning area. T shares a lot of the abilities of Gaya. The focus is on a flexible platform facilitating future development, and the biological sub-models, i.e. distance-independent individual-tree growth and mortality models based on permanent sample plots from the Norwegian NFI. Economic sub-models estimate roundwood prices and harvesting costs for individual trees. For each management unit (i.e. stand), the simulator produces treatment schedules with all feasible combinations of user-defined treatment and regeneration options (e.g. pre-commercial thinning, thinning, different kinds of regeneration cutting with different kinds of regeneration options and selective cutting). Net present value is calculated for all treatment schedules.

In future, the simulator is intended to constitute the basic module in Norwegian decision-support systems for large-scale and long-term analyses in practical management planning, where it is integrated with GIS tools and a decision module (e.g. with an optimization routine based on linear programming). T may also be used as an independent system for stand-by-stand analysis for research as well as practical planning. The program has been developed at the Norwegian University of Life Sciences. T may be applied to problem type 1 only, and has so far only been used for research at the Norwegian University of Life Sciences.

18.3.4 Bestverd

Bestverd is not a forest management simulator/optimizer, but rather calculates forest land values (Svendsrud 2001, in Norwegian). It is developed mainly for use in land valuation where the state purchases land from private land owners (expropriation).

Svendsrud (2001) made a set of normalized tables containing land values for different stand characteristics like tree species, site index, density, and different forest management schedules, interest rates etc. The Bestverd program makes use of these tables as a database to look up relevant values. Bestverd is freely available through a web portal (http://statisk.umb.no/ina/forskning/bestandsverdi/Applet1.html).

The program has been developed at the Norwegian University of Life Sciences, and may be applied to problem type 1 only. The program is frequently used by forest experts dealing with different land valuation problems.

18.3.5 NorFor

NorFor (Sjølie et al. 2011) is a spatial, partial equilibrium model of the Norwegian forest sector based on the assumption of perfect competition and perfect foresight. Maximising NPV of the annual net social payoff, the model determines optimal behaviour in forestry and forest industry as well as consumers. The structure and data input of the forest industry part of the model is based on NTMII (Bolkesjø 2004). Forest growth is simulated with Gaya (Hoen and Eid 1990). Incorporation of forest management yields into the optimization problem is based on the regional models developed for Oregon (Adams and Latta 2005, 2007).

NorFor has four main parts: forest management and harvesting; industrial capacity and processing; wood products consumption and prices; and trade of timber and wood products. The model covers Norway (except Finnmark county) and a foreign region for import and export with no industrial production and includes only the net trade with Norway. The model uses NFI data.

The solid wood industry is defined at the county level, while the pulp, paper and board industry is defined at mill level. If no action is taken, capacity is depreciated at a fixed percent per year. Industry agents may also choose to maintain the capacity level or to add new capacity. Inputs other than wood and intermediate wood products, such as capital, labour, energy and recycled paper are priced exogenously.

The demand for final products drives processing and harvesting. Demand functions for final products are represented by basic prices and quantities from NTMII runs and elasticities based on econometric studies. Bioenergy is a rather insignificant commodity in the large heating market, dominated by electricity in Norway. Thus, energy demand is perfectly elastic at a fixed price, implying that bioenergy production does not impact the energy price. Wood and wood products can be transported between all regions in Norway and to/from abroad, and shipments take place if the price difference is greater than the transport costs.

The program has been developed at the Norwegian University of Life Sciences, and may be applied to problem types 2 and 6, and has so far only been used for research at the Norwegian University of Life Sciences.

18.4 Discussion and conclusions

18.4.1 Stakeholders, problem types and DSS

For problem type 1, four different DSS are available. By applying Gaya-SGIS and T(ree) the user may simulate a large number of alternative treatment schedules for individual forest stands, while in Avvirk-2000 and Bestverd changes in user defined assumptions have to be made in order to analyse alternatives (Table 2). Problem type 3 requires a tool that may handle multiple objectives. Gaya-SGIS may handle multiple objectives by means of the linear programming module if we assume that the variable applied in the objective function and other variables applied in the constraints can be regarded as different objectives. The typical example of such a problem is to maximize the net present value subject to an even harvest flow constraint. Alternatively, Gaya-SGIS may be said to handle multiple objectives as long as they can be measured in monetary terms and thus combined in the objective function, for example wood production and carbon sequestration. Problem type 4 requires tools that can handle market wood products as well as market non-wood products. Gaya-SGIS handles both if we assume that forest residues or carbon quantities are non-wood products. No Norwegian DSS are able to handle spatial neighbourhood interrelations, i.e. there is no available tool for solving problem type 5. NorFor is the only DSS that can approach problem type 6 because this DSS is the only one able to handle the whole range of goods and services. Problem type 2, defined as important for management planning for all types of forest owners in Norway (see Table 1) can be approached by all three DSSs; Gaya-SGIS, Avvirk-2000 and NorFor.

None of the DSS has integrated specific functions or tools for either KM techniques or methods for participatory planning. However, all the systems more or less depend on the use of databases. Some systems also take advantage of GIS. It is possible to enhance these systems by applying other KM techniques, e.g., expert systems to evaluate effects on biodiversity. It should also be possible to incorporate the use of participatory planning by organizing the information stored and produced by the different DSS in relevant ways or by applying new optimization tools.

In Table 3 we summarize and synthesize how existing DSS cover the problem types that are important to different Norwegian stakeholders. In the table, the DSS are written in order of 'appropriateness' for solving the problem types for the different stakeholders. There are two dominating combinations of stakeholders and problem types: forest owners with management planning needs, and forestry organizations that need consequence analyses. The existing selection of DSS in Norway handles the basic problem types (1, 2, 3 and 4) and in that respect serves the purpose well for the forest owners. The obvious conclusion one can infer from the table is that there is a knowledge gap with respect to spatial neighbourhood interrelations and that there is room for improvement with respect to "non-wood goods and services".

Table 3. Stakeholders, relevant problem type and available DSS for the prevalent problem

Stakeholder	Relevant problem type	DSS for the prevalent problem type
Small-scale forest owners	1	Gaya-SGIS, Avvirk-2000, T(ree), Bestverd
	2	Gaya-SGIS, Avvirk-2000
Large-scale forest owners	1	Gaya-SGIS, Avvirk-2000, T(ree), Bestverd
	2	Gaya-SGIS, Avvirk-2000
	3	Gaya-SGIS
	4	Gaya-SGIS,
	5	na
Public forest owners	1	Gaya-SGIS, Avvirk-2000, T(ree), Bestverd
	2	Gaya-SGIS, Avvirk-2000, NorFor
	3	Gaya-SGIS
	4	Gaya-SGIS,
	5	na
Forestry organizations	6	NorFor
NGOs related to forestry	6	NorFor
Public institutions	6	NorFor
Public administration	6	NorFor
Forest industry	6	NorFor
R&D and education sector	1	Gaya-SGIS, Avvirk-2000, T(ree), Bestverd
	2	Gaya-SGIS, Avvirk-2000, NorFor
	3	Gaya-SGIS
	4	Gaya-SGIS,
	5	na
	6	NorFor

The complexity of decision-making processes in forest management is high. Varying spatial levels (stand, forest, region, country) require different types of information and thus different approaches to data collection. Different products (e.g., timber and biological diversity) have to be described and quantified, and temporal aspects including decision-making at strategic, tactical and operational levels have to be considered. This complexity imposes several conflicting goals in the development of DSS and at the same time elucidates the needs of different stake holders. A (basic) requirement for a DSS from the user perspective is realism. This means that natural processes have to be described relevantly and comprehensively and that flexibility and diversity in defining treatments should be high. At the same time, however, users require simplicity and transparency. For the development of a DSS this is an obvious challenge. When users in addition require high precision in estimates on the one side and low costs in data collection and application on the other, developing a DSS becomes nearly infeasible. Still, it is the developer's responsibility to consciously consider these challenges, and search for a balance between the conflicting goals reflected by the practical use of the DSS.

One obvious evolving conflict seen when looking back on the development history of Gaya-SGIS has been the conflict between realism and simplicity. This DSS has developed from a relatively simple system with limited possibilities and obvious shortcomings to a more comprehensive and realistic system with multiple options. Gaya-SGIS today, however, is rather complicated to operate. The user interface therefore needs to be emphasized in future developments of Gaya-SGIS in order to facilitate simplicity, transparency and user-friendliness. This is even more obvious for T(ree), which in many respects is similar to Gaya-SGIS, but with the added complexity of the individual tree-based simulations.

18.4.2 Future development and use of DSS

There are three obvious gaps in the development of DSS for strategic planning in Norway: Problems with i) spatial relations, ii) multiple decision-maker-problems and iii) multiple objectives. The last point is based on the fact that the existing DSS only accept multiple objectives if they can be handled in monetary terms. For tactical and operational planning, very little development has taken place in Norway with regards to DSS. This is especially true when combined with spatial planning. No efforts are made at this time to develop tactical and operational planning systems. There seems to be no accentuated demand for this.

There are ongoing projects in Norway which aim at developing DSS that are able to handle spatial relations in optimizations. Many ideas exist for further model development and improvements of Gaya-SGIS. In particular this relates to the emerging range of questions concerning biomass production for energy purposes and adaptations to and mitigation of climate change, as well as environmental considerations. We expect many of these to be implemented in Gaya-SGIS in the coming years.

Given the recent developments in forest inventories with improved quality and decreased data acquisition costs, it is our hope that more effort is put into utilizing the data for strategic planning purposes and not only tactical/operational short-term planning. Our contribution in this respect is to show the possible advantages of proper planning processes. In addition, we must ensure that the relevant DSS produce relevant information for users.

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References

Adams, D.M. and Latta, G.S. 2005. Costs and Regional Impacts of Restoration Thinning Programs on the National Forests in Eastern Oregon. Canadian Journal of Forest Research 35 (6): 1319-1330.

Adams, D.M. and Latta, G.S. 2007. Timber Trends on Private Lands in Western Oregon and Washington: A New Look. Western Journal of Applied Forestry 22 (1): 8-14.

Bergseng, E., Ask, J.A., Framstad, E., Gobakken, T., Solberg, B. and Hoen, H.F. 2012. Biodiversity protection and economics in long term boreal forest management - a detailed case for the valuation of protection measures. Forthcoming in Forest Policy and Economics.

Bolkesjø, T.F. 2004. Modeling supply, demand and trade in the Norwegian forest sector. Department of Ecology and Natural Resource Management, Agricultural University of Norway.

Eid, T. 2007. Utvikling og bruk av prognoseverktøy for beslutningsstøtte i skogforvaltning. INA fagrapport 10. http://www.umb.no/statisk/ina/publikasjoner/fagrapport/if10.pdf

Eid, T. and Hobbelstad, K. 2000. AVVIRK-2000: A large-scale forestry scenario model for long-term investment, income and harvest analyses. Scandinavian Journal of Forest Research 15 (4): 472-482.

Eid, T., Hoen, H.F. and Økseter, P. 2001. Economic consequences of sustainable forest management regimes at non-industrial forest owner level in Norway. Forest Policy and Economics 2 (3-4): 213-228.

Eid, T., Hoen, H.F. and Økseter, P. 2002. Timber production possibilities of the Norwegian forest area and measures for a sustainable forestry. Forest Policy and Economics 4 (3): 187-200.

Eriksson, L.O. 1983. Long range forestry planning - A case study of a forest in a transition period. Dept. of Operational Efficiency, Swedish Univ. of Agric. Sciences, Garpenberg. 1-78 pp.

Gobakken, T. 2003. Brukerveiledning til SGIS - et Skoglig Geografisk Informasjonssystem, Ver. 2.1. Manuscript. Dept. of Forest Sciences, Agric. Univ. of Norway, Ås. 26 pp.

Gobakken, T., Lexerod, N.L. and Eid, T. 2008. T: A forest simulator for bioeconomic analyses based on models for individual trees. Scandinavian Journal of Forest Research 23 (3): 250-265.

Hobbelstad, K. 1979. Edb-program for beregning av balansekvantum. In: Bruaset A (ed.) Landbrukets årbok. Tanum-Norli, Oslo, pp. 190-198.

Hoen, H.F. and Eid, T. 1990. En modell for analyse av behandlingsalternativer for en skog ved bestandssimulering og lineær programmering [A model for analysing forest treatments by stand simulation and linear programming], Ås-NLH. 35 pp.

Hoen, H.F. and Solberg, B. 1994. Potential and economic efficiency of carbon sequestration in forest biomass through silvicultural management. Forest Science 40 (3): 429-451.

Hoen, H.F. and Gobakken, T. 1997. Brukermanual for bestandssimulatoren GAYA v.1.20. Dept. of Forest Sciences, Agric. Univ. of Norway, Ås

Hoen, H.F. and Solberg, B. 1999. Policy options in carbon sequestration via sustainable forest management: an example from the north. In: Palo M (ed.) Forest transitions and carbon fluxes. The United Nations University, World Institute for Development Economics Research, pp. 117-132.

Hoen, H.F., Eid, T. and Økseter, P. 2001. Timber production possibilities and capital yields from the Norwegian forest area. Silva Fennica 35 (3): 249-264.

Lappi, J. 2005. J-user's guide Version 0.9.4. Finnish Forest Research Institute Sounenjoki February 2005.

Larsson, J.Y. and Hylen, G. 2007. Skogen i Norge. Statistikk over skogforhold og skogressurser i Norge registrert i perioden 2000-2004 [Statistics of forest conditions and forest resources in Norway]. Viten fra Skog og landskap 1/07: 91.

Liski, J., Palosuo, T., Peltoniemi, M. and Sievanen, R. 2005. Carbon and decomposition model Yasso for forest soils. Ecological Modelling 189 (1-2): 168-182.

Næsset, E. 1997. Geographical information systems in long-term forest management and planning with special reference to preservation of biological diversity: A review. Forest Ecology and Management 93: 121-136.

Næsset, E. 2004. Practical large-scale forest stand inventory using a small-footprint airborne scanning laser. Scandinavian Journal of Forest Research 19: 164-179.

Raymer, A.K.P., Gobakken, T., Solberg, B., Hoen, H.F. and Bergseng, E. 2009. A forest optimisation model including carbon flows: Application to a forest in Norway. Forest Ecology and Management 258 (5): 579-589.

Raymer, A.K., Gobakken, T. and Solberg, B. 2011. Optimal forest management with carbon benefits included. Silva Fennica 45 (3): 395-414.

Rørstad, P.K., Trømborg, E., Bergseng, E. and Solberg, B. 2010. Combining GIS and forest management optimisation in estimating regional supply of harvest residues in Norway. Silva Fennica 44 (3): 435–451.

Sjølie, H.K., Latta, G., Gobakken, T. and Solberg, B. 2011. NorFor - a forest sector model of Norway - Model overview and structure. INA fagrapport 18. http://www.umb.no/statisk/ina/publikasjoner/fagrapport/if18.pdf

Svendsrud, A. 2001. Tabeller for beregning av verdien av skogbestand [Tables for valuation of forest stands]. Rapport fra skogforskningen, Supplement 17: 16 [30]. In Norwegian.

19 Computer-based tools for supporting forest management in Portugal

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19.1 Introduction

Portugal's geographical position and natural resources endowment combined to make forestry and forest industry key elements in the Portuguese specialization pattern (Borges 1997). In recent years, the forest sector has contributed on average to 4% of the GNP – one of the largest relative contributions in the EU - 10% of exports and 9% of the industrial employment (INE 2009). The forest area extends over 3.5 million ha corresponding to over one-third of the country's territory.

Ecological diversity is determined by climatic influences ranging from Mediterranean to Atlantic or Continental. Over 80% of the forest area is occupied by four species. The northern region is dominated by Maritime pine (*Pinus pinaster* Ait.), a species that extends over about 26% of the forest area. Eucalypt (*Eucalyptus globulus* Labill) extends over about 21% of the forest area. The southern region is characterized by cork and holm oak ecosystems (*Quercus suber* and *Quercus ilex*) extending over about 12% of the forest area. Pine and eucalypt stands provide most of the country's timber growing stock while cork oak ecosystems provide the raw material for the cork industry. Timber and cork account for 41% and 29% of the gross economic value of forest products (GEVFP). Other non-wood marketable products (e.g. pine nuts), range management products, hunting and recreation account for 20% of GEVFP. Environmental services account for the remaining 10% (Mendes 2005). Forest management planning in Portugal thus encompasses timber, market and non-market non-wood products and services' supply objectives within a single or a multiple-objective decision-making framework (Table 1).

Non-industrial private landowners (NIPF) hold about 86% of forest land while the industry holds about 7%. This corresponds to one of the highest percentages of private forest land in Europe and the world. In northern and central Portugal more than 50% of the forest area is in holdings of up to 10 ha (Mendes 2005). In these regions, often a holding consists of a single stand. In southern regions where oak agro-forestry systems are prevalent, over 75% of the forests is in holdings of over 100 ha. Across regions, about 25% of non-industrial private forest land is in holdings with an area between 10 and 100 ha. Local communities own about 6% of forest land, while only 1% is national forest managed by the state.

This land tenure pattern is thus associated with a wide range of management planning problems. They are characterized by spatial scales that range from stand to forest levels in the case of single NIPF and of industry, community or state ownership, respectively. In the case of the latter, areas may extend over several thousand hectares. For example, the pulp industry manages self-owned or rented areas extending over 180,000 non-contiguous hectares while public forests and community areas typically extend over up to 10,000 ha. Temporal scales may range from operational to tactical and strategic in the case of most ownership. Nevertheless typical long-term horizons may extend from 36 to over 100 years in the case of, respectively, eucalypt and oak ecosystems management planning. The spatial context dimension also ranges from non-spatial in the case of stand-level management planning with a timber supply objective to spatial with neighbouring relations in the case of forest-level problems (Table 1).

The land tenure pattern also impacts the number of parties that are typically involved in decision-making. It ranges from a single decision-maker to several decision-makers in the case of a single NIPF and of a group of NIPF or the state, respectively (Table 1). In fact, as a consequence of the threat of forest fires – that have burned over 3.8 million ha in the period from 1975 to 2007, i.e. nearly 40% of the country area (Marques et al. 2011) – the forest policy has encouraged the association of forest owners. As of 2010, 129 groups of landowners (ZIF - Zonas de Intervenção Florestal) were responsible for joint management of areas that totalled about 600,000 ha while 51 other groups were being organized to manage areas extending over a total of 400,000 ha (AIFF 2010).

Over 90% of the forest land is private. Yet private management planning is constrained by regional and national considerations (AFN 2006). As of 2010, the area of impact of formal management plans extended over about 700,000 ha (AIFF 2010). In the same year, the area with certified management (mostly through the FSC) extended over about 270,000 ha, of which 74% belongs to the pulp industry. Formal management plans must comply with regional regulations (PROF – Planos Regionais de Ordenamento Florestal). Forest management planning has to further address specific conservation goals when the land is within the National Network of Protected Areas. These extend over about 6% of the forest area.

This paper addresses forest management planning according to the FORSYS focus. Nevertheless, the importance in Portugal of forest logistics planning problems encompassing products distribution, intermediate storage in yards, transportation scheduling and mills reception should not be underestimated. These are key segments of the supply chain that have been addressed by recent initiatives aiming at the integration of wood supply chain planning (Marques et al. 2011). Some problems may be classified using FORSYS dimensions as single decision-maker, tactical/operational, spatially explicit plans addressing one or several wood products and targeting one or several objectives (e.g. optimal yards arrangement, minimum yard stock levels). The remaining logistic decisions, undertaken by small-scale entrepreneurs specialized in timber trade and transportation, are driven by wood mills supply levels as well as by prior empirical estimates of local wood availability used to lay out harvesting agreements with the forest land owners. These decisions impact the use of equipment, trucks and crews. Still using FORSYS dimensions these problems may be classified as single decision-maker on a medium to short-term scale, supported by a spatial representation of the market wood products distribution network.

This paper aims at the inventory and analysis of computerized tools used to support the forest management problem types prevalent in Portugal. The analysis will encompass a summary description of the key features of these tools. The description emphasis will thus be on the tools' building blocks - models, methods and knowledge management techniques. The analysis will further address how the tools came about. Specifically it will focus on both the institutional and the development contexts and architectures. Problem types will thus be instantiated and the tools' success in addressing them will be assessed. Current trends in computerized tools use will be further addressed and interpreted.

Table 1. Classification of forest management planning problems in Portugal according to the FORSYS dimensions

ID	Spatial scale	Temporal scale	Spatial context	Objectives	Parties involved	Goods and services
18	Regional/national level	Strategic	Non-spatial	Multiple objectives	More than one decision-maker / stakeholders	Market wood products Market non-wood products Market services Non-market services
38	Regional/national level	Operational	Spatial w no neighbourhood relations	Multiple objectives	Single decision-maker	Market wood products
28	Forest level	Strategic	Non-spatial	Multiple objectives	Single decision-maker	Market wood products
3	Forest level	Strategic	Non-spatial	Multiple objectives	More than one decision-maker / stakeholders	Market wood products Market non-wood products
30	Forest level	Strategic	Spatial w no neighbourhood relations	Multiple objectives	Single decision-maker	Market wood products Market non-wood products
8	Forest level	Strategic	Spatial w no neighbourhood relations	Multiple objectives	Single decision-maker	Market wood products
5	Forest level	Strategic	Spatial w no neighbourhood relations	Multiple objectives	More than one decision-maker / stakeholders	Market wood products Market non-wood products
1	Forest level	Strategic	Spatial w no neighbourhood relations	Multiple objectives	More than one decision-maker / stakeholders	Market wood products Market non-wood products Market services Non-market services
6	Forest level	Strategic	Spatial w neighbourhood relations	Multiple objectives	Single decision-maker	Market wood products
16	Forest level	Tactical	Spatial w neighbourhood relations	Multiple objectives	Single decision-maker	Market wood products
17	Forest level	Operational	Spatial w neighbourhood relations	Multiple objectives	Single decision-maker	Market wood products

ID	Spatial scale	Temporal scale	Spatial context	Objectives	Parties involved	Goods and services
21	Stand level	Strategic	Spatial w no neighbourhood relations	Single objective	Single decision-maker	Market wood products
22	Stand level	Strategic	Spatial w no neighbourhood relations	Multiple objectives	Single decision-maker	Market wood products
23	Stand level	Strategic	Spatial w no neighbourhood relations	Multiple objectives	Single decision-maker	Market wood products Market non-wood products Non-market services
25	Stand level	Tactical	Spatial w no neighbourhood relations	Single objective	Single decision-maker	Market wood products
36	Stand level	Operational	Spatial w no neighbourhood relations	Multiple objectives	Single decision-maker	Market wood products Market non-wood products Non-market services

19.2 Materials and methods

The information about forest management planning problems and computerized tools to support them is spread across several Portuguese institutional sites, technical reports and national and international research publications. Nevertheless, as the area of impact of formal management plans extends over less than one third of the country's forest area and as most plans are privately owned (e.g. by the NIPF, the industry), the documentation about planning processes and plans is often not publicly available. This prompted the development of a combination of approaches to acquire and analyze the data and information needed to inventory and analyze computerized tools used to support the forest management problem types prevalent in Portugal.

This research carries out the first thorough survey of the computerized tools developed to support forest management planning in Portugal. The survey is supported by a review of technical and scientific publications and websites as well as of web-based knowledge repositories such as the FP0603 wiki page for growth and yield models (G&YM) (www.isa.utl.pt/def/fp0603forestmodels/wiki-forest-models.html) and the FORSYS Wiki page for decision support systems (DSS) (www.fp0804.emu.ee/wiki/index.php/Main_Page). Actually, this research further aims at providing additional information to the latter.

The survey also builds upon the results of a forest stakeholders' engagement plan (Marques et al. 2012a). This participatory process started with a series of meetings with the local forest land owners association (ACHAR) whose insight into the regional forestry context was instrumental for selecting 11 representative forest stakeholders groups in a typical southern Portugal region. Representatives of all groups met in 14 workshops aiming at forest management decision processes interactive design. A short questionnaire focusing on tendencies/requirements on methods, techniques and tools was also used in the framework of the engagement plan. Its content was instrumental for describing the FORSYS problems from the different decision-makers'/stakeholders' perspectives. It further allowed the identification of the computerized-tools, knowledge management and public participation techniques in use to support the FORSYS problems.

The survey took also advantage of thematic interviews with 192 NIPF conducted by a local forest owners association (AFVS) in a typical northern Portugal region. The interviews provided valuable information about the importance of FORSYS problem type dimensions as perceived by NIPF. Moreover it provided information about how NIPF perceive the usefulness of computerized tools namely of prescription writers and decision models to develop forest management plans.

The survey further builds from 24 replies to a specific questionnaire about computerized-tools developed in Portugal, available at a dedicated website (www.isa.utl.pt/cef/pub/FAGF). This site will become the first structured and easily accessible repository of forest management planning tools in Portugal. It displays the content of the questionnaire replies, when authorized by the respondent, covering a wide range of tools, such as spatial databases and information systems (IS), G&YM, other statistic models, simulators, optimization models and DSS. The 15-minute questionnaire with multiple-selection questions focused on the computerized tools characterization from a utilization perspective (e.g. status, target users, main functionalities) as well as its data requirements and technical features (database, development environment, user requirements, installation requirements, training). It further included attributes for direct mapping into the FORSYS problem dimensions.

19.3 Results

The strategic dimension is present in most prevalent forest management problems in Portugal (Table 2). Long-term planning is usually conducted by a single decision-maker, focusing on multiple objectives that encompass both wood and non-wood products (problems 6, 8, 28 and 30).

Problem 28 is shared by many decision-makers (e.g. national forests, industrial PF, forest owner associations) as it is mostly focused on maximum sustainable yield concerns with no reference to the location or the spatial context of management planning decisions. The computer tools used for non-spatial strategic planning started to be developed in the early 1990s. They include stand-alone implementations of some of the growth and yield models (G&YM) for the main forest species e.g. DUNAS (Falcão 1999), Pbravo, PBIRROL, MODISPINASTER, PPinaster, GLOBULUS (Tomé et al 1998), Glob3PG, SUBER (Tomé at al. 1998), as well as more sophisticated simulators e.g. SIMPLOT (Barreiro and Tomé 2011) and CELPASIM 2.0 (Falcão 2009) and DSS e.g. SADfLOR (Borges and Falcão 1999, Reynolds et al. 2007), EfLOR and PfLOR (Garcia-Gonzalo et al. 2011c, d Submitted). Some of these implementations of G&YM were disseminated within the forest practitioners' community and were used to provide sustainable yield projections to support the development of forest management plans. Recently developed forest simulators - SIMPLOT and CELPASIM 2.0 – further address a regional/national perspective to forecast sustainable harvest levels based on user-defined cutting rules and scenarios (e.g production target per period, proportion of areas abandoned per year, proportion of area burned per year). They further check whether a specific target can be achieved or not. SIMPLOT may be used to forecast harvest levels for the main Portuguese forest species – Maritime pine, eucalypt and cork oak. It is currently being used for Portuguese forest products sustainability assessment within a project funded by the association of Portuguese forest industries (AIFF) (Barreiro and Tomé 2011). CELPASIM 2.0 is used by the association of the pulp and paper industry to assess the potential eucalypt pulpwood supply from areas not owned by its associates. These simulators do not include any optimization module. Several DSS may be used for addressing this same problem (Table 2). Problem type 28 is typically addressed by linear programming methods within DSS even though mixed integer programming and heuristics may also be used.

Problems 8 and 30 are typically associated to the setting up of legally binding Forest Management Plans (PGF) for national forests and non-industrial plantations. Joint management of forest areas faces similar problems when the definition of objectives is made by a single decision-maker (e.g. forest owner association). The PGF goals often focus on the supply of one main market wood or non-wood product (e.g. cork). The spatial representation of the forest units is of importance yet neighbourhood relations are mostly ignored. The development of the legally binding PGF is mostly a technical exercise that involves the selection of a silviculture model for each stand. No economic considerations are taken into account (e.g. no financial analysis is conducted). Thus most computerized tools used in Portugal to support the elaboration of PGFs are information systems built upon spatial databases accessed by graphical and spatial user interfaces. In fact, almost 50% of the computerized tools reported for addressing these problems are information systems (14% of the total number of tools developed in Portugal). WinForest (MIIT 2011) is a stand-alone Information System that consolidates the information required for the PGF, including additional features related with the implementation of PEFC certification processes. Metafarm (Metacortex 2011), GeoFlorestar (Florestar 2011) and Geocerne (Transwood) are examples of other web-based information systems where the utilization scope goes beyond the PGF elaboration. They target activities performed by Forest Owners Associations, including the registering of its associates, the inventory of its holdings and the record of forest operations performed. Yet, the management planning and commercialization processes are mostly ignored. Most of these tools lack projection or selection capabilities as they do not integrate G&YM and decision models.

Nevertheless, several DSS are available to address problems 8 and 30 (Table 2). SADfLOR is a stand-alone research and demonstration prototype developed by university researchers with the cooperation of forest stakeholders e.g Forest Service, Conservation Agency and Forest Industry (Borges and Falcão 1999, Reynolds et al. 2007). It includes a database that stores spatial and aspatial information (Miragaia et al. 1999). It further includes GIS software to present information in maps. In this DSS, empirical growth and yield models (e.g. DUNAS, GLOBULUS and SUBER) are used within a prescription generator (Borges and Falcão 1999b) to simulate alternative management pathways for the main Portuguese forest species. SADfOR takes this information to build forest management planning models (e.g. mathematical programming (Falcão and Borges 1999) and heuristics such as dynamic programming based techniques (Borges and Falcão 1999b) simulated annealing, tabu search, genetic algorithms (Falcão and Borges 2001 and 2002) to help identify efficient strategies.

The SADfLOR concept inspired the development of three DSS for three pulp and paper firms to address problem 8 with a regional/national perspective. They include a G&YM, a prescription writer and a linear programming module (e.g. Borges and Falcão 1998, 2000). The focus was on the assessment of the sustainability of supply of pulpwood from forests owned by the industry that are distributed all over the country.

The DSS PfLOR, EfLOR and MfLOR correspond to updates of SADfOR to address problem types 8 and 30 for maritime pine, eucalypt and cork and holm oak areas, respectively. They may also address a regional/national perspective and include more than one forest. The architecture is similar to SADfLOR's. They include a management information system that stores and reads inventory data needed to feed the growth and yield models. They further include a prescription generator which allows automatic generation of management alternatives. Then these alternatives are simulated using growth and yield models which feed the mathematical formulation module. Both DSS generate linear programming, mixed integer programming and goal programming models to find the maximum sustainable yield for a forest region/area. The EfLOR innovation lies in the incorporation of a process-based growth and yield model (i.e. Glob3PG) so that it may take into account climate change scenarios. It further allows computing carbon stocks in the forest pools. Thus, this tool is specially indicated to analyze climate change impacts on forest planning. PfLOR consists of an adaptation of the SADfOR concept to develop a strategic planning for the Leiria National Forest (Garcia-Gonzalo et al. 2011c Submitted) at the request of the Portuguese Forest Service. MfLOR adapted the same concept to address scenario analysis at the request of a Agro-Forestry Regional Office (Borges et al. 2008).

Problem 6 is prevalent in privately-owned industrial plantations. It presents similarities with the previous problems (i.e. 8, 28, 30) but within a more complex spatial context where the interactions between decisions made in neighbouring stands are of importance. The industry typically aims at fulfilling timber supply for its transformation units, while meeting additional temporal and spatial objectives/constraints (e.g. annual budget constraints, wood availability and price at the national and international markets, maximum harvesting opening area, regular harvesting levels and timber stocks). This problem is often addressed with MIP formulations and solved by exact or heuristic methods (e.g. Borges and Hoganson 1999, Borges and Hoganson 2000, Falcão and Borges 2002, Martins et al. 2005, Constantino et al. 2008). SADfLOR may be used for solving this problem using exact mathematical formulations (i.e. MIP) or heuristics. Further, the EfLOR model base may be easily updated to address problem 6. The SADfLOR concept has inspired the development of at least three industry-owned DSS in Portugal (Ribeiro et al. 2005, Marques et al. 2010, 2012b). These are modular DSS that are usually composed by a spatial database, an application layer with the simulator and optimizer and graphical user interfaces.

Recent studies addressed the need for integrating fire risk in strategic management planning. Garcia-Gonzalo et al. (2011a, 2011b), Marques et al. (2011b) and Marques et al. (2011c) developed risk and damage models for Portuguese conditions and Fernandes et al. 2000 presented the research prototype PiroPinus for forest fires simulations in maritime pine stands. Addressing wildfire risk in strategic management planning requires the acknowledgement of stand neighbouring relationships. Accordingly problem 6 importance is expected to increase at the cost of problems 8 and 30. Ferreira et al. (2012c in preparation) and Ferreira et al. (2012d in preparation) used these fire risk and damage models and applied mixed integer programming and stochastic mixed integer programming models respectively to optimize forest management under risk of fire, taking into account the interaction between neighbouring stands.

Table 2. Computerized tools/DSS, KM techniques and participatory planning methods used/developed for each Forest planning problem types

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
18	AGflor	LP model, Positive mathematical programming, Simulated Annealing	Growth and yield models, Database, GIS	Meetings with stakeholders (Regional Agriculture and Forestry Office)
	MfLOR	LP model	Growth and yield models Database, GIS	Meetings with the stakeholders (Regional Agriculture and Forestry Office)
	-	-	Database, GIS, SWOT analysis, Plans (PROFs)	Forest experts meetings, Public audiences with stakeholders
38	SADPOF	Simulated Annealing; Case-specific heuristic; IFTPP model	Database, Maps, Plans	Enterprise Architecture for System Design
	-	-	Personal records, Negotiations and verbal	-

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
			contracts	
28	EfLOR	LP models, MIP models, Goal Programming	G&YM (3PG, Globulus 3.0, Glob3PG), Database, GIS, Graphics	Meetings with stakeholders (Forest Industry)
	PfLOR	LP models, MIP models, Goal Programming	Yield and econ. Projections, Strategic analysis, Database, Graphics	Meetings with stakeholders (Forest Service)
	SADfLOR	Linear programming, Optimization, heuristics	Strategic analysis, Database, GIS, G&YM/ models (DUNAS, GLOBULUS, SUBER)	Meetings with stakeholders (Forest Service, Conservation Service, Forest Industry)
	SIMPLOT, CELPASIM 2.0	Forest simulator	G&YM/simulators	(Meetings with stakeholders (Forest Service, Forest Industry)
	Implementations of G&YM	G&YM (Pbravo, PBIRROL, MODISPINASTER, PPinaster, GLOBULUS, Glob3PG, SUBER)	G&YM, Ms Excel sheets	-
8, 30	SADfLOR	MIP Optimization,	Strategic analysis, Database, GIS,	Meetings with stakeholders (Forest

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
		heuristics	G&YM/simulators (DUNAS, GLOBULUS, SUBER)	Service, Conservation Service, Forest Industry)
	EfLOR	MIP models, Goal Programming	G&YM (3PG, Globulus 3.0, Glob3PG), Database, GIS, Graphics	Meetings with stakeholders (Forest Industry)
	MfLOR	LP model	Growth and yield models Database, GIS	Meetings with the stakeholders (Regional Agriculture and Forestry Office)
	PfLOR	MIP models, Goal Programming	Yield and econ. Projections, Strategic analysis, Database, Graphics	Meetings with stakeholders (Forest Service)
	Metafarm, WinForest, GeoCerne, GeoFlorestar	-	Spatial Databases, Prescription models, Plans (PGF),	meetings for PGF's goals
6	Proprietary DSS's	MIP models, Heuristics	Spatial Databases, Strategic Plan, Maps	-
	SADfLOR	MIP, Optimization, heuristics	Strategic analysis, Database, GIS, G&YM/simulators (DUNAS,	Meetings with stakeholders (Forest Service, Conservation

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
			GLOBULUS, SUBER)	Service, Forest Industry)
	PiroPinus	Forest fire simulator	-	-
1, 3, 5	Gestão Baldios	-	Spatial Databases, Prescription models, Plans (PGF_ZIF, PUB)	-
	SADfLOR	MIP, Optimization, heuristics	Strategic analysis, Database, GIS, G&YM/simulators (DUNAS, GLOBULUS, SUBER)	Meetings with stakeholders (Forest Service, Conservation Service, Forest Industry)
	3D visualization module	G&YM	Spatial Databases, Graphical 3D interfaces	-
	MfLOR	LP model	Growth and yield models Database, GIS	Meetings with stakeholders (Regional Agriculture and Forestry Office)
	PfLOR	MIP models, Goal Programming	Yield and econ. Projections, Strategic analysis, Database, Graphics	Meetings with stakeholders (Forest Service)
	EfLOR	MIP models, Goal Programming	G&YM (3PG, Globulus 3.0, Glob3PG), GIS, Database,	Meetings with stakeholders (Forest

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
			Graphics	Industry)
	MDCA module	Mathematical Programming, Feasible Goals Method/Interactive Decision Maps (FGM/IDM) technique	Tradeoffs analysis	-
	-	-	Ms. Excel sheets, Plans (PGF_ZIF, PUB), meeting Act	Local communities audiences, Voting, negotiation, meetings with ZIF adherents
16, 17	SADPOF	MIP models, Case specific heuristics	Database, Maps, Plans	Enterprise Architecture for System Design
21, 22, 23, 25	DinDUNAS(SADfLOR)	G&YM/simulators, Dynamic programming	G&YM models, Prescription generator, Yield and econ. Projections	Meetings with stakeholders (Forest Service)
	StandSIMOPT	Non-linear programming optimization	G&YM models, Prescription generator	
		-	Personal records, Ms. Excel sheets	-

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
36	Wise Forms	-	Spatial Databases, Projects	-
	-	-	-	Posted info for the community, Personal records, Negotiations and verbal contracts

Problems 1, 3 and 5 are typically associated to the cases of community forest land and of the recently created Forest Intervention Areas (ZIFs) aggregating the holdings of several NIPF. These problems address multiple objectives and target mainly market wood and non-wood products (problems 3 and 5). They may be addressed by DSS such as SADfLOR, EfLOR, PfLOR and MfLOR. Nevertheless, recent studies (e.g. Marques et al. 2012a) emphasized the need for innovative methods to address participation processes. The decisions regarding the use of community or of jointly owned forests are driven from the consensus among forest owners. Forest technicians may facilitate this process as moderators. They may use participatory planning approaches based on voting and negotiation to support the definition of the joint management goals. These goals may be further documented by using a specific plan template defined by the Forest Service for the community forest land (PUB) and ZIFs.

Computerized-tools are seldom tailored to support participation processes, although some studies (e.g. Martins and Borges 2007) highlighted the potential for application of multi-criteria and other decision-making methods to support it (e.g. real-time 3D visualization tools such as the one developed by Falcão et al. (2006) and applied by Madureira et al. (2011) in central Portugal). Borges et al. (in preparation) have further presented a methodology to find the efficient (Pareto) frontier of a multiple-criteria forest management planning problem. It relies on mathematical programming and Feasible Goals Method/Interactive Decision Maps (FGM/IDM) technique. It allows the analysis of tradeoffs between criteria and supports the selection of forest-level policies accommodating the preferences of multiple stakeholders.

Only one information system was reported to support specifically the management of community forest lands (Gestão de Baldios). Yet, other systems are being upgraded to meet the ZIF's specific management requirements (e.g. the SADfLOR concept, Winforest). The development of the SADfLOR concept aims at integrating the use of the Interactive Decision Maps to support the selection of forest-level policies in a strategic multi-objective problem (e.g. cork production, carbon stocking, timber production) have been developed by university researchers (Garcia-Gonzalo et al. 2011f). This system combines a database, growth and yield simulator, a linear programming model base, an optimizer and the interactive decision maps module.

Problem 18 is of concern to public agencies such as the Portuguese Forest Service. In Portugal, regional forest plans (PROF) provide a framework for forest management planning (Martins et al. 2004). The framework aims at the fulfillment of regional forest development goals – e. g. increase of area that is following a forest management plan - and includes recommendations regarding the forest species and the silviculture models to be adopted by management planning in each of the 21 PROF regions. The development of the frameworks took advantage of computerized tools such as databases and geographical information systems to process information spread across multiple national data sources. It included SWOT analyses to identify the three dominant forest functions foreseen in spatially delimited homogeneous PROF sub-regions (production, protection, conservation, range and forestry, fishing and hunting or recreation and landscape) (Martins et al. 2004). Despite these zoning considerations, the regional plans are non-spatial as they do not integrate stand-level detail. Further, they did not involve projections of forest growth.

PROF and the corresponding management planning frameworks were discussed in meetings where forest stakeholders' representatives were present (Martins et al. 2004). They may be accessed at the Portuguese Forest Service website (www.afn.min-agricultura.pt) and complementary technical documentation is provided by several forestry organizations, such as www.forestis.pt or www.pefc.pt.

PROF were developed in the early 2000s by forestry experts from consulting firms and universities working under the supervision of the Forest Administration (Martins et al. 2004). They are currently suspended and awaiting revision. DSS developed to address specific regional agriculture and forest goals - AGflor (Borges et al. 2009) and Mflor (Borges et al. 2008) - may provide valuable information for PROFs revision. Other DSS and forest simulators currently used to address strategic forest-level problems may also be used to enhance the revision of PROF.

Problems 16 and 17 are prevalent in privately-owned industrial plantations. The solution to Problem 16 is constrained by the solution of Problems 6, 8 or 30. The latter supply the pool of stands that are to be harvested over the tactical planning horizon. The process is often decentralized by industry and it involves monthly harvest scheduling. Tactical plans usually target only market wood products. Yet they involve multiple objectives and constraints (e.g. availability of harvest equipment, crews and trucks, monthly demand levels, quality of the existing forest road infrastructure, maximum clearcut openings). These plans provide the basis for annual forestry budgeting and contracting with service and wood suppliers. The solution to Problem 17 encompasses weekly to daily scheduling of operations foreseen by the tactical plans. Both tactical and operational plans require the acknowledgement of stands' neighbourhood relations.

The DSS SADPOF was recently developed by university researchers, with the cooperation of a consulting firm and forest industry, for joint optimization of harvesting with other forest logistics decisions undertaken over the wood distribution network (including several harvest units, intermediate storage yards, pulp mills and biomass plants) (Marques et al. 2012b). It encompasses a spatial database, an optimization module with exact and heuristic methods

(Simulated Annealing and a case-specific heuristic) to solve the underlying MIP formulations. It further incorporates graphical user interfaces. It provides monthly harvest plans, monthly wood delivery plans and detailed forest operations schedules. It further enables tradeoff analysis to assess the impact of the model parameters over the tactical/operational plans of the baseline scenario. Other computerized tools used to address these problems are proprietary MS. Excel sheets and geographical databases.
Problem 38 has similarities with 16 and 17. Yet, this regional-level problem focuses on the wood flows between the supply and demand locations over the wood distribution network. It often aims at defining the size of the transportation fleet and the trucks' daily transportation routes. This routing problem may be addressed with MIP formulations with multiple objectives and constraints (e.g. maximum route duration, available fleet, maximum distance travelled, obliged stopping points). Spatial information is often used (e.g. location of forest sites, location of the yards and mills, road network) although without considering neighbourhood relations. This problem may also be addressed by SADPOF which provides routing plans that comply with harvesting and monthly wood delivery plans.

The strategic stand-level problems prevail on small-scale non-industrial private forest land (problems 21 to 23). Nevertheless, stakeholders that typically face forest-level problems may conduct stand-level planning under specific situations (e.g. buying or selling wood from a particular stand, managing a stand with particular conservation characteristics). The solutions to these problems involve decisions regarding the rotation length, the thinning schedule and the regeneration options. In the case of NIPF, the planning process is often unstructured and the decisions are built upon empiric insights and traditional silviculture models rather than on standard managerial principles. Single objective problems, targeting market wood products, are most common in northern Portugal (problem 21). Multiple-objective problems, targeting market wood and non-wood (e.g. cork) products, are most common in southern Portugal (problem 23). Nevertheless, environmental concerns (e.g. wildfire protection) and the supply of other products (e.g. fruits, herbs and mushrooms) are becoming more important (Problems 22 and 23). This was highlighted by the information conveyed by the 192 NIPF interviewed by a forest owners association. Problem 25 has similarities with problem 21 yet it focuses on the tactical temporal scale. The solution to this problem provides a monthly schedule of forest operations over a period from two to five years.

The NIPF often rely on spatial and non-spatial stand information for addressing problems 21 to 25. MS Excel sheets and paper documentation are the most common tools used by NIPF. Forest associations and other large-scaled public and private forest land owners may use information systems as well as G&YM also available for forest-level problems. Other computerized-tools designed specifically for stand-level problems may also be used. The DinDUNAS module within SADfLOR (Borges and Falcão 1998) uses Dynamic Programming for selecting the thinning regime and the rotation length that maximizes the income in Leiria National Forest maritime pine stands. A similar module was recently developed using Stochastic Dynamic programming for eucalypt and maritime pine management under risk of fire (Ferreira et al. 2011a, Ferreira et al. 2011b, Garcia-Gonzalo et al. 2011b). Another system recently developed - StandSIMOPT (Garcia-Gonzalo et al. 2011e, In preparation) - combines a growth and yield simulator and the use of non-linear programming optimization techniques and heuristics to find the optimal prescription for a single maritime pine stand. It

allows the maximization of wood market products (i.e. timber) or forest services (i.e. carbon storage). The potential for increasing the use of simulators and decision modules for NIPF management planning was highlighted by the information provided by the 192 thematic interviews. Over 85% of forest owners stated that the use of these tools would contribute to making better decisions and enhance their plans.
Stand-level operational planning (Problem 36) is shared by many decision-makers. They are also one of the problems prevalent in the case of NIPF as often they do not follow a managerial approach and make decisions that do not take into account medium or long-term projections. The operational planning process presents variations among decision-makers. For example, in the case of small NIPF, harvests may be delayed if no buyer is found. Operational planning on public areas usually follows standard procedures for auctioning and contracting the timber sales. In both cases, computerized tools are seldom used. Verbal wood-trade contracts, personal paper records and unstructured MS Excel sheets prevail. In the case of the forest industry, this encompasses a detailed description of forest operations (project). This project is built upon all spatial and non-spatial data available, usually stored in proprietary information systems. Specific data may be collected on land surveys. For this purpose, the commercial information systems WiseForms (Makewise 2011) developed by a Portuguese Informatics company have been used by some pulp companies.

The FORSYS questionnaires further enabled the characterization of the computerized tools' technical and functional features (Table 3). Accordingly, DSS represent 29% of the forest planning computerized-tools in Portugal (most tools consist of G&YM modules or simulators). The first DSS (SADfLOR) was developed in the late 1990s by the Portuguese Centre for Forest Studies in cooperation with the Forest Service, the Forest Industry and the Nature Conservation Service. It provided the foundation to develop other decision modules and DSS (e.g. DinDUNAS, AGfLOR, MfLOR, EfLOR, PfLOR, StandSIMOPT). The G&YM have been recently integrated within simulators used in several strategic scenario analysis projects (e.g. SIMPLOT). Three commercial products were developed (Metafarm, CELPASIM 2.0 and 1 industry-owned DSS). The latter was developed using an Enterprise Architecture approach, conducted by multidisciplinary teams of informatics experts, forest researchers and decision-makers (e.g. Marques et al. 2012).

More sophisticated tools (e.g. DSS and simulators) are used mostly by industrial owners, regional forest service offices and university outreach and consultancy centres. There are significant similarities in the underlying architecture of all DSS as a consequence of a common root (SADfLOR). Typically, they are multicomponent systems, with various combinations of models and optimization techniques, supported by Database Management Systems (DBMS) and accessed by spatial and graphical user interfaces (Marques et al. 2012c). The IT environment and DBM has been evolving from stand-alone/MS Access to web-based/.NET or Java/SQL. Most DSS have geographical display functionalities and yet only 30% are integrated with a proprietary GIS solution. Growth simulation and prescription writing take advantage of G&YM for the main Portuguese species. The exception is SADPOF which does not provide growth projection as it addresses operational planning and that relies on logistics models and specific logistics data (e.g. transportation resources). The optimization module may include a freeware solver (e.g. LP Solve, GNU), a commercial solver (e.g. CPLEX) or meta-heuristics, such as Simulated Annealing, Genetic Algorithms, Random Search or other case-specific heuristics.

Table 3. Main technical and functional features of the computerized tools developed in Portugal

Features	FORSYS questionnaires main results
Type of tool	▪42% of the computerized tools are G&YM modules or simulators (including wildfires simulators). The three main forest species are covered (maritime pine, eucalypt and cork oak). ▪29% of the tools are commercial spatial DB and IS. ▪29% are DSS used for research, education, consultancy or industrial forests management planning.
Origin/owner	▪58% of the tools were developed by Portuguese Forest Research Centres. These institutions are in the genesis of all G&YM modules and simulators (since the 1980s) and DSS (since 1999). Some of these tools were developed for research and demonstration purposes, others for consulting and others for the use of the forest industry. ▪The number of Informatics companies has increased in the late 2000s and new tools are available. They provide mostly IS with no projection or optimization functionalities. Currently there are 5 forestry/informatics companies, two of which have specialized on DSS design and development in partnership with the forest research centres. ▪There are two forest owners associations actively involved in IS development and commercialization.
Scope of utilization	▪About 60% of G&YM modules, simulators and DSS are mostly used for research, education and outreach. ▪About 50% of the DSS are in use either for consultancy by university experts or to support management planning by forest-based industries. This includes the industry-owned DSS and university-owned DSS. ▪About 60% of the commercial IS are in use, especially by forest owners associations. ▪Only 3 G&YM can be easily accessed on the developers' web site (Pbravo, PiroPinus, Geoflorestar). ▪In the case of the 4 tools for which user data is available, the number of users varies between 3 and 20.
Target user group	▪54% of the tools target forest owners associations, large-scale NIPF and industrial owners. These groups use information systems, G&YM modules, simulators and DSS. ▪40% of target public land managers and the Forest Service. ▪Single small-scale NIPF (outside an Association) often do not use any computerized tool.
Data requirements	▪Forest inventory data is required to use about 60% of the tools, including all G&YM modules, simulators and DSS. ▪Data requirements by DSS are typically higher and yet depend on the problem type being addressed. ▪54% of the tools provide wood/non-wood projection functionalities. ▪Only the DSS and the simulators are capable of addressing ecological and economical management goals. ▪33% of the tools claim to produce forest management plans. Yet, only the DSS provide optimal prescriptions selection. ▪There is only 1 tool (SADPOF) that explicitly addresses tactical/operational planning.
IT environment & IT requirements	▪65% are stand-alone applications. The majority of these have been developed with Visual Basic under the Ms Windows environment and include MS Excel/Access data modules. ▪30% of the tools are web-based, including 2 of the DSS, developed on .NET or JAVA environment, with SQL/Oracle DBs. ▪Since 2004 there is an increasing tendency for web-based developments, but stand-alone applications are still used.

Features	FORSYS questionnaires main results
	▪ 54% of the tools do not have installation/utilization requirements. The remaining tools require GIS licensing or network/server equipment.
Participatory planning	▪ Most DSS have been developed in cooperation with stakeholders. A few used Enterprise Architecture approaches to further engage the decision-makers/stakeholders in the design phase. ▪ No system is available with specific functionalities to support participatory planning processes. ▪ 54% of the tools do not offer users manuals, user support or training.

19.4 Discussion and conclusions

The survey of computerized tools developed to support forest management planning in Portugal revealed the existence of a wide range of tools with research and commercial purposes. Most tools are used to support strategic forest-level problems with multiple-objectives (problems 1, 3, 5, 6, 8, 28 and 30). The results of the DSS application show that they can effectively address the spatial and temporal planning issues of real-world problems (e.g. SADFLOR, EfLOR, PfLOR). Nevertheless, the regular use of forest decision support systems in Portugal is still confined to a small group of users, most of them in the pulp and paper industrial sectors and in outreach and consultancy groups at the university.

The low level of DSS utilization by most forest owners is consistent with the low level of active forest management, itself a consequence of the Portuguese forest land property structure. Only about 25% of the forest area is under the impact of formal management plans. Further, these plans consist mostly of technical descriptions that involve the identification of a silviculture model for each stand. No economic considerations are taken into account (e.g. no financial analysis is conducted). DSS inventory and economic data modules and growth projection capabilities that are key for effective management planning are costly and useless if no active management is pursued and/or if no resource allocation concerns are considered.

Innovative technologies such as LIDAR and/or simpler inventory procedures, leveraged on existing National Inventory Forest Inventory data (www.afn.min-agricultura.pt/portal/ifn) may decrease DSS usage costs and foster the users' adoption. Yet the key factor underlying the low level of DSS utilization by most forest owners is not the lack or the inadequacy (cost) of the supply of computerized tools that might enhance forest management planning. It is rather the lack of active management that leads to the lack of demand for the tools needed to support it. The role of Regional Forest Service Offices and of Forest Owners Associations is key for promoting active management and disseminating the use of tools needed to support it.

The survey further showed that fewer tools are available and used to address long-term, stand-level management planning problems (21 to 25) even though they are among the most common in Portugal especially among the small-scaled NIPF. Again this is a consequence of the lack of active management (mostly by NIPF). It may be also a consequence of managerial perspectives of some NIPF in Portugal. Baptista and Santos (2005) reported results of a survey where 61% of the owners, with less than 5 ha, see their forests as a reserve, where harvests are triggered by criteria other than profitability. Frequently the forest operations (e.g. bush removal) are not performed (Property-reserve rational) or rely exclusively on the owners own labour and equipment resources (Labour-reserve rational). Nevertheless, there is no lack of supply of tools needed to support it (e.g. Garcia-Gonzalo et al. 2011e in preparation). These tools encompass user-friendly interfaces, require simple data sets for input, do not need a link to a database (although it may have one) and therefore may be used by small forest owners or entrepreneurs in addition to more sophisticated users such as industry and outreach and consultancy university units.

The forest land owners associations may play a key role in promoting active management planning among NIPF and the usage of tools to support it. A more pro-active contact between DSS developers and these associations would be beneficial. In addition, there is a need for training the forestry community in the usage of recent tools for forest planning. The studies of forest land owners' behaviour further suggests a more managerial behaviour in the case of forest owners with holdings larger than 5 ha, especially with eucalypt stands. If successful, earlier dissemination efforts by the associations targeting these owners might trigger the adoption of active management by smaller-scale NIPF.

The survey further highlighted the shortcomings of current computerized-tools and pointed out the need for additional DSS research and development to address emergent planning contexts. In fact, there is a lack of tools tailored to address participatory planning processes that are relevant to support regional planning processes (problem 18) as well as the multiple decision-maker problems prevalent in community forest lands and ZIFs (problems 1, 3 and 5). The ripening of the ZIFs structures suggests the development of innovative DSS addressing business models for joint commercialization and direct negotiation with the industry buyers. It further suggests the integration of participatory-planning techniques and of G&YM and landscape analysis models to project the supply of other market non-wood products, such as biomass, fruits and mushrooms, recreation and other market services (Mendes 2005) (Problem 1). In the case of vertically integrated industries (Problem 6), the DSS development might focus on the whole wood supply chain management (e.g. D'Amours et al. 2008).

The solution of tactical and operational planning problems, both at forest level (Problems 16 and 17) and stand level (Problem 36) also requires further research. The complexity of the interactions and interdependencies among agents in the wood supply chain and the high economical impact of the logistics cost over the total timber cost at the transformation centre calls for novel forest logistic planning DSS with commercial purposes, possibly built upon research prototypes such as SADPOF. The novel DSS should rely on state-of-the-art technological platforms as well as standard data-models (e.g. www.papinet.org) to ensure interoperability, communication and integration of individual supply chain agents. Furthermore, research should be conducted to integrate these DSS with other devices for operations control and follow-up in order to trigger re-plan events. This research should focus on the development of an interoperability platform for the entire wood supply chain. The technological framework for the Portuguese wood procurement supply chain presented by Marques et al. (2012) underlined the functional and technological requirements for integrating DSS with other mobile devices (e.g. infra-red surveillance cameras for fire detection, RFID wood track-and-trace devices, embedded wood truck GPS positioning devices and autonomous PDAs for operations on-land monitoring).

Lastly, the survey sheds light on some key DSS development features that may be influential to foster their adoption by end-users. The use of participatory techniques (e.g. according to the enterprise architecture approach), proved to be effective in engaging the decision-makers/stakeholders in the DSS design phase, thus facilitating users training and tool deployment in the implementation phase. Web-based architectures may be more adequate to support multiple decision-making contexts. The tools' scalability and upgrade is enhanced by fully modular architectures (e.g. independent simulators, optimization modules, data modules and spatial and graphical user interfaces). Finally, Service-Oriented-Architecture approaches are most appropriate when interoperability features are required.

References

Alegria, C. 2007. PBIRROL Modelo de crescimento e produção para os povoamentos de pinheiro bravo de estrutura irregular do concelho de Oleiros. Agroforum 15 (18): 13-18.

AFN 2006. Estratégia Nacional para as florestas. www.afn.min-agricultura.pt

AIFF 2010. Relatório de caracterização da fileira florestal 2010. www.aiff.org.pt

Baptista, F.O. and Santos, R 2005. Os proprietários florestais: Resultados de un inquérito. Celta. Oeiras. 94 pp.

Barreiro, S. and Tomé, M. 2011. SIMPLOT: Simulating the impacts of fire severity on sustainability of eucalyptus forests in Portugal. Ecological Indicators 11 (2011) 36–45.

Borges, J. G. 1997. Analysis of the markets for roundwood and forest industry products in Portugal. In: B. Solberg and A. Moiseyev (Eds.) Demand and Supply Analysis of Roundwood and Forest Products Markets in Europe. EFI Proceedings no. 17. Pp. 309-328.

Borges, J. G. and Falcão, A. 1998. Simulação expedita de planos estratégicos para a área de eucaliptal da Portucel Florestal. Grupo de Economia e Gestão em Recursos Florestais, Departamento de Engenharia Florestal, ISA, Lisboa, 394 p.

Borges, J. G and Falcão, A. 1999a. Programação Dinâmica e gestão de povoamentos florestais com estrutura regular e composição pura. Aplicação à mata nacional de Leiria. Revista Florestal. Vol XII, (1/2). Pp 69 – 82.

Borges, J. G. and Falcão, A. 1999b. sagFlor - Um simulador de alternativas de gestão em ecossistemas florestais. Revista Florestal XII(1/2): 63-68.

Borges, J. G., and Hoganson, H. M. 1999. Assessing the impact of management unit design and adjacency constraints on forest wide spatial conditions and timber revenues. Canadian Journal of Forest Research 29: 1764-1774.

Borges, J. G., Hoganson, H. M. and Rose, D.W. 1999. Combining a decomposition strategy with dynamic programming to solve spatially constrained forest management scheduling problems. Forest Science 45: 201-212.

Borges, J.G. and Hoganson H.M. 2000. Structuring a landscape by forest land classification and harvest scheduling spatial constraints. Forest Ecology and Management 139(1-3): 279-279.

Borges, P., Marques, S., Borges, J. G. e Tomé, M. 2008. Scenario analysis applied to cork and holm oak forest ecosystems in Southern Portugal. In: Palahi, M., Birot, Y., et al. (Eds) Modelling, valuing and managing Mediterranean Forest ecosystem for non-timber goods and services, EFI Proceedings 57: 49-56.

Borges, P. J., R. Fragoso., Garcia-Gonzalo J., Borges J. G., Marques S. and Lucas, M.R. 2010. Assessing impacts of Common Agricultural Policy changes on regional land use patterns with a decision support system. Forest Policy and Economics 12 (2): 111-120.

Borges, J.G., Garcia-Gonzalo, J., Bushenkov, V.A., Borges, P.J., McDill, M., Finding the efficient frontier of a multiple criteria planning problem; Scenario analysis applied to cork and Holm oak forest ecosystems in Southern Portugal. (In preparation)

Constantino, M., I. Martins, et al. 2008. A New Mixed-Integer Programming Model for Harvest Scheduling Subject to Maximum Area Restrictions. Operations Research 56(3): 542-551.

D'Amours, S., Rönnqvist M. and A. Weintraub. 2008. Using Operational Research for supply chain planning in the forest product industry. INFOR 46 (4): 47-64.

ESRI 2011. www.esri.com/software/arcview

Falcão, A.O. 1999. DUNAS - A Growth Model for the National Forest of Leiria. In: Amaro A. and Tomé M.M. (Eds.). Proceedings in the IUFRO Workshop Empirical and Process-Based Models for Forest Tree and Stand Growth Simulation. Oeiras, Portugal: Edições Salamandra, pp. 145-154.

Falcão, A. and J. G. Borges. 1999. Programação linear e gestão estratégica em recursos florestais. Aplicação à Mata Nacional de Leiria. Revista Florestal XII(1/2): 93-98.

Falcão, A.O. and Borges J.G. 2001. Designing an evolution program for solving integer forest management scheduling models: An application in Portugal. Forest Science 47(2): 158-168.

Falcão, A.O. and Borges J.G. 2002. Combining random and systematic search heuristic procedures for solving spatially constrained forest management scheduling models. Forest Science 48(3): 608-621.

Falcão, A.O., M. Próspero dos Santos and J. G. Borges. 2006. A real-time visualization tool for forest ecosystem management decision support. Computer and Electronics in Agriculture 53: 3–12.

Falcão, A.O. 2009. CELPASIM 2.0 Manual do Utilizador Versão 2.0.0. Departamento de Informática - Faculdade de Ciências da Universidade de Lisboa, Lisboa. 39 pp

Fernandes, P., H. Botelho and C. Loureiro 2000. A prescribed burning guide for maritime pine stands, version 1.0. Task 6 - Deliverable F2 of the Fire Torch project: Prescribed Burning as a Tool for the Mediterranean Region. ENV4-CT98-0715, European Commission, DG XII, Science, Research and Development, Programme: Environment and Climate.

Florestar 2011. O sistema Geoflorestar. http://www.tudogere.com/geo/geral/login/login.asp

Ferreira, L., Constantino, M. and Borges, J.G. 2011a. Optimizing management of Pinus pinaster stand under risk of fire. An application in Portugal. First Online in June 2011 in the international scientific journal Annals of Operational Research.

Ferreira, L., Constantino, M., Borges, J.G., Garcia-Gonzalo, J. 2011b. Optimizing Eucalyptus globulus Labill stand management scheduling under the risk of fire. Submitted in the International Scientific Journal Forest Science (In print).

Ferreira, L., Constantino, M., Borges, J.G. and Garcia-Gonzalo, J. 2011c. A Mixed Integer programming approach to include wildfire risk in landscape level planning. (In preparation)

Ferreira, L., Constantino, M., Borges, J.G. and Garcia-Gonzalo, J. 2011d. A stochastic programming approach to include wildfire risk in landscape level planning. (In preparation)

Fonseca, T.F., C.P. Marques, B.R. Parresol 2009. Describing maritime pine diameter distributions with Johnson's SB distribution using a new all-parameter recovery approach. For. Sci. 55(4):367-373.

Garcia-Gonzalo, J., Marques S., Borges J.G., Botequim B., Oliveira M.M., Tomé, J., Tomé, M. 2011a. A three-step approach to post-fire mortality modelling in Maritime pine (Pinus pinaster Ait) stands for enhanced forest planning in Portugal. Forestry. 84(2): 197-206.

Garcia-Gonzalo, J., Pukkala, T., Borges, J. 2011b. Integrating fire risk in stand management scheduling. An application to Maritime pine stands in Portugal. Annals of Operational Research. First Online May 2011. DOI 10.1007/s10479-011-0908-1

Garcia-Gonzalo, J., Palma, J., Borges, J. G., J, Freire, J, Tomé, M. 2011c. PfLOR - A tool for strategic management planning. Applying the Forest Model concept. (In preparation)

Garcia-Gonzalo, J., Palma, J., Borges, J.G., Soares, P., Tomé, M., Pereira, J. S., Miranda, P. 2011d. Designing a Decision Support System for eucalypt forest management under scenarios of climate change. An Application In Portugal. (In preparation)

Garcia-Gonzalo, J., Tomé, M. Borges, J.G., Freire, J., Zubizarreta-Gerendiain, A. 2011e. StandSIMOPT - New tool for simulation and optimization of small scale forestry. A stand management problem in Leiria National Forest (In preparation).

Garcia-Gonzalo, J., Bushenkov, V.A., McDill, M., Borges, J.G. 2011f. Using MFLORMO to find the efficient frontier of a multiple criteria planning problem in cork and holm oak forest ecosystems in Southern Portugal (in preparation).

INE 2009. Estatísticas agrícolas – 2009. www.ine.pt

Intergraph 2011. Geomedia GIS solution. www.intergraph.com

Madureira, L., Nunes, L. C., Borges, J. G. and Falcão, A. O.. 2011. Assessing forest management strategies using a contingent valuation approach and advanced visualisation techniques: A Portuguese case study. Journal of Forest Economics 17: 335-432.

Makewise 2011. Wise Forms applications description. www.makewise.pt

Marques, S., Borges, J. G., Garcia-Gonzalo, J., Moreira, F., Carreiras, J.M.B., Oliveira, JM. M., Cantarinha, A., Botequim, B. and Pereira, J. M. C. 2011a. Characterization of wildfires in Portugal. European Journal of Forest Research 130: 775-784 DOI: 10.1007/s10342-010-0470-4

Marques, S., Garcia-Gonzalo J, Borges J.G., Botequim B., Oliveira M. M., Tomé, J., Tomé, M. 2011b. Developing post-fire Eucalyptus globulus stand damage and tree mortality models for enhanced forest planning in Portugal. Silva Fennica 45 (1), 69-83. http://www.metla.fi/silvafennica/full/sf45/sf451069.pdf

Marques, S., Botequim, B., Garcia-Gonzalo, J., Borges, J.G., Tomé, M., Oliveira M. M. 2012. Assessing wildfire risk probability in Pinus pinaster Ait. stands in Portugal. Forest Systems 21(1): 111-120

Marques, A., Borges, J. G., Sousa, P. and Pinho, A. M. 2010. An enterprise architecture approach to forest management decision support design. An application to pulpwood supply management in Portugal. European Journal of Forest Research 30: 935-948

Marques, A. F., Borges, J.G., Garcia-Gonzalo, Lucas, B., 2012a. A participatory approach to design a regional forest management planning decision support toolbox. Forest Systems (in print)

Marques, A.F. and J.G. Borges. 2012b. A hybrid approach for integrating harvest scheduling and product assortment and assignment to transformation centres. (In preparation)

Marques, A. F., Borges, J.G., Sousa, P. M., Fonseca, M., Gonçalves, J. and Oliveira, J. 2012c. Chapter 1: An Enterprise Architecture Approach for Designing an Integrated Wood Supply Management System. In: Varajão, J., Cruz-Cunha M.J., Trigo, T. Organizational Integration of Enterprise Systems and Resources: Advancements and Applications. IGI Global. ISBN13: 9781466617643

Martins, H., Marey, M., Uva, J. C., Ribeiro, R. P. e Borges, J. G. 2004. The contribution of regional planning for the development of forest management plans - a comparative analysis of case studies from Portugal and Spain. In: Actas do II Simposio Ibero-Americano de Gestão e Economia Florestal, 18-20 Setembro, 2004, Barcelona, Espanha. https://www.gruponahise.com/simposio/papers%20pdf/Marey%20IV.pdf

Martins, H. and Borges, J. G. 2007. Addressing collaborative planning methods and tools in forest management. Forest Ecology and Management 248(1-2): 107-118.

Martins, I., M. Constantino and J. G. Borges. 2005. A column generation approach for solving a non-temporal forest harvest model with spatial structure constraints. European Journal of Operational Research 16: 478-498

Mendes A. 2005. Portugal. In: Merlo, M. And Croitoru L. (Eds.). Valuing Mediterranean Forests: Towards Total Economic Value. Wallingford Oxon (UK). CAB International, pp. 331-352.

Metacortex (2011). Metafarm applications description. www.metacortex.pt

MIIT 2011. Winforest for forest management. http://83.240.136.253/Miit/Default.aspx?tabid=60

Miragaia, C., Borges, J. G. e Tomé, M.. 1999. inFlor, um sistema de informação em recursos florestais. Aplicação em gestão na Mata Nacional de Leiria. Revista Florestal XII(1/2): 51-56.

Novais, A. and Canadas M.J. 2010. Understanding the management logic of private forest owners: A new approach. Forest Policy and Economics (12): 173-180.

Páscoa, F. 2001. Pbravo v.2.0. Modelo de Produção para o Pinheiro Bravo. Federação dos Produtores Florestais de Portugal. Manual do Utilizador (47pp). A. D. Medida 4.

Reynolds, K. M.., Twery, M., Lexer, M. J., Vacik, H., Ray, D., Shaom, G. and Borges, J. G. 2007. Decision support systems in natural resource management. In: Burstein, F., Holsapple, C. (ed) Handbook on decision support systems, Springer Verlag International.

Ribeiro, R. P., J. G. Borges, C. M. Pereira, P. M. Sousa and J. P. Lé. 2005. Designing an Integrated Forest Planning System for the forest industry: an application in Portugal. In: M. Bevers and T. M. Barrett (Tech. Comps.) Systems Analysis in Forest Resources. Proceedings of the 2003 Symposium, October 7-9, 2003, Stevenson, WA, USA. Gen. Tech. Rep. PNW-GTR-656. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 89-96.

Tomé, M.M., Falcão, A.O. and Amaro, A. 1998. GLOBULUS V.1.0.0: a regionalized growth model for eucalypt plantations in Portugal. In: Ortega A. and Gezan S. (Eds.), Modelling Growth of Fast-Grown Tree Species, Proceedings, IUFRO Conference. Valdivia, Chile: IUFRO, pp. 138-145.

Tomé, M.M., M.B. Coelho, M.B., Pereira, H., Lopes, F. 1999. A management oriented growth and yield model for cork oak stands in Portugal. In: Amaro A. and Tomé M.M. (Eds.), Proceedings in the IUFRO Workshop Empirical and Process-Based Models for Forest Tree and Stand Growth Simulation. Oeiras, Portugal: Ediçoes Salamandra, pp. 271-289.

Tomé, M.M. 2004. Modelo de crescimento e produção para a gestão do montado de sobro em Portugal. Projecto POCTI/AGR/35172/99. Relatório Final – Relatório de Execução Material (Volume I). Publicações

GIMREF RFP 1/2004. Universidade Técnica de Lisboa. Instituto Superior Agronomia. Centro de Estudos Florestais. Lisboa. 89 pp.

Tomé, M., Faias, S., Tomé, J., Cortiçada, A., Soares, P., Araújo, C., 2004. Hybridizing a stand level process-based model with growth and yield models for Eucalyptus globulus in Portugal. Proceedings of the IUFRO Conference Eucalyptus in a Changing World, Aveiro, 11-15 October, pp: 290-297.

Tomé, M., Oliveira, T., Soares, P. 2006. O modelo Globulus 3.0. Publicações GIMREF - RC2/2006. Universidade Técnica de Lisboa. Instituto Superior de Agronomia. Centro de Estudos Florestais. Lisboa. 23 pp.

20 Computer-based tools for supporting forest planning and management in Slovenia

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20.1 Introduction

The Republic of Slovenia became independent in 1991. It covers 20,256 km^2 and has a population of 1.9 million. In 2009, forests covered 58.5% (1,186,104 ha) of the total country area. The forest cover has increased for several decades mainly due to overgrowing of abandoned agricultural areas. Approximately 25% of the forests are state-owned and the rest are privately owned by approximately 320,000 owners. One of the basic characteristics of Slovenia is extreme nature diversity. On a relatively small area, the Alps, the Mediterranean, the Dinaric Mountains, and the Pannonia Basin converge. Beech sites cover 71% of the total forest area; European beech and Norway spruce are two dominant tree species. The average growing stock amounts to 276 m^{3}ha^{-1} (SFS 2010) and has been constantly increasing in last 60 years.

There is a rich tradition in close-to-nature forestry in Slovenia. The main principles in forestry are also a cognitive approach to forest management, simultaneous planning at a broader scale and at a detailed level, the conservation of natural environment and keeping the ecological balance of the landscape, preservation of the sustainability of all forest functions, and mimicking natural processes (Resolution on national… 2008). Among silvicultural systems, small-scale irregular shelterwood system and selection system are mainly applied; clear cutting has been prohibited by law since 1949. Mean harvest rate amounts to only 60% of total increment, mainly due to low cutting intensities in small-scale private forests.

The forest policy framework in Slovenia is set by the Forest Act (1993) and by the Resolution on National Forest Programme passed by Parliament in 2007 (Resolution on national… 2008). Forest policy defines particular measures of forest management in accordance with close-to-nature and multi-objective forestry. It also strongly emphasizes the public interest in forests as well as the principles of sustainability: ecological, social and production functions ought to be respected in forest management irrespective of ownership. In compliance with the Forest Act, subordinate regulations are issued to regulate specific forest activities or forest management in detail. Public interest is assured through several legislative regulations, like: (1) free access- and movement- possibility in all forests, (2) prohibition of clear-cutting, (3) forest and wildlife planning for the entire forest area regardless of ownership.

The forest policy is implemented through forest management plans; they define conditions and measures for coordinated forest use, the necessary extent of silvicultural and protection measures, the allowable cut and conditions for wildlife management. Forest management plans are elaborated by the Slovenia Forest Service (hereinafter SFS) and verified by the Minister in charge of forestry. There are three types of forest management plans:

- regional forest management plans (for 14 regional forest units);
- forest management unit plans (for 236 forest management units);
- detailed silvicultural plans.

The main problems related to decision-making in forest management are (listed in decreasing order of importance): organisation of sustainable and multipurpose forest management; considering natural hazards and climate changes; preservation and protection of wild game and their habitats, and provision of coexistence with humans; improving forest management and planning in private forests; mobilization of timber wood supply; land-use planning, balancing stakeholders' demands on forests; participatory planning; forest road network extension and maintenance; planning of forest operations technologies; and forest planning of priority areas and management regimes in protection forests.

The main strategic problems in forest management planning are: organisation of sustainable and multipurpose forest management, preservation and protection of wild game and their habitats, and provision of coexistence with humans, mobilization of timber wood supply, and land-use planning and balancing stakeholders' demands on forests. Most urgent medium-term problems refer to adaptive forest management in forests exposed to natural hazards and climate changes, and forest management and planning in private forests. A typical example within this problem type is decision-making in private forest property, where the decisions can be characterised as a result of a single decision-maker at the property level. Among tactical problems, forest road network extension and maintenance is another typical example of a tactical problem. The operational problem that we consider more attention should be paid to is participatory planning. Participatory planning techniques are an example of short-term decision-making where more than one decision-maker is involved.

Table 1. The list of problem types and an overview of selected examples of the decision support systems (DSS) applications.

Problem type	**Computerized tool/DSS**	**Models and methods**	**KM techniques (if applicable)**	**Methods for participatory planning (if applicable)**
Organisation of sustainable and multipurpose forest management	FIS (Forest Information System)	GIS-based FIS	Knowledge repositories, development of own software solutions in the Department for Informatics, SFS, thematic workshops for SFS employees	-

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
Considering natural hazards and climate changes in forest management planning	GIS model	Regression-type decision tree model for predicting salvage cut	-	-
Preservation and protection of wild game and their habitats, and provision of coexistence with humans	GIS model	Raster models of game density populations, habitat suitability models, game modelling, ungulate browsing models	Continuously updated knowledge banks of research results captured through the telemetry systems	DSS was developed in cooperation between SFS and research institution (University of Ljubljana)
Improving forest management and planning in private forests	Computerized tool FORPLAN	Includes: Cut intensity model Wood quality model	Forest property plans for case studies	FORPLAN was developed in cooperation between SFS and owners' association
Mobilization of timber wood supply	Computerized tool WISDOM	GIS model of fuelwood production/consumption	-	-
Land-use planning, balancing stakeholders' demands on forests	GIS tools (e.g. MPX or Mapinfo)	GIS tools are used to locate the object of possible intervention and to analyze the impact of the intervention on the forest and forest space.	Knowledge repositories, inter-institutional communication through the network HKOM	Other state institutions: e.g. Institute of the Republic of Slovenia for Nature Conservation
Participatory planning	The Web based platform	GIS with graphical data of the proposed protection forests and forests of special purpose, active participation of municipalities	PR department in SFS responsible for developing participatory methods	Active participation of local communities
Forest road network extension and maintenance	Computerized tool	GIS model, distance analyses	-	-
Planning of forest operations technologies	Computerized tool	GIS model – spatial modelling, cost – distance analyses	Case studies	DSS was developed in cooperation between public forest service and research institution

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
				(University of Ljubljana)
Forest planning of priority areas and management regimes in protection forests	FIS (Forest Information System)	GIS-based FIS	-	-

Ten representative problem types and selected DSS used in problem solving are presented in Table 1 and categorised according to the dimensions proposed in FORSYS in Appendix 1. The detailed description of DSS is provided in the results. Most of the 10 problems described in the results are spatial problems, where neighbourhood interrelations are considered and more than one decision-maker is involved. A typical urgent decision problem, which does not relate to spatial context and is the subject of a single decision-maker, is decision-making in private forest properties (i.e. finding tools which would support owner-oriented forest management planning). Another example of a non-spatial problem type is participatory decisions made by the stakeholders (e.g. adding suggestions to the draft of legal regulations of protected forests via the internet-based platform).

Most of the described problems refer to stand level (adaptation of forest stands to natural hazards, modelling Slovenia's fuelwood production/consumption from the stand level to regional level or objective evaluation of forest construction investments allocation). For two problem types at the national level the DSS have been particularly intensively developed recently; for the organisation of sustainable and multipurpose forest management and for private forest management.

Almost all problems are multi-objective and they address market and non-market goods and services.

Regional forest management plans follow the guidelines of the Resolution on National Forest Programme and define the following: forest functions (priority areas for particular management objectives), operational goals and directions and measures for their achievement, directions for wildlife management which present the basis for the regional hunting plan, areas of protection forests and special purpose forests as well as the guidelines for sanitary measures in damaged forests.
Forest management unit plans consider the guidelines of the regional forest management plan. They define: forest management goals, intensity of forest management, guidelines for goal achievement, measures and methods for their implementation in different planning units (e.g. forest types) of forest area.

Detailed silvicultural plans aim at the implementation of forest management unit plans on the stand level. In silvicultural plans, silvicultural goals, guidelines and measures at stand level are defined. Further, the extent, intensity and urgency of silvicultural and protection measures are defined, the areas where individual tree marking for felling is not obligatory are specified, spatial and time restrictions for harvesting, methods and conditions for timber harvesting, and guidelines for preserving and improving ecological and social forest functions.

The purpose of this report is to review the existing computerized tools that support forest management and planning. We focus on the problem types that are significantly important for Slovenia. The efficiency (advantages, disadvantages, limitations) of current and perspective use of DSS is reviewed and discussed.

20.2 Materials and methods

This report was prepared by a team of experts in the field of forest planning and management and forest technology. The information about the available forest management, planning and computerized DSS was acquired mostly from forest inventory systems carried out by SFS. The main information layers considered in forest management decision-making are permanent sampling plots, cadastral maps, stand maps, forest functions, forest roads and register of different measures. We reviewed planning procedures, the usage of participatory methods, and applications of DSS in the past five years based on published research works. We present some examples of computerized tools. We did not consider unpublished models, the prototypes or specific models incorporated in more complex DSS. Likewise, presenting a historic overview of DSS development in Slovenia, more in-depth analyses of all computer-based tools and the presentation in the FORSYS Wikipedia would be beyond the goals of this report. In addition, we evaluated the success of described tools in practice with the following aspects (Table 2): (a) the quality of development process of a tool, (b) methodological adequacy in addressing and structuring the problem, (c) the level of knowledge management and techniques applied, and (d) the involvement of stakeholders and their power in decision-making. Possible reasons for the success of described computer-based tools are discussed.

20.3 Results

Problem types, addressed by DSS, are listed in Table 1 in decreasing order of importance and the examples of DSS, their structure and use in forest practice are described.

20.3.1 Adaptive, sustainable and multi-objective forest planning as a fundamental tool for sustainable and multipurpose forest management

Forest planning in Slovenia is characterized by the combination of planning, implementation, monitoring and evaluation in a closely connected and continuous management cycle, i.e. using an adaptive approach. In adaptive forest management, every management problem encountered to during the planning could be defined as a search for the optimal output (i.e. solution) based on the available inputs. Continuous use of data from the Forest Information System (hereinafter FIS) and transforming it into management information is inherent to the system and fundamental for decision-making.

Adaptive forest management planning claims that the planned objectives and measures are improved and adapted by using additional information and experiences, gathered during the management process. The planning process integrates the following planning phases

(Bončina and Čavlović 2009; Figure 1.): (1) identifying the current conditions and analysing past management, (2) setting the management goals, (3) planning strategies, guidelines and restrictions for forestry activities, which is later followed by implementation and (4) monitoring. The monitoring of forest development and forest management is a crucial phase representing a basis for evaluation of recent forest management and corrections of objectives and measures for management in the future and thus connecting all phases into the adapted planning process.

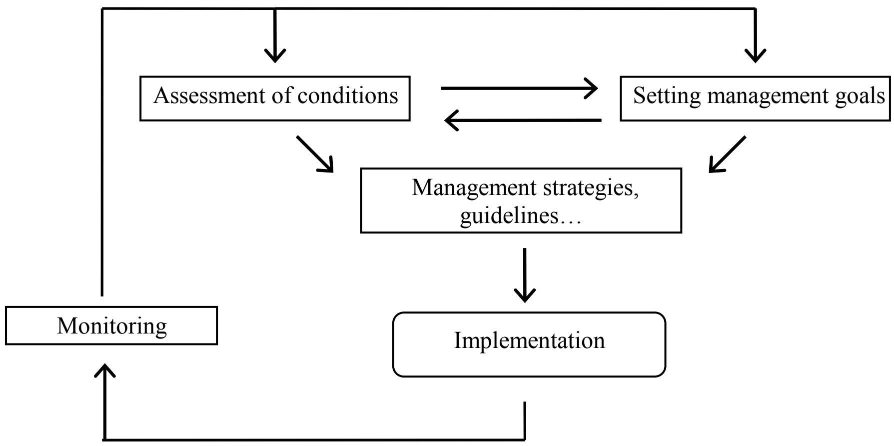

Figure 1. Phases of adaptive forest management planning.

20.3.2 Computer-based tools

20.3.3 Forest information system (FIS)

The complexity of decision-making requires a comprehensive information system which enables proper management problem structuring and provides relevant information. FIS, as described here, was developed in 1990s and since then it has been continuously maintained and upgraded, mainly by the professionals of SFS. FIS is based on relational database theory and it is designed to be open, dynamic and modular. The FIS consists of different information layers, including data on the state of forests, forest management and the socio-economic environment. It covers the entire forest area (Figure 2).

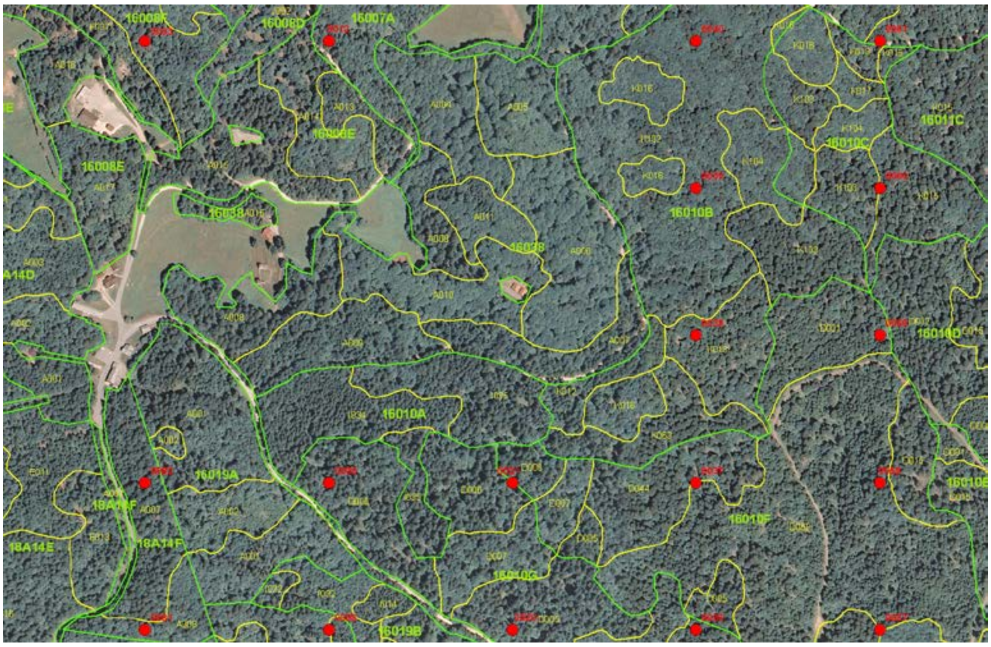

Figure 2. Main information layers on forests carried out by Slovenia Forest Service (SFS 2009).

Four main information layers: compartments (N = 54,525), Forest stands (N = 302,473), Forest functions, Permanent sample plots (N = 102,445).

Forest inventory data is one of the main inputs in FIS. The entire forest area in Slovenia is divided into management units (2,000 ha to 9,000 ha). The mean inventory period is 10 years; every year approximately 10% of the total forest area of Slovenia is re-measured. In addition, other crucial information sources for FIS obtained either from forest inventory or through monitoring of forest management are presented in Figure 3.

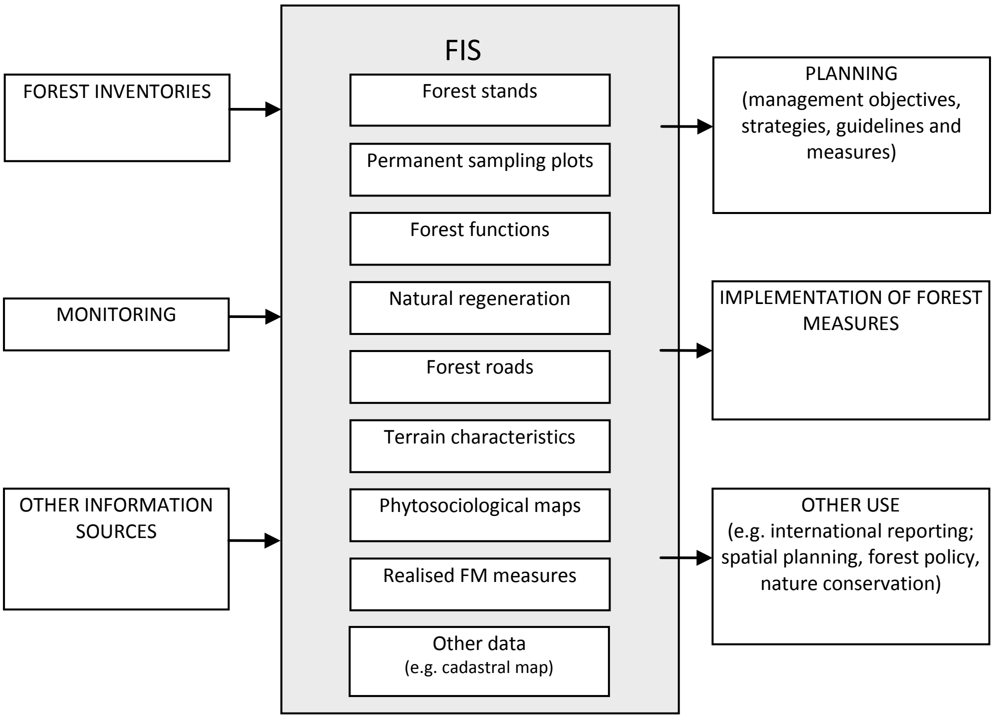

Figure 3. Conceptual framework of forest information system (FIS).

FIS provides a framework for solving forest management problems at different spatial scales (stand, landscape and regional level), and for different fields of forest management. However, the main attention is given to decisions concerning the development of forest stands:

- At regional level, general guidelines concerning forest stand management are defined for a long- and medium-term period (e.g. decisions on silvicultural systems, regeneration policy, harvest intensities, investment priorities, thinning regimes, forest conversion policy).
- At landscape level (forest management unit) forest planning is focused on a 10-year period. Decisions on silvicultural treatments in stands in different forest types (i.e. site conditions) are stressed. In addition, management intensity, allowable cut and silvicultural and protection measures are planned.
- On the stand level, a short guideline is defined for each stand. FIS enables the district forester to have a geo-referenced overview of stand types, types of silvicultural treatments, locations of silvicultural measures and their priority ranking. Thus, a district forester still has to use his expert knowledge for yearly-based decisions while taking forest owners' demands or current timber market situation into account.

20.3.4 DSS applications in forest management and planning

Different methods and applications of DSS have been used in Slovenian forestry, from early ones (e.g. Gašperšič et al. 1984) to more recent (e.g. Košir and Krč 2000; Krč and Diaci 2001; Košir et al. 2006; Krč 2006). However, from the beginning until today, a huge gap between the scientific knowledge on DSS and its application in practical forest management is noticed. Fundamental research in the field of DSS in forestry has been conducted within the research group for applied mathematics at the Department of forestry, Biotechnical faculty in Ljubljana. The researchers addressed several issues, e.g. integrating the fuzzy analytic hierarchy process with a dynamic programming approach for determining the optimal forest management decisions (Zadnik Stirn 2006) or the application of dynamic, fuzzy and AHP procedures in a multi-criteria decision process in the ecosystem management (Zadnik Stirn 2009).

Recently, the development of DSS and their use in applied research tasks has gained substantial importance. The following tools have been used in solving the problems (Table 1).

Problem type no. 1: DSS in forest ecosystem management (e.g. optimal forest models for regional forest management plans, i.e. targeted tree species composition, optimal growing stock per site strata (Veselič 2002), modelling long-term stand dynamics in silver fir–beech forests (Klopčič et al. 2010) or modelling the dynamics of silver fir in different site strata using artificial intelligence (Ficko et al. 2011).

Example: FIS as a DSS for sustainable and multipurpose forest management at regional, forest, and stand level

FIS is designed as a spatial information system aiming at decision support. It was upgraded with two computerized modules which have enabled building optimal forest models and strategic decisions about allowable cut. Veselič (2002) designed computerized modules for optimal tree species composition, stand structure, production and regeneration period for 28 forest types on the basis of growth and yield tables, comparison between the theoretical, "optimal", and current structure of a forest type obtained from FIS. In 2008, Veselič designed the second tool for strategic planning of allowable cut (Veselič 2008). The determination of allowable cut is closely related to forest development planning and it results from the quantification of different options of forest stand development. The module enables modelling changes in forest structure under different management intensities or silvicultural measures (thinning, regeneration). The end-users of both computerized tools are forest planners from the SFS. However, FIS provides the outputs also to policy decision-makers in other public institutions and research organizations.

Problem type No. 2: DSS aiming at risk assessment due to natural hazards and impacts of climate changes, e.g. predicting forest fire danger (Kobler 2001), modelling the forest health in Slovenia (Ogris 2007), predicting susceptibility of forest stands to windthrow, snow-breakage and insect attack (Klopčič et al. 2009), projections of sanitary felling for various climate change scenarios (Ogris and Jurc 2010), the assessment of natural hazards in forested landscapes (Lorz et al. 2010), or predicting forest vegetation shift due to different climate-change scenarios (Kutnar and Kobler 2011).

Example: Regression-type decision tree model for predicting salvage cut

The model predicts salvage cut of Norway spruce due to spruce bark beetle attacks (*Ips typographus*, *Pityogenes chalcographus*) in Slovenia according to different climate change scenarios. The model was developed using a M5' model tree with Weka 3.4 software (Witten and Frank 2005). The M5' algorithm builds tree-based models with top-down induction of decision trees where the leaf is represented by a multivariate linear model. The model development is described in Ogris (2007) and in Ogris and Jurc (2010). It incorporates climate, forest, landscape, topography, and soil variables. The basic spatial resolution of the model is 1 km^2, and the time step is one year. The model tree consists of 28 linear models, and model was calculated for three different climate change scenarios extending over a period until 2100, in 10-year intervals. The model is valid for the entire area of Slovenia; however, climate change projections were made only for the case study region (596 km^2). The model enables the identification of the areas of high risk for increased salvage cut and could serve as a support tool for the professionals from SFS, responsible for forest protection.

Problem type no. 3: DSS for preservation and protection of wild game and their habitats, and provision of coexistence with humans (e.g. habitat suitability modelling with the conservation management applications: Kobler and Adamic (2000), Jerina et al. (2003), Jerina and Adamič (2008).

Example: DSS for brown bear management and provision of coexistence with humans

Several models aiming at brown bear population management were developed by the team of experts from the Department of forestry at the Biotechnical faculty, Slovenian Forestry Institute, and the Department of knowledge technologies at the Institut Jozef Stefan (Jerina et al. 2003) using measurements or observations of the population. SFS participated in data acquisition and in testing the models. To estimate the size of the brown bear population in

Slovenia and its dynamics, a difference equation model was developed. In modelling the expansion and the potential habitat, GIS-visualized inductions of decision tree models were used. The results are the estimates of population size, maps of the spatial expansion and maps of optimal and maximum potential habitat which were based on natural suitability. Wild game population models shall substantially improve the wild game management planning by SFS.

Problem type No. 4: DSS in private forest management. The concept of a private forest property plan as a new instrument in owner-oriented forest management planning was developed recently (Ficko et al. 2005; Ficko et al. 2010) and tested in several individual private forest properties. A computer-based tool FORPLAN was developed as an universal interface between the data from FIS and owners' demands (Mori and Županić 2008). A model by Pezdevšek-Malovrh et al. (2010) also concerns private forest management; it aims at the identification of the factors influencing joint forest management.

Example: FORPLAN

FORPLAN is computerized application primarily developed as a DSS for owners' management decisions in private forests (Mori and Županić 2008). FORPLAN is a result of multilateral cooperation in the project Interreg IIA between SFS, National chamber for agriculture and forestry (NCAF), Municipality of Varazdin (Croatia), and the Association of forest owners Mirenska dolina. The application can be freely downloaded from the web portal of the Association of private forest owners (MojGozd 2011) by the members of NCAF. The Microsoft Access-based application is user-friendly and enables detailed owner-oriented planning in private forests for the next decade, ensures spatial control over the owner's property and quantifies the management output in financial terms. The system consists of several incorporated models (i.e. harvesting model, wood assortment quality model), which were based upon large numbers of measurements or data, such as mean harvesting intensities or average expected quality of wood assortments in specific site, stand and density characteristics. In-build models can be manually adjusted to real situations or can be refined according to the owner's personal experiences. The information sources (e.g. stand map and the parameters, forest infrastructure) included in the application are primarily taken from the FIS and upgraded with specific information of interest to owners, such as wood assortment prices, working costs etc. FORPLAN enables a forest landowner to simulate the management in a particular part of his holding and to monitor its behaviour in financial terms. Net income can be calculated either for each economic planning spatial unit, which is defined as a unit with similar conditions for forest operations, or for the total holding's area. The system enables the calculation of the costs of alternative management regimes (e.g. different harvesting intensities, working models) and is thus primarily the operational tool for forest landowners.

Problem type No. 5: DSS for strategic wood energy planning and mobilization of timber wood supply.

Example: WISDOM

WISDOM (Woodfuels Integrated Supply/Demand Overview Mapping) methodology was developed by the Wood Energy Programme of FAO in collaboration with the University of Mexico. WISDOM is a spatially-explicit method oriented to support strategic wood energy planning and policy formulation, through the integration and analysis of existing woodfuels demand and supply-related information and indicators (Drigo and Veselič 2006). WISDOM allows a holistic vision of the wood energy sector and the national-level aggregations of key parameters constituted the main entries of the Slovenia Wood Energy Information System (SWEIS). Rather than absolute and quantitative data, WISDOM is meant to provide relative/qualitative values such as risk zoning or criticality ranking, highlighting, at the highest possible spatial detail, the areas deserving attention and, if needed, additional data collection (Drigo and Veselič 2006). WISDOM is based on:

- the use of geo-referenced socio-demographic and natural resource databases integrated within a geographical information system;
- a minimum spatial unit of analysis at sub-national level;
- a modular, open, and adaptable framework which integrates information of relevance to wood energy from multiple sources;
- a comprehensive coverage of fuelwood resources and demand from different energy users.

The main value of WISDOM as a planning tool is in its ability to present the results spatially. Its fine spatial and thematic resolution makes it a flexible tool for the representation of Slovenia's fuelwood production/consumption situation in different locations and, in synthesis, for the definition of priority areas under a wide variety of perspectives (Drigo and Veselič 2006).

SFS is in charge of upgrading and updating of WISDOM Slovenia, i.e. updating the geo-referenced database by including new reference data, expanding the study object by including non-wood sources of biomass, and developing the spatial analysis component to allow woodshed analyses (Drigo 2010). The basic parameters, which assist the end-users in decision-making, are also published on the web (MOP 2006).

Problem type No.6: DSS in land-use planning, and balancing stakeholders' demands on forests.

Example: Computerized tool used in the procedure for issuing approvals for the interventions in forests and forest space
GIS layers of forest stands, forest functions, protective forests, and forest reserves with respective attributive databases are the basis for decisions regarding forest landuse. GIS tools (e.g. MPX or Mapinfo) are used to locate the object of possible intervention and to analyze the impact of the intervention on the forest land. The GIS layers from other state institutions, such as from Institute of the Republic of Slovenia for nature conservation (e.g. NATURA 2000 areas, protected areas), are used to determine the kind of procedure for issuing approvals. After the request/application for a special intervention in the forest has been received (e.g. for a deforestation for agricultural purposes, building an industrial facility, construction of power lines), SFS at first digitizes the object as an independent layer. Combining the existing GIS layers from SFS and other state institutions, an authorized expert from SFS with advanced professional knowledge, skills and long-term experience in this field approves or rejects the decision about the possibility of the particular intervention. In more

difficult cases, a field visit is obligatory. In cases of rejection, the applicant has the possibility of appeal to the Ministry for agriculture, forestry and food.

Problem type No.7: DSS in participatory planning (e.g. participatory methods in preparing the regulations for protection forests (Matijašić 2004), participatory process of the preparation of the National forest programme (Resolution on National… 2008).

Example: Participatory methods in preparing the regulations for protection forests
The participatory planning during the preparation of the regulations for protection forests (Matijašić 2004) was carried out with the participation of all municipalities concerned by the regulation. An internet-based platform with the graphical data of the proposed protection forests and forests of special purpose was established (Protection forests… 2010). It enabled the municipalities to have virtual access to the location, size description of the proposed areas and the chance to submit the amendments. The SFS used the tool to incorporate the proposals into the final version of the regulation.

Example: Participatory process of the preparation of the National Forest Programme
During the preparation of the National Forest Programme, SFS together with the ministry responsible for forestry, organized a number of workshops with all the stakeholders, who may be concerned with the issue (Fund for agricultural land and forests, NCAF, Slovenian Forestry Institute, Department of forestry at the Biotechnical faculty and many others). The results of the workshops were incorporated into the draft of the National Forest Programme. The Assembly of the Republic of Slovenia approved it in 2007.

Problem type No. 8: DSS for forest road network extension and maintenance

Example: DSS of forest road network extension
The forest road network extension model (Košir and Krč 2000) is a single objective model, particularly designed for the objective evaluation of forest construction investments allocation. It enables the specification of the target road densities in forest management regions. It is a medium- to long-term strategic model aiming at the optimisation forest road network density regarding the relevant site characteristics and existing road density. It enables the modelling of road density for different possible forest operation technologies. The modelling procedure is based on the presumption that forests with certain site quality, with low functional forest road network density exceeding the minimum threshold of the area, have the potentials for forest construction investments. Considering such constraints, for each stand the neighbourhood stands are considered in searching for a critical area of under-exploited forests due to low forest road network density. Clustering of the neighbourhood stands is iterative until the critical area of forests with suitable site and stand characteristics is achieved. The model is initially based on a forest stand, but could be up-scaled to regional or national level.

Problem type No. 9: DSS in forest operation technology planning, e.g. modelling the suitability of harvesting technologies (Krč and Košir 2009a) or modelling the wood procurement from stump to a sawmill (Lubello et al. 2007; Krč and Košir 2009b).

Example: DSS for indicative planning of forest operation technologies

The model developed by Krč and Košir (2009a) is single objective model, particularly designed for the evaluation of forest operation technologies. It enables the determination of forest operation technology. It is a medium-term DSS, particularly useful in the period of transition from current forest operation technologies towards machine harvesting. It evaluates the suitability of selected forest operation technology for forest stands. The system is based on FIS. However, it does not consider the spatial context of neighbouring stands. The information sources for the model are mainly sub-compartments. Some additional outputs (such as skidding direction) do consider the spatial context by including the topological position and the distance from the compartment (each raster cell) to the forest roads. The model was built on data from forest stands but could be up-scaled to regional and national level. On the national scale the decision for selected forest operations technology is presented as a raster system. The end-users of DSS outputs are forest management and planning authorities, forest landowners, and contractors. However, the main user is SFS. By setting the optimal forest operation technology, the economics of forest operations is improved and thus also the competitiveness of private entrepreneurship.

DSS for indicative planning of forest operations technologies are used for research purposes and in strategic evaluation of the suitability of up-coming, mainly mechanized cutting forest operation technologies. The model was elaborated through the cooperation between the Department of forestry at the Biotechnical faculty and SFS.

We argue that by including the spatial aspect and neighbourhood interrelations (spatial joining of forest stands by the same technology type and skidding means) the model shall be considerably improved. The additional improvement should be related to the accuracy of input data which are used as influential factors. A high resolution digital elevation model should be used. The complexity of the model is moderate to medium.

Problem type No. 10: Forest planning of priority functions and management regimes in protection forests.

Example: DSS for mapping the priority functions and defining management regimes in protection forests

In forest inventory and forest planning in protective forests (declared by the Regulation of Protection forests and forests with special purpose) forest management professionals define the needed measures, such as potential cut and necessary silvicultural and protection measures. In the completely inaccessible protection forests, the measures are not envisaged at all. In all other protection forests, the measures are determined regarding the risk assessment of the protection functions and fully in accordance with the provisions of the protection forests and forests with special purpose. The priority of the interventions is given to the forests with unsuitable stand structure.. The professionals of SFS carry out the procedure. We assess, that a more accurate map of priority interventions in protection forests is needed.

20.4 Discussion and conclusions

Adaptive forest management is characterised by a high level of uncertainty. However, using appropriate methods and an adaptive approach, the uncertainty can be at least partly or even to a great extent exceeded. The monitoring of forest ecosystems and monitoring of forest management present an essential part of adaptive forest management. In the recent development of forest planning and management, a huge amount of data was obtained; unfortunately, its use in management decisions is unsatisfying. This problem was partly solved in 1990s by the application of geographical information systems in forest management and planning (e.g. Hočevar et al. 1992). However, some relevant tasks still exist: FIS should be permanently improved. One of the relevant tasks is to make it more user-friendly, and to develop integration tools which would enable efficient combination of graphical and attributive data. The next prospect concerning FIS is related to the improvement of DSS for the stakeholders. Forest owners represent an important group of stakeholders. The question arises how to enable them to use data and management support from FIS more efficiently.

Table 2 summarizes the success of the described DSS in practice. Possible reasons are discussed for each computer-based tool.

Table 2. Successfulness of described computer-based tools in practice.

	Indicators of successfulness			
Computer-based tool	Quality of development process	Methodological adequacy in addressing and structuring the problem	Level of knowledge management and techniques applied	Involvement of stakeholders and their power in decision making
(1)	+	+	○	n/a
(2)	+	+	○	n/a
(3)	+	+	+	-
(4)	○	○	-	+
(5)	+	+	○	n/a
(6)	○	○	+	n/a
(7)	○	○	-	○
(8)	+	○	○	n/a
(9)	+	○	○	n/a
(10)	○	○	-	○

Legend: ++ successful, ○ moderate lack of success, -- poor or failed in successfulness, n/a not applicable

(1) FIS is a powerful and indispensable tool for forest management planning, for it enables efficient knowledge identification, generation, knowledge repository and its transfer to the end-users. It significantly contributes to the quality of decision-making in forest management at different spatial scales. The FIS is updated yearly with new datasets.

Modules are continuously upgraded, and new modules are under development (e.g. forest function planning, the economic evaluation of planned activities).

(2) For the regression-type decision tree model for predicting salvage cut, the following shortcomings should be mentioned: the model is based on the assumption that the relationships between variables that are valid for current conditions are also valid for predictions, i.e., the structure of the model is fixed, and therefore only the independent variable values can be changed and not the relationships among them. In addition, the development of the model was based on the dataset obtained for sanitary felling of Norway spruce in Slovenia in a decade, which is rather short period being already under the influence of climate change. Therefore, the model should be validated using available data from the period of at least 30 years before 1976 for the model to be reliable and undisputable. Unfortunately, such data was not available.

(3) The DSS for brown bear management provides unbiased knowledge on decades-long scientifically and publicly debated issues on habitat suitability of different areas and their importance for the conservation of bears and the expected spatial expansion of bears. It is actually used as support for future conservation management of the brown bear in Slovenia. However, the issues on conservation management of the brown bear in Slovenia are still a challenging task, constantly requiring attention to changeable multi-stakeholders' needs and the current political sphere. Finally, it depends on the state agencies to what degree the results from this model will actually be taken into account, when making strategic decisions on the spatial development of Slovenia. The results from this model are among the first steps towards long-term conservation of the brown bear in Slovenia.

(4) FORPLAN was developed as a computerized tool for private forest management. However, in the first place, it would be important to examine which information the end-users (e.g. private landowners) actually consider in their forest management decisions and what is the relevance of information in decision-making (Kangas 2010). Recently, a survey on private forest owners' management behaviour and decision-making modes has been conducted (Ficko and Bončina 2011a).

(5) WISDOM is a powerful tool intended also for external users such as municipalities, entrepreneurs and individuals who want to improve management and planning of renewable resources.

(6) The tool used in the procedure for issuing approvals for interventions in forest land has been developing for the last 13 years. The development was initiated in 1997, after the first digital ortophoto (DOF5) became available also for standard forest inventory field procedures. It gained momentum with the implementation of the digital cadastre plans (DCP) for all forests in 2001, and with the completion of the national forest stand map (FSM) in 2007. The system requires a higher grade of GIS knowledge, permanent education in this field and systematic updating (three to five years) of all the above-mentioned basic layers (DOF5, DKN and FSM). Despite continuous upgrading and more than a decade-long knowledge management in that field of decision-making, the development of the tool should be directed towards the extensive inclusion of explicit knowledge.

(7) The participatory process of the preparation of the National Forest Programme resulted in the guidelines which are furthermore incorporated in the Regional Forest Management Plans for the period 2011–2020 (RFMP). The RFMP are obliged to undergo public disclosure before final approval. The public has thus the full possibility to check the consistency of the goals and guidelines from the RFMP with the contents of the National Forest Programme and give new suggestions and amendments. The suggestions are collected using a unique email and subsequently sent to the SFS employee responsible for the elaboration of the plan. In this way, therefore, the feedback loop NFP – RFMP – public is closed.

(8) The forest road network extension model is meant as a support in the preparation of the technological part of forest management plans made by the public forest service. Plans are opened to stakeholders; thus the stakeholders are informed about the possibilities for forest road construction. The model shall improve the management intensity in productive forests. In addition, the extension of the forest road network has a beneficial influence on non-wood goods and services, such as tourism, recreation and rural development. The forest road network extension model is used by the SFS in the elaboration of regional forest management plans.

(9) In order to improve the accuracy of DSS for forest road network extension and maintenance, we shall consider additional criteria and influential factors for improved and more reliable evaluation of optimal forest road density:

- identification of ridges for splitting long and narrow hilly regions for more reliable determination of minimal unopened area;
- elaboration of the criteria for steep slope terrain according to cable crane skidding operation demands for forest openness;
- inclusion of the skidding trails data to enable more reliable assessment on forest openness (winching distance from skidding trails);
- differentiated and more adequate determination of the minimal unopened area (to be justified for access road construction).

(10) We assess that DSS for mapping the priority functions and defining management regimes in protection forests is at an initial phase. The DSS needs to be upgraded with explicit knowledge, expected to emerge partly from the currently ongoing projects (e.g. MANFRED 2009) or research results (Guček and Bončina 2011).

There are two additional shortcomings common to most of the DSS described. First, models are rarely freely available outside the institutions where they were developed, i.e. the dissemination of the models to potential users is deficient. Second, developers rarely assign a name to the model or provide the acronym, which certainly does not facilitate referencing or broader recognition of a tool.

An improvement in the collaboration between the spatial planning and forest management planning is also a relevant task: using an appropriate interface between both information systems seems to be the challenging task. The next prospect is the improvement of DSS for forest planners. The current set of growth models and various scenarios of stand development (under different silvicultural treatments and natural disturbance regimes) is insufficient. New or improved models or scenarios would play an important part in adaptive forest management. Another major improvement of current DSS would be the introduction of a probabilistic (Bayesian) approach. In such way, each DSS output would be given in terms of probability. It is likely that decision-makers would have more trust in models that weigh the decisions in probabilities, e.g. when selecting management alternatives. Currently, research efforts are undergoing to incorporate uncertainty in the private forest owner typology building (Ficko and Bončina 2011b).

Multi-objective forest management has become more and more important. At the beginning of the development of DSS, forest management and planning models were based on the maximization of timber production. With the rising awareness of environmental and social functions of forests and with increasing demands towards different forest goods and services the models broadened to also include social and environmental aspects of forest management. In the integration approach, several of the management objectives should be considered in the same forest area. The use of DSS that are based on a single objective is not appropriate. However, some multi-criterion DSS can be applied as an additional tool for multi-objective forest management planning; the models developed in recent years (Zadnik Stirn 2006; Kangas et al. 2008) are based on multiple criteria (e.g. economic, ecological, social) and multiple alternatives (different management objectives, different management operations etc.). In addition, they consider relationships (dependence) between the criteria (e.g. ANP). The possibility of use beside quantitative and qualitative data is an important advantage of existing DSS for multi-objective forest planning. The information used as an input in the planning process is often soft and therefore hard to analyze. The value of soft information in the process of decision-making is often underestimated. For environmental and social management objectives, the input data is often in the shape of descriptive estimations that are the results of participatory approaches (methods) or expert's opinions. Multi-criteria decision-making methods and models can therefore be a useful additional in forest planning. However, their role in decision-making is somehow limited due to many reasons, like diversified natural conditions and ownership structures.

The development of the DSS mentioned above can intensify the use of various participatory methods in procedures in forest management planning. Until now, public disclosure was accepted as the main form of participatory planning in Slovenia; improved FIS, upgraded with efficient applications, models and scenarios can contribute to the affirmation of participation. Many decisions are namely socially dependent – often more than scientifically based. Therefore the development of different DSS in participatory planning is one of the challenging tasks.

References

Bončina, A. and Čavlović, J. 2009. Perspectives of forest management planning: Slovenian and Croatian experience. Croatian Journal of Forest Engineering., 30: 77-87.

Drigo, R. 2010. Second Interim Report. Consultancy report after third mission to SFS, Ljubljana, 30 August – 3 September 2010, 78 p.

Drigo, R. and Veselič., Ž. 2006. Woodfuel Integrated Supply / Demand Overview Mapping (WISDOM) - Slovenia - Spatial woodfuel production and consumption analysis. FAO Forestry Department – Wood Energy Working Paper. FAO. http://www.fao.org/docrep/009/j8027e/j8027e00.HTM

Ficko, A., Poljanec, A. and Bončina, A. 2005. Presoja možnosti vključitve načrta za zasebno gozdno posest v zasnovo gozdarskega načrtovanja. In: Adamič, M. and Winkler, I. (eds.). Prihodnost gospodarjenja z zasebnimi gozdovi v Sloveniji, Strokovna in znanstvena dela 123. Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire, Ljubljana. Pp. 119-135.

Ficko, A., Poljanec, A. and Bončina, A. 2010. Forest management planning in small scale forestry : forest property plan (FPP) and owners` attitudes. In: Medved, M. (edt.). Small scale forestry in a changing world : opportunities and challenges and the role of extension and technology transfer : proceedings of the conference. Slovenian Forestry Institute, Slovenia Forest Service, Ljubljana, Slovenia. Pp.188-203.

Ficko, A. and Bončina, A. 2011a. Social, ecological and economic aspects in private forest management decision-making. In: Hartebrodt, C. and Howard, K. (eds.). IUFRO small-scale forestry conference: synergies and conflicts in social ecological and economic interactions : special workshop sessions on figures for forests II proceedings. Freiburg, Fakultät für Forst- und Umweltwissenschaften der Universität: Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg (FVA). Pp. 181-190.

Ficko, A. and Bončina, A. 2011b. Probabilistic typology of management decision-making in private forest properties. Forest Policy and Economics, submitted.

Ficko, A., Poljanec, A. and Bončina, A. 2011. Do changes in spatial distribution, structure and abundance of silver fir (*Abies alba* Mill.) indicate its decline? Forest Ecology and Management 261: 844-854.

Forest Act. 1993. Official Gazette of Republic of Slovenia, No. 30/1993.

Gašperšič, F., Kotar, M., Vadnal, A. and Zadnik Stirn, L. 1984. Planiranje šumskog gazdovanja po metodu dinamičkog programiranja. In: Zbornik radova : SYM-OP-IS '84, Herceg Novi, 8-10. oktobar 1984. Beograd, Yugoslavia. Pp. 277-283.

Guček, D. and Bončina, A. 2011. Zaščitni gozdovi v Sloveniji. Stanje, posebnosti in upravljanje. In: Zorn, M., Komac, B., Ciglič, B., Pavšek, M. (eds.) Naravne nesreče 2.Neodgovorna odgovornost. ZRC založba, Ljubljana. Pp 112-120.

Hočevar, M., Hladnik, D. and Kovač, M. 1992. Zasnova prostorskega informacijskega sistema (PIS/GIS) kot podlage za večnamensko gospodarjenje z gozdom in gozdnato krajino. Dela. 9: 153-167

Jerina, K., Debeljak, M., Džeroski, S., Kobler, A. and Adamič, M. 2003. Modelling the brown bear population in Slovenia : a tool in the conservation management of a threatened species. Ecological Modelling. 170: 453-469.

Jerina, K. and Adamič, M. 2008. Fifty years of brown bear population expansion: effects of six-biased dispersal on rate of expansion and population structure. Journal Of Mammalogy 89: 1491-2501.

Kangas, A., Kangas, J. and Kurttila, M. 2008. Decision Support for Forest Management. Springer. 221 p.

Kangas, A. 2010. Value of forest information. European Journal of Forest Research 129: 863-874.

Klopčič, M., Poljanec, A., Gartner, A. and Bončina, A. 2009. Factors related to nature disturbances in mountain Norway spruce (*Picea abies*) forests in the Julian Alps. Écoscience 16: 48-57.

Klopčič, M., Jerina, K. and Bončina, A. 2010. Long-term changes of structure and tree species composition in Dinaric uneven-aged forests: are red deer an important factor? European Journal of Forest Research 129: 277-288.

Kobler, A. and Adamič, M. 2000. Identifying brown bear habitat by a combined GIS and machine learning method. Ecological Modelling 135: 291-300.

Kobler, A. 2001. Prostorski model požarne ogroženosti gozdov. Zbornik gozdarstva in lesarstva 66: 65-93.

Košir, B. and Krč, J. 2000. Where to Place and Built Forest Roads - Experience From the Model. Journal of Forest Engineering 11, 7-19.

Košir, B., Košir, Ž. and Krč, J. 2006. Natural composition of tree species as a basis for model development of stumpage price. Croatian Journal of Forest Engineering 27: 71-80.

Krč, J. 2006. A model for evaluating forest road by forest operations. In: Ackerman, P. (edt.). Precision forestry in plantations, semi-natural and natural forests: proceedings of the Interational precision forestry symposium. Stellenbosch University, South Africa. Matieland: Stellenbosch University, Faculty of forestry. Pp. 437-450.

Krč, J. and Diaci, J. 2001. Ocenjevanje nujnosti negovalnih del v mlajših razvojnih fazah gozda z metodo večkriterialnega vrednotenja. Zbornik gozdarstva in lesarstva 65: 59-81.

Krč, J. and Košir, B. 2009a. Predicting Wood Skidding Direction on Steep Terrain by DEM and Forest Road Network Extension. Croatian Journal of Forest Engineering 29: 177-188.

Krč, J. and Košir, B. 2009b. GIS-based model of wood procurement from stump to small sawmills in the Alpine region - a case study. Zbornik gozdarstva in lesarstva 88: 31-42.

Kutnar, L., Kobler, A. 2011. Prediction of forest vegetation shift due to different climate-change scenarios in Slovenia. Šumarski list 135: 113-126.

Lorz, C., Fürst, C., Galić, Z., Matijašič, D., Podrazky, V., Potočić, N., Simončič, P., Strauch, M., Vacik, H. and Makeschin, F. 2010. GIS-based probability assessment of natural hazards in forested landscapes of Central and South-Eastern Europe. Environmental Management 46: 920-930.

Lubello, D., Grigolato, S., Krč, J., Emer, B., Cavalli, R. and Košir, B. 2007. Evaluating cost on wood supply chain for supporting Slovenian and Italian forest cooperation. FERIC, 3rd Forest Engineering Conference, Mont Tremblant, Quebec, Canada. http://www.feric.ca/en/?OBJECTID=9D89028D-BC8C-A58C-9CFCBD334D266708

MANFRED. 2009. Project Management strategies to adapt Alpine Space forests to climate change risk. Italian Ministry for the Environment Land and Sea. Climate Change and Energy Director General. http://www.manfredproject.eu/index.php

Matijašić, D. 2004. Participativno načrtovanje-izkušnje pri pripravi predpisa o razglasitvi varovalnih gozdov in gozdov s posebnim namenom. In: Bončina, A. (edt.). Participacija v gozdarskem načrtovanju, strokovna in znanstvena dela, 119. Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire, Ljubljana, Slovenia. Pp. 67-74.

MojGozd.net. 2011. Web portal of The Association of Slovenian private forest owners. Supported by Steza.net. Ljubljana, Slovenia.
http://www.mojgozd.net/MojGozd/index.php?option=com_content&view=frontpage&Itemid=63

MOP. 2006. Lesna biomasa. Ministrstvo za okolje in prostor, Ljubljana, Slovenia. http://www.biomasa.zgs.gov.si/

Mori, J. and Županić, M. 2008. Načrt gozdne posesti z informacijsko podporo-FORPLAN. Lepoglava, Varaždinska županija. 59 p.

Ogris, N. 2007. Model of forest health in Slovenia : PhD dissertation (in Slovene). Ljubljana. 138 pp.

Ogris, N. and Jurc, M. 2010. Sanitary felling of Norway spruce due to spruce bark beetles in Slovenia : a model and projections for various climate change scenarios. Ecological modelling. 221: 290-302.

Pezdevšek Malovrh, Š., Zadnik Stirn, L. and Krč, J. 2010. Influence of ownership and property structure on willingness of private forest owners to cooperate. Šumarski List 134: 139-149.

Protection forests. 2010. Web presentation of protected forests, GIS layer for free download. Slovenia Forest Service. Ljubljana, Slovenia. http://www.zgs.gov.si/slo/gozdovi-slovenije/o-gozdovih-slovenije/varovalni-gozdovi/index.html

Resolution on National Forest Programme. 2008. Ljubljana, Zveza gozdarskih društev Slovenije, Ministrstvo za kmetijstvo gozdarstvo in prehrano. 108 p.

Slovenia Forest Service. 2010. National report of Slovenia Forest Service for forests in 2009. Zavod za gozdove Slovenije, Ljubljana. 89 p.

Veselič, Ž. 2002. Optimalni modeli gozdov: Strokovna izhodišča in način oblikovanja modelov ob izdelavi gozdnogospodarskih načrtov območij za obdobje 2001-2010. Gozdarski vestnik. 60: 445-460.

Veselič, Ž. 2008. Prispevek k objektivnosti določevanja možnega poseka pri izdelavi gozdnogospodarskih načrtov. Gozdarski vestnik 66: 35-48.

Zadnik Stirn, L. 2006. Integrating the fuzzy analytic hierarchy process with dynamic programming approach for determining the optimal forest management decisions. Ecological Modelling 194: 296-305.

Zadnik Stirn, L. 2009. Dynamic, fuzzy and AHP procedures in a multi-criteria decison process : an application to ecosystem management. In: Trzaskalik, T., Wachowicz, T. (eds.). Multiple criteria decision-making '08. Katowice: Karol Adamiecki University, University of Economics, Katowice, Poland. Pp. 243-263.

Witten, I.H. and Frank, E. 2005. Data Mining: Practical Machine Learning Tools and Techniques, (second ed.). Morgan Kaufmann, San Francisco. 524 p.

Appendix

Appendix 1. List of the main groups of problems addressed in forest management planning.

Dimensions	1[19]	2	3	4	5	6	7	8	9	10
Temporal scale										
Long-term (strategic)	x		x		x	x				
Medium-term (tactical)		x		x				x	x	x
Short-term (operational)							x			
Spatial context										
Non-spatial				x			x			
Spatial with neighbourhood interrelations	x	x	x		x	x		x		x
Spatial with no neighbourhood interrelations									x	
Spatial Scale										
Stand level		x			x			x	x	x
Forest level			x			x	x			
Regional/national level	x			x						
Parties involved										
Single decision-maker				x						
More than one decision-maker / stakeholders	x	x	x		x	x	x	x	x	x
Objectives										
Single					x			x		
Multiple	x	x	x	x		x	x		x	x
Goods and services										
Market non-wood products	x	x	x				x			
Market wood products	x	x		x	x		x	x	x	
Market services	x	x		x		x	x			
Non-market services	x	x				x	x		x	x

Legend:
1. Organisation of sustainable and multipurpose forest management
2. Considering natural hazards and climate changes in forest management planning
3. Preservation and protection of wild game and their habitats, and provision of coexistence with humans
4. Improving forest management and planning in private forests
5. Mobilization of timber wood supply
6. Land-use planning, balancing stakeholders' demands on forests
7. Participatory planning
8. Forest road network extension and maintenance
9. Planning of forest operations technologies
10. Forest planning of priority areas and management regimes in protection forests

[19] Sustainable and multipurpose forest management is strategic, tactical and operational problem type addressed in forest management planning at regional level, forest management unit level and at stand level. See section DSS applications in forest management and planning under results for detailed explanation.

21 The design and use of computer-based tools for supporting forest management in the Russian Federation

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21.1 Introduction

Russia is the biggest forest country in the world. As of January 1, 2010, the total area of Russian forests was 1,183.7 million ha, including area of the Forest Fund - 1,143.6 million ha (Forest Fund Land). According to the legislation of the Russian Federation, the category of Forest Fund includes forest and non-forest land. Forest land is the parcels that are covered with forest vegetation and parcels that are not covered with forest vegetation, but are meant for forest restoration: clear cuts, burns, forest plantations with non-closed canopy, etc. Non-forest land includes land serving for forest management: roads, rides, etc. More than 20% of the world's timber stock is located in Russia. As of January 1, 2010, the total growing stock of Russian forests was 83,454.07 million m^3, including 79,977.20 million m^3 within the Forest Fund (The Russian Forests 2010).

Russian forests play a key role in the environment and stabilization of negative climate changes. Forests have been and remain the primary type of vegetation and are an essential natural feature of Russia. As Russia has very varied forest growing characteristics; the following eight forest site-specific zones are identified: (1) pre-tundra forests and sparse taiga, (2) taiga, (3) coniferous and broadleaved forests, (4) forest steppe, (5) steppe, (6) semi-deserts and deserts, (7) North Caucasian mountains, (8) South Siberian mountains. These geographical forest zones are divided into 34 forest regions. Every forest region has relatively similar states of use, conservation, protection, and reproduction of forests. Based on that, every forest region has its own cutting age limits, rules of harvesting wood and other resources, rules of fire and sanitary safety, reforestation and forest management regulations.

Russian forests are mostly boreal. The main forest species are: larch, pine, spruce, oak, beech, birch and aspen. They occupy more than 90% of forested land. Other trees (pear, chestnut, common walnut, Manchurian walnut, etc.) occupy less than 1%, and the remaining 9% of the area is covered with the shrubs (dwarf pine, birch shrub, etc.). The average forest cover of the country is 46.6%. The greatest forest cover (over 80%) is found in taiga areas in European Russia, and the least forest cover (below 1%) is in semi-deserts in European Russia. In the Forest Fund, the most prevalent stands (43.7%) are mature and over-mature.

Forests growing on lands of the Forest Fund are divided into three categories: protective forests, production forests and reserve forests. Protective forests are subject to maintaining environmental, water protection, conservation, sanitary-hygienic, recreational, and other beneficial functions of forests. Use and management of Protective forests is possible only if it is compatible with the designation and beneficial functions of the forest. The total area of Protective forests in the Forest Fund of the RF amounts to 275,002,800 ha. Production forests are intended for sustainable, maximum efficient production of high-quality wood, other forest resources, and products of their processing while preserving their beneficial functions. They occupy a total area of 610,723,600 ha. Reserve forests are special, because they are not intended for timber harvesting within the nearest 20 years; their total area is 257,837,300 ha (The Russian Forests 2010).

The part of the forest resources of Russia that is not included in the Forest Fund of the RF is the forests in Specially Protected Natural Territories (SPNT). A generalized report on the state of the Russia's SPNT system can be found in the annual governmental Reports on the State and Protection of the Environment in the Russian Federation (www.mnr.gov.ru). The system of SPNT in the RF plays an important role in the conservation of typical and unique natural landscapes, the diversity of flora and fauna, objects of natural and cultural heritage. Currently, there are 204 federal SPNT in Russia, with a total area of about 58,000,000 ha. They are located in 84 Constituent Entities of the Russian Federation.

According to the new Forest Code of the Russian Federation (2006), all forest parcels within the Forest Fund land are subjects of federal property (Article 8). Civil legislation and the Forest Code (Forest Code… 2007) guarantee citizens the right to stay in forest freely and gratis and to use it for their subsistence needs in the form of the following activities: harvesting and collecting wild fruit, berries, nuts, mushrooms, and other food non-timber forest resources (Article 11).

Besides using forest for citizens' subsistence needs, there are four types of access to forest resources in Russia: (1) lease of forest parcels, (2) sale and purchase of forest stands, (3) permanent use of the forest parcels (use for indefinite periods), (4) the rights for gratuitous use of the forest parcels during established periods. Forest parcels can be leased to legal persons or citizens. A lease agreement shall be concluded based on the results of an auction (Article 74).

Through one of four types of access to forest resources mentioned above, different subsets of forest uses are permitted in the forests of the RF: 1) wood harvesting (logging), 2) resin harvesting, 3) harvesting and collecting of non-timber forest resources, 4) harvesting of food forest resources and collecting of medicinal plants, 5) game management and hunting, 6) agriculture, 7) scientific research activities, education activities, 8) recreational activities, 9) establishing and using of forest plantations, 10) cultivation of forest fruit, berry, ornamental plants, and medicinal plants, 11) works related to geological exploration of mineral resources and development of mineral resource deposits, 12) construction and operation of water reservoirs and other man-made water bodies as well as water engineering facilities and special-purpose ports, 13) construction, reconstruction, and operation of power transmission lines, communication lines, roads, pipelines, and other linear utilities, 14) processing of wood and other forest resources, 15) religious activities, 16) other uses (Forest Code... 2007). Wood harvesting is possible only under lease agreement or forest stands purchase.

In accordance with the Forest Code, there are several types of forest accounting works: monitoring of forest fire safety (Article 53), forest pathology monitoring (Article 56), radiation pollution surveys of forest (Article 58), Forest Inventory and Planning (Chapter 5, Article 67-70), State Forest Inventory (Article 90), State Forest Ledger (Article 91), State Cadastral Registration of forests (Article. 92). The goals of today's Forest Inventory and Planning include: 1) planning of Forest Management Units (FMU), there are two types of

FMUs in the Forest Fund of the RF: Forest Districts and Forest Parks, 2) planning Production, Protective, and Reserve Forests, and also Specially Protected Areas of forest, 3) planning of forest parcels, 4) determination and marking the exact boundaries for Forest Districts, Forest Parks, Production, Protective, and Reserve Forests, Specially Protected Areas of forest, and forest parcels, 5) Forest Evaluation (identification, registration, evaluation of qualitative and quantitative characteristics of forest resources), 6) planning activities for the conservation, protection, and reproduction of forest. The State Forest Inventory throughout the all Russian Federation territory is carried out by the Federal Forestry Agency (Rosleshoz).

21.1.1 Prevalent types of forest management problems and the legal framework in Russia

Planning in the area of forest use, conservation, protection, and reproduction is critical for providing sustainable forest management and sustainable development of territories. It provides a basis for forest use. The Russian Federation adopted a multi-level system of forest planning. Forest planning underlies the development of forests at all levels. Forest development planning at regional level for Constituent Entities of the RF is documented as Forest Plan of the Constituent Entity. At local forest level within Russian FMUs it is documented as the Forest Development Plan. SPNT belongs to the local level and their developing plan is documented as the Forest Development Plan.

According to Article 86 of the Forest Code, Forest Plans define the goals and objectives of regional forest planning, activities to achieve the forest development targets and zones of such development, measures on the involvement of forests into economic activities and zones designated for such activities. Forest Plans of the Constituent Entity specify key objectives of forest use, protection and renewal depending on the resource/economic, environmental and social significance of the forests in the regions. Forest Plans are developed for a period of 10 years. A Forest Plan is subject to mandatory public or municipal review that is supposed to be undertaken by the authorized bodies of regional public authorities or by the local self-governance bodies. All Constituent Entities of the RF have their Forest Plans approved.

Forest Plans of the Constituent Entities have the following dimensions of forest management planning problems: regional level, medium-term (tactical), spatial with neighbourhood interrelations, more than one decision-maker/stakeholders, multiple objectives - market wood and non-wood products, market and non-market services. The Federal Forestry Agency and/or the Constituent Entities of the RF are responsible for solving forest management planning problems on regional level. These include planning of forest use, conservation, protection, and reproduction.

Another large group of forest management planning problems comes from the planning for the FMUs, which has the following dimensions: forest level, medium and/or short term, spatial with neighbourhood interrelations, single or more than one decision-maker/ stakeholders, single or multiple objectives - market wood and non-wood products, market and non-market services. Leaseholders and the administration of FMUs solve these types of planning problems through working-out a Forest Development Plan. Such planning is often aimed primarily at the market wood products. However, recently, interest has been significantly increased in the market non-wood products, market and non-market services. For stakeholders of Forest Districts and Forest Parks, the use, conservation, protection, and reproduction of forests are based on the Forest Development Plan. This Plan is based on the Forest Management Regulation for the given FMU, data from the State Forest Ledger, data of the Forest Plan of the Constituent Entity and other special-purpose surveys, and territorial planning documents. Forest Development Plans are developed for the period of 2-10 years. Forest Development Plans are not publicly accessible. The smallest element of forest management planning is a forest parcel. In common practice, a Forest Development Plan for a particular forest parcel would be developed only if needed: in case of leasing, wood selling or other uses. As of January 2010, there were 21,600 forest parcels in Russia. Of these 16,700 parcels have Forest Development Plans.

SPNT stay separate from the Forest Fund forests, but according to the Forest Code, their boundaries must be marked on all maps and forest schemes. Also, existing and planned SPNT shall be included in the regional Forest Plans which regulate citizens' activities in the lands of the Forest Fund. According to the Order of the Ministry for Natural Resources No. 491 dated December 13, 2007 "On the Improvement of the Planning System for Core Activities of State Reserves and National Parks", all SPNTs of Russia are required to prepare Forest Development Plans. These plans are the main documents defining the objectives and budgets of each SPNT; they also provide a basis for subsequent evaluations of the effectiveness of SPNTs' activities.

Modern forest legislation makes it possible for the public to participate in the development of public policy and decision-making in the "forest management planning" field. For example, the Forest Plan of the Constituent Entity and also planned forest development measures with proposed zones of such development should pass through public hearings and consultations. Any interested parties, including stakeholders (e.g. leaseholders, forest service employees, timber industry representatives, traders, representatives from Non Government Organizations, and community members) can take part in these hearings and consultations.

Our analysis shows that the legal framework does not cover the challenges of strategic planning for the Russian forest sector and planning problems on the national level. However, Russian science may solve some of these problems at the strategic level: Alexandrov 2007, 2010; Alexandrov and Matsunaga 2008; Alexandrov and Yamagata 2002; Brezgin and Filatova 2002; Chertov et al. 2005, 2006; Gusev and Nasonova 2010; Isaev et al. 2009; Kolobov 2009; Korovin and Karpov 1995; Olchev et al. 2002, 2008, 2009; Voronov at al. 2010. State systems monitoring forest fires, forest pests and diseases provide data for the Federal Forestry Agency for the planning works in these areas at the national level. However, the planning time-frame for this work is only 5-10 years, which is not enough to discuss it as strategic planning. We note that, currently, ecosystem services (e.g. carbon sequestration, ecosystem functions, biodiversity) are not major objectives of the forest management planning in Russia, while importance of ecosystem functions of forests are internationally recognized (UNFF, FAO CBD, UNFCCC and others).

Based on the above submissions and FORSYS suggested dimensions of forest management planning problems, we generated a classification of planning problem types in Russian forestry. It is presented in Table 1.

Table 1. Prevalent forest management problem types in Russia according to FORSYS dimension categories

		Types					
		Strategic planning of the RF	Information System of Rosleshoz	Forest Plan	Forest Management Regulation	Forest Development Plans	Operational planning
	Dimensions	R1	R2	R3	R4	R5	R6
Temporal scale	Long-term (strategic)	X		(X)			
	Medium-term (tactical)		X	X	X	X	
	Short-term (operational)						X
Spatial context	Non-spatial						
	Spatial with neighbourhood interrelations		X	X		X	X
	Spatial with no neighbourhood interrelations	X			X		
Spatial Scale	Stand level					X	X
	Forest level	(X)		X	X		
	Regional/national level	X	X				
Parties involved	Single decision-maker						X
	More than one decision-maker/stakeholders	X	X	X	X	X	
Objectives	Single	X	X			X	X
	Multiple	(X)	(X)	X	X	(X)	
Goods and services	Market non-wood products			X	X	X	(X)
	Market wood products	X	X	X	X	X	X
	Market services	X	X	X	X	X	(X)
	Non-market services	X	X	X	X	X	(X)

This report presents the inventory and analysis of computerized tools used to support forest management planning in Russia. The analysis will give a summary description of the tools' building blocks - models, methods and knowledge management techniques. We will give examples of using these blocks in practical computerized tools. At the end, we will describe the recommended steps of the future development of DSS technologies for forest management planning in Russia.

21.2 Materials and methods

Three main sources of information were used in this report. In the first place were scientific and technical reports, national and international research publications, and information available on the internet (2.1). The main laws and regulations that regulate the management of Russian forests were the second source of information (2.2). Third, we carried out a questionnaire of institutes of the Russian Academy of Sciences (RAS), other scientific institutes, and organizations of the Federal Forestry Agency of the RF (2.3).

21.2.1 Scientific and technical reports, national and international research publications, information available on the internet

Russia still does not have a tradition of placing all published materials (or bibliographic indexes and summaries on them) on the internet. Many scientific periodicals stay on shelves in a paper version, and authors of current articles did not have enough time and energy to look through all of them. Only a few publications can be found on the internet. In addition to that, developers working for the industry have no intention to publish their results, therefore many small computer tools for DSS were left behind our review. Scientists, on the contrary, report their results in periodicals promptly and care about their representation on the internet.

The most full spectrum of developed tools and DSS for forest management planning is represented in the publications of thematic conferences, for example, Mathematical modelling in ecology: proceedings of 1st and 2nd National conferences with the international participation, 2009, 2011. The significant information on the status of the forest ecosystems, their dynamics and biodiversity was accumulated by scientific institutes of the RAS. The information about existing databases, knowledge bases, algorithms, and models can be found on websites of forest institutes of the RAS (www.ras.ru) and Rosleshos (www.rosleshoz.gov.ru); however, in this case often only mentions of works without direct references to information resources are presented.

The information on two DSS systems for the federal (national) level is accessible on the site of the Federal Supervision Agency for Information Technologies and Communications (Roscomnadzor) in the section Register of Federal State Information Systems (www.rsoc.ru/it/register/). Brief information on the DSS and tools for forest management planning on the national level can be also found on the websites of the Federal Forestry Agency of the RF (www.rosleshoz.gov.ru), Federal State Budgetary Institution Russian Centre of Forest Protection - FSBI Roslesozashchita (www.rcfh.ru), Federal State Budgetary Institution Aviaprotection of Forests – FSBI Avialesoohrana (www.aviales.ru), Federal State Unitary Enterprise Roslesinforg (www.roslesinforg.ru), and sites of their affiliated divisions. On the same sites it is possible to find information about databases and knowledge bases created in an electronic medium, however, access to information on the majority of these resources is restricted and/or all data are in Russian language only. In the future, these may become a base for DSS tools.

21.2.2 Laws and regulations

The forest management planning processes in Russia are thought out and formalized: the organization of forest planning and designing is regulated by a number of regulatory legal acts of the Russian government. They are available on the Federal Forestry Agency website (www.rosleshoz.gov.ru) and the websites of Authorized Executive Body of the Constituent Entities of the RF. The government of the Russian Federation establishes the contents and the procedures of preparation of a Forest Plan of Constituent Entity and a Forest Development Plan. Both of them should have the attached maps with marked boundaries of Forest Districts, Forest Parks, and zones of their intended development. The Forest Plan of Constituent Entity shall be approved by the head of the highest Executive Body of the Constituent Entity.

The Forest Management Regulations are mandatory for citizens and legal persons engaged in the use, conservation, protection, and reproduction of forests within Forest Districts or Forest Parks. The authorized Federal Executive Body defines the contents of, development procedures for, effective periods of, and revision procedures for the Forest Management Regulations. These regulations define: 1) permitted forest uses defined in accordance with Article 25 of Forest Code, 2) ages of cutting, allowable cuts, terms of use, and other parameters of their permitted use, 3) forest use restrictions referred to in Article 27 of Forest Code, 4) forest conservation, protection, and reproduction requirements. The Forest Management Regulation is a very important document for forest management planning for a given FMU as it contains a lot of data, qualifications, standards, and algorithms for planning works. Each FMU in the RF now has its own Forest Management Regulations. Forest Management Regulations are composed for a period of 10 years, and thereafter shall be revised. Their actual periods of validity depend on the intensity of forest development and trends in regional economic development. They are publicly accessible documents. All Forest Districts and Forest Parks have their Forest Management Regulations approved. It may be said with confidence that these Regulations make a solid base for the development of various algorithms for DSS for forest management planning.

The forest management planning processes are realized in the regional Forest Plans and in the local Forest Development Plans of FMUs. The Forest Plans are accessible on websites of regional administrations; they contain results of forecast analysis for medium-term (tactical) management planning. However, the analysis of these documents shows that they don't contain any description of (or references to) the tools used for making such forecasts. Experts assert that usually such forecasts are built just on the basis of yield tables of stands.

21.2.3 Questionnaire

Twenty seven DSS developers, mainly from the academic science environment, responded to our questionnaire. Branch organizations of Rosleshoz have barely participated in answering the questions. We found a similar misbalance of results searching the internet, where branch organizations of Rosleshoz DSS publications usually are unavailable because they are placed on closed corporate sites, while scientific publications are available to the public.

Working with collected information on Russian prevailing forest planning problems, we used the set of FORSYS project methods. Responding authors structured all their data for analysis based on problem types, according to the FORSYS dimension categories.

Two of the Russian DSSs, EFIMOD-DLES and FORRUS, have been published on the FORSYS Wiki internet site. It was done by the responding authors of the tool (Prof. A. Komarov & Dr. L. Khanina and Prof. S. Chumachenko & Dr. M. Palenova), who are at the same time the Russian experts in the FORSYS project.

A peculiarity of the Russian field of DSS development is the very weak representation of the created DSS and their elements on the internet. In addition, only an insignificant part of these accessible information resources is translated into English. Both problems create an image of “Russian black space” (terra incognita) for our foreign colleagues. We express our thanks to the organizers of COST Action FP0804 - Forest Management Decision Support Systems (FORSYS) for the opportunity “to slightly open a curtain”.

21.3 Results

21.3.1 Overview

Currently, a broad spectrum of state-of-the-art technologies is used in the forest sector and research institutes of the Russian Federation (see Table 2). These technologies include, in particular, automated and remote sensing systems used for monitoring of the state of forest ecosystems and specific natural resources, various databases and information systems, models (forest, soil, water, etc.), GIS technologies, and satellite imaging. To a certain extent, those technologies are used by all Russian forest sector organizations. The most different models, methods, knowledge management techniques for DSS were developed or are now under development within the framework of research institutes and branch organizations of Rosleshoz and scientific institutes of the RAS.

However, an inventory of DSS and tools for DSS that were developed and used in Russian forest management planning processes, is not an easy task due to the lack of publication about them on the internet or in academic periodicals. Summing up, we have to admit that the most of the Russian DSS tools for forest management planning are not presented either on the internet or in periodicals but are developed and widely used in practice (Excel sheets, databases, small programs and so forth). Spreadsheets, databases, and small programs are first in this category, and their features we can not analyze and describe here due to lack of information about them.

Analyzing the carried out inventory, we found that the following software products have been used for development Russian DSSs: C++, PERL, EASI, Visual Basic, FORTRAN, Visual Pascal/Delphi, Nature, MATLAB and others.

Table 2. Computer-based tools for supporting forest management planning in the Russian Federation

Problem type	Computer-based tool for supporting forest management	Models and methods	KM techniques	Applications
R1	NORMAL FOREST NBP The web-based tool is intended for use in scientific researches related to the	Matrix model Simulation models	Web-based learning Geovisualization	It was used for evaluation of the carbon sink formed by

Problem type	Computer-based tool for supporting forest management	Models and methods	KM techniques	Applications
	task on the development of forest management strategies for enhancing carbon sinks (Alexandrov 2007). The amount of carbon stored in a forest stand depends on its age and productivity. The tool calculates the effect of harvest age on the forest carbon stock based on the normative NPP (Alexandrov and Matsunaga, 2008) and the forest growth curve (Alexandrov 2010). The results of calculations are presented in the form of a world map.		of spatial and spatio-temporal data	increasing harvest age in Japanese forests. The tool is a part of the next version of the Carbon Sink Archives5 (Alexandrov and Matsunaga 2009) web-based service for studies of the terrestrial carbon sink.
R1	INDIVIDUAL-BASED MODEL OF FOREST COMMUNITIES' DYNAMICS is a tool to forecast the dynamics of uneven-aged mixed forest stands with mechanisms of interspecies competition for light (Kolobov 2009).	Dynamic modelling Data mining Monte Carlo method	Databases Interactive maps Statistical graphics Simulation models	Application at the stand level in the Russian Far East forests for long-term prognoses with and without tree cutting, thinning, and planting.
R1	A TOOL FOR A LONG-TERM FORECAST of the age structure dynamics and resource potential of forest ecosystems. Simulation of forest fire dynamics. Forecast of extraordinary fires (Korovin and Karpov 1995).	Matrix models Multi-criteria decision analysis Dynamic modelling	Databases Expert Systems	Long-term prognosis of forest dynamics, forecasting of extraordinary forest fires and levels of carbon emission under different levels of forest fire protection for Russia.
R1/R2	SWAP represents a complex of process-based models describing heat and mass exchange processes occurring in a soil–vegetation/snow cover–atmosphere system. It is a tool for simulating the dynamics of energy and water balance components at the land–atmosphere interaction as well as different characteristics of the hydrothermal regime of territories, hydrological objects (catchments, river basins) and ecosystems (Gusev and Nasonova 2003).	Physically based modelling Global optimisation techniques	Databases Expert Systems Simulation models	Assessment of dynamics of heat, water and carbon balance components of terrestrial ecosystems.
R2	SPORM (Siberian Pest Outbreaks Risk Model) is a tool for risk assessment of Siberian forest insects' outbreaks and for decision-making in forest protection. Model takes into account the vitality state of trees and individuals in the population of pests	Multi-criteria decision analysis Dynamic modelling Monte Carlo method	Databases Expert Systems Simulation models	Evaluation of population dynamics and pest outbreaks in Siberian taiga forests.

Problem type	Computer-based tool for supporting forest management	Models and methods	KM techniques	Applications
	and climatic conditions. Model allows the estimation of carbon fluxes after damages to trees by insects and processes of forest recovery in the territory after the attacks of insects (Isaev et al. 2009).	Bayesian method Non-linear optimisation method		
R2	FOREST REGISTER - Information System of the Federal Forestry Agency of Russian Federation: the information about regional forest resources is structured, catalogued and kept in a databank (www.roslesinforg.ru).		Excel sheets Databases Web portal Simulation models	The system is used for evaluation of quantity and quality characteristics of forests, identifies and helps to take into account changes resulting from the use of forests, evaluates the effectiveness of measures on conservation, protection and reproduction of forests. The system works for the state forest inventory, cadastre of forest land, information support, forest management, forest planning and design.
R2	ISDM ROSLESHOZ: Information Sub-System "AVIALESOOKHRANA" System of remote monitoring of forest fires: 1. Monitoring forest fire danger with the goal of predicting and detecting forest fires, and evaluating their effects, 2. Evaluating the technical effectiveness of fire protection work by the regions of the Russian Federation, 3. Aerial monitoring of fire danger in the forests of the Moscow Region, 4. Monitoring the organization and condition of forest use, 5. Evaluation of expenditures on forest fire protection by the regions. (www.aviales.ru).	Heuristic Interpolation Dynamic modelling	Excel sheets, Databases Web portals Experimental forest sites Simulation models Geovisualization of spatial and spatio-temporal data Interactive maps GIS	ISDM Rosleshoz is practically the only DSS in Russia conducting real-time ecological monitoring on a national level. It uses satellite and lightning detection data, as well as GIS technology for daily evaluations and for management decisions. Currently, over 200 organizations from forestry, timber industries, the Ministry of Emergency Response, and others comprise the users of this system. Resulting products are accessible to the registered users in any place in the Russian Federation through the internet in

Problem type	Computer-based tool for supporting forest management	Models and methods	KM techniques	Applications
				the form of tabulated reports or geographically adhered composite images in GIS format with the attributive information. The circle of users is rapidly expanding, as attested by numerous requests.
R2	ISDM ROSLESKHOZ: Information Sub-System ROSLESOZASCHITA - The System of Remote Pest Monitoring conducts forest pathology monitoring and forecasting: 1. Planning of sanitary-improving actions and pest control, 2. Evaluation and forecast of stand damage level under different amount and condition of insect populations, 3. Evaluation of damage depending on intensity of damage for stands in different ecological conditions, 4. Estimation of damage and expenses for carrying out protective actions. Evaluation of thresholds of nocuity (injuriousness) of insects and illnesses of forests. (www.rcfh.ru).	Heuristic Multi-criteria decision analysis Interpolation Data mining	Excel sheets, Databases Web portals Scientific content management sites Library services Geovisualization of spatial and spatio-temporal data Interactive maps GIS	The system implements fully automated technology for satellite data acquisition and distribution. Currently it presents automatically updated information on observed wildfire conditions, fire elimination statistics and reports, results of specialized satellite data processing with the coverage of almost entire Russia. The resulting products are accessible to registered users in any place in the Russian Federation through the internet in the form of tabulated reports or geographically adhered composite images in GIS format with the attributive information.
R2	INTERACTIVE MAPS OF FMUs OF RUSSIA Digital cartographic database with borders of forest districts and forest parks of Russia (Malysheva, 2010).		Databases Interactive maps GIS	Thematic maps for regional and national levels. Visualization of statistical reporting about Russian forests.
R2	ESTIMATION OF CARBON ADSORPTION ABILITIES OF FORESTS IN THE URAL REGION. The information system makes it possible to evaluate the potential level of forest ecosystems absorption of carbon dioxide emissions, and therefore allows the enhancement of the efficiency of economical management of Ural region and	Model	Excel sheets Databases	The realized projects "System engineering of the spatial analysis of carbon adsorption by forest ecosystems on the Ural region" and "Development of the automated system of an estimation carbon adsorption abilities of

Problem type	Computer-based tool for supporting forest management	Models and methods	KM techniques	Applications
	municipal institutions (Voronov at al. 2010).			Russian forests".
R2/R3	ESTIMATION OF CHANGE OF ASSIMILATION POTENTIAL IN FOREST ECOSYSTEMS allows the calculation of carbon adsorption functions losses in forest ecosystems; to estimate the size of absorption of carbon in forest stands and a pool of deposited carbon (Brezgin and Filatova 2002).	Model	Excel sheets Databases	The system was applied to the calculation of absorbing ability of growing forest stands and the loss of carbon adsorption functions as a result of cuttings and fires within the framework of the projects "Economic estimations of resources and ecological functions for territory of Ivano-Arahlejsky lakes on Hilok river" and "Indicators of quality of economic growth for transitive economy". The system was used for the estimation of loss of carbon adsorption functions due to construction of a water basin in Krasnoyarsk region (Motygin hydroelectric power station).
R3	PSKOV MODEL FOREST INFORMATION SYSTEM is intended to: • forecast the forest dynamics according to the alternative scenarios of forest use with proper consideration for ecological restrictions and economic requirements, • assess the acceptable amount of forest use based on the approved scenario. (Romanyuk et al. 2002, 2005)	Dynamic modelling Data mining Multi-criteria decision analysis	Databases Expert Systems Simulation models Geovisualization of spatial and spatio-temporal data GIS	The system of forest conservation planning in accordance with SFM requirements and ecological/landscape approach. It works for different levels of planning for conservation of biodiversity and other ecological functions of forests, from the landscape to the key biotopes. Priorities in forest conservation planning are chosen depending on specific features of the given territory.
R3/R5	FORRUS-S (FORest of RUSsia – Stands)	Dynamic modelling	Databases Expert Systems	Numerous applications in different regions of

Problem type	Computer-based tool for supporting forest management	Models and methods	KM techniques	Applications
	The package forecasts stand dynamics in the zone of mixed uneven-aged coniferous and broadleaved forests as well as in the middle and southern taiga of European Russia. It was designed for simulation modelling and analysis of dynamic processes in forest ecosystems (Chumachenko et al. 1997, 2000). FORRUS-S consists of models Natural Development, Exogenous Influence (including sylvicultural activities) and a service block comprising GIS and a set of accessory (Chumachenko et al. 2003a).	Data mining Multi-criteria decision analysis	Simulation models Geovisualization of spatial and spatio-temporal data GIS	Europe including Russia: Forecast modelling on alternative scenarios of forest management for 4 districts of FMU, Moscow Region (20,000 ha); Design of the Forest Development Plans for Nagorskoe forestry (38,000 ha) and Slobodskoe forestry (50,000 ha), Kirov region.
R1/R3	EFIMOD-DLES (EFIMOD-Discrete Lattice Ecosystem Simulator) is a tool to forecast carbon and nitrogen flows in forest ecosystems with a strong feedback mechanism between soil and stand. It provides description and spatial analysis of mixed stand dynamics and ground vegetation diversity calculation in boreal and temperate forests at different management and external impacts (Chertov et al. 2001; Komarov et al. 2003; Khanina et al. 2007).	Component-based approach (framework for models integration) Individual based modelling Dynamic modelling Process modelling Dynamic programming Data mining Monte Carlo method Bayesian method Multivariate upscaling Areal and point process modelling	Databases Expert Systems Simulation models Interactive maps Statistical graphics Geovisualization of spatial and spatio-temporal data	Numerous applications in different regions of Europe including Russia and in Canada: Prediction of carbon and nitrogen dynamics in soil and stand vegetation, biodiversity, and stand productivity at different forest management regimes (Chertov et al. 2005). Prediction of carbon and nitrogen dynamics in soil and stand vegetation and biodiversity at different forest management regimes, climate change, natural disturbances and different levels of nitrogen deposition from the atmosphere (Shanin et al. 2011).
R3	SVAT-Regio is a regional scale model that is providing a spatial interpolation on meteorological data, describing local canopy microclimate, determining local and regional H_2O and CO_2 fluxes for spatially heterogeneous landscapes (Olchev et al. 2002).	Regional model		SVAT-Regio was applied to estimate the possible influence of deforestation and land-use changes on evaporation and CO_2 exchange in non-uniform landscapes in the European part of Russia (Olchev et al.

Problem type	Computer-based tool for supporting forest management	Models and methods	KM techniques	Applications
				2002) and in tropical regions (Olchev et al. 2008).
R3/R5	INFORMATION SYSTEM FOR PLANNING THE OPTIMAL DEVELOPMENT OF FOREST RESOURCES. The system is based on GIS; it optimizes harvesting, transport and woodworking processes. A head of a logging company receives a package of appropriate management solutions with the economic rationale for the development of forest resources for the next 5-10 years (Mokhirev 2007).	Heuristic and linear programming Multi-criteria decision analysis Dynamic modelling Non-linear optimisation method	Databases Expert Systems Geovisualization and interactive maps GIS Data mining	Siberian taiga forest. Design of the Forest Development Plans for lease sites of Lesosibirskiy LDK No.1 and Novoeniseyskiy LDK
R3/R6	MODEL FOR CULCULATION WOOD ASSORTMENT FOR RUSSIA FORESTS in the electronic reference book “Assortment and commodity tables for Russian forests” (Verhunov and Chernyh 2007).	Non-linear optimization method Simulation models	Databases Library services Web-based learning	Application at the forest inventory: quantitative and qualitative assessment of the Russian forest resources Design of the Forest Development Plans for Samara, Nizhny Novgorod regions, and the Mari El Republic (2008-2010)
R5/R6	MIXFOR-SVAT is based on an aggregated description of the physical and biological processes on the leaf, tree and stand levels that allows the application of this model for prediction of atmospheric fluxes for the different vegetation types from grasslands and agricultural crops to vertically structured mono-specific and mixed forest stands represented by one or by many different tree species, as well as for description of the flux partitioning among different canopy sub-layers and different tree species (Olchev et al. 2008).	Dynamic modelling, Process modelling, Dynamic programming.	Databases, Simulation models, Expert Systems Interpolation of spatial and spatio-temporal data	Mixfor-SVAT was applied to the estimation and prediction of primary production and evaporation of boreal and tropical forest ecosystems under present and estimated future climatic conditions (Olchev et al. 2002, 2008, 2009), and for estimation of dry deposition in forest stands in Central Europe.
R5/R6	MIXFOR-3D is a three-dimensional model for description of radiation regime and canopy microclimate in uneven-aged mixed forest stands with high spatial and temporal	IBID	IBID	Mixfor-3D was used to estimate the influence of various silvicultural practices on a microclimate and

Problem type	Computer-based tool for supporting forest management	Models and methods	KM techniques	Applications
	resolution. The algorithm describing the solar radiation regime in the forest stand takes into account transfer of direct and diffuse radiation, including its penetration through the gaps, and its reflection and transmission by foliage, branches and trunks of trees. Superimposing the 3D vegetation structure on a topographic map allows us to estimate radiation fluxes taking into account local relief heterogeneity (Olchev et al. 2009).			productivity of forest ecosystems in Central Europe (Olchev et al. 2009).
R3/R5/R6	Multi-criteria simulator for OPTIMIZATION OF HARVESTING OPERATIONS is a tool for strategic decision-making in selection of wood harvesting technology for Russian conditions. The system is designed to support forest machinery designers. (Syunev 2004).	Multi-criteria decision analysis Monte Carlo method Non-linear optimisation method	Simulation models Geovisualization of spatial and spatio-temporal data	Work was carried out in the projects: "Development of the environmental and economic studies of forest engineering education at Petrozavodsk State University" and "Development of wood harvesting equipment, machinery and methods".
R5/R6	GIS-based decision-support SYSTEM FOR PLANNING AND OPTIMIZATION OF FOREST ROAD NETWORK is designed to support the strategic decision-making in improving the forest road infrastructure and decreasing the costs of transportation of industrial and fuel wood in specific soft soil conditions in Russia (Gerasimov et al. 2011).	Multi-criteria decision analysis Dynamic programming Data mining	Excel sheets, Databases Expert Systems GIS	Work was carried out in the projects: "Wood harvesting and logistics"; "Development of the forest road infrastructure and logistic system for transportation of industrial and fuel wood".
R3/R5/R6	GIS-based decision-support SYSTEM FOR PLANNING AND OPTIMIZATION OF HARVESTING OPERATIONS is designed for planning and analyzing industrial and fuel wood supply chain associated with cut-to-length operations at the logging company level for Russian conditions. The logistic system is designed to support strategic, tactical and operational decisions (Gerasimov et al. 2008, 2010).	Multi-criteria decision analysis Dynamic programming Data mining	Excel sheets, Databases GIS	Work was carried out in the projects: "Wood harvesting and logistics"; "Development of the forest road infrastructure and logistic system for transportation of industrial and fuel wood"; "Intensification of forest management and improvement of wood harvesting in

Problem type	Computer-based tool for supporting forest management	Models and methods	KM techniques	Applications
				Northwest Russia".
R5/R6	GRSTOCK&ASSORT (Growing Stock and Assortment) is designed for standing volume and stem components calculation in relation to the size classes and height. It is based on tree stem taper equation (modified Weibull function, computer program StemShape) (Kaplina 2009).	Regression model, least squares method	Excel sheets	1) Tables of stems volumes and tables of stem taper applicable for the forest forming species in Russia were calculated. 2) Method of sample estimation of growing stock and assortment was proposed and tested.

DSS of almost all variants of DSS architecture, according to the classification offered by F.Burstein and C.W.Holsapple (Burstein and Holsapple 2008): document management, database-oriented DSS, models and solvers (knowledge management), spreadsheet technique for representing and processing knowledge, OLAP (On - Line Analytical Processing) do exist in Russia. However, the majority of them are actually just elements of DSS, represented by various tools. At the federal level of forest resources management in Russia, both web-based DSS (Information System of the Federal Forestry Agency of Russian Federation FOREST REGISTER, ISDM ROSLESHOZ) and artificially intelligent DSS were developed and implemented in forest management. During the last years the quantity of developments that unite already existing knowledge bases, databases and various models in the uniform program and technical base has been increasing, for example - the subsystem of the Estimation of efficiency of actions for protection, reproduction and use of forests of FSBI Roslesozashchita (www.rcfh.ru).

The list of models and methods used by Russian authors for tools and DSS for forest management planning is wide enough: document management, spreadsheet techniques for representing and processing data (the first to mention are yield tables and assortment tables, which are very common in silvicultural practice), database-oriented DSS (DBMS: MySQL, PostgreSQL, ADABAS, Microsoft SQL Server, Nature, MATLAB, Microsoft Office Access, etc.), models and solvers (knowledge management), OLAP, and others, along with expert systems, web-based DSS.

The Russian developers of models for forest management planning processes use various approaches in their modelling of forest ecosystems and their components. In general, existing models are capable of covering the big variety of production, ecological and landscape tasks of forest management planning. We can name the following types of used models, intended for forest management planning:

(1) simulators of growth and efficiency of forest stands that can be conditionally divided (according to the classification of Pretzsch et al. 2008) into:

(a) models predicting average characteristics of a forest stand at stratum level from statistical models (Usoltsev 2007; Verhunov and Chernyh 2007);

(b) models considering development of separate trees, taking into account conditions of habitat and competition between neighbours (Chumachenko 1993; Kolobov 2009);

(c) 3D models where tree growth is defined by its physiological parameters and environmental conditions. They calculate potential growth from light, site conditions and derive individual development from competition (Chumachenko et al. 2003b; Litinsy 2007);

(2) balance models that provide detailed carbon and nitrogen balances. They are primarily used to estimate ecological issues such as carbon sequestration and nutrient sustainability (Komarov et al. 2003);

(3) SVAT (Soil – Vegetation – Atmosphere Transfer) models that are oriented to detailed description of heat and water transfer in the soil-vegetation-atmosphere system. They describe radiation, heat, water and carbon exchange at different scales (Gusev and Nasonova 2010; Olchev et al. 2002, 2008, 2009);

(4) Landscape models comprise a broad class of spatially explicit models that incorporate heterogeneity of site conditions, neighbourhood interactions and potential feedbacks between different spatial processes. They differ widely in the way in which detailed forest structure and matter fluxes are represented and which interactions between spatial processes are taken into account (Chumachenko et al. 2003a).

Overall, currently developed forest models describe the growth and regeneration of individual trees or tree cohorts on the basis of physiological processes that are linked to the water and nutrients balances of the particular sites. Such models are sensitive to environmental changes as well as to the different kinds of disturbances, and can be used for short- and long-term planning of forest management.

Optimization tasks in DSS in Russia, as well as all over the world, are usually completed by means of methods of linear programming, heuristic algorithms, MultiCriteria Decision Models (Gusev and Nasonova 2003; Syunev 2004; Mokhirev 2007; Verhunov and Chernyh 2007; Isaev et al. 2009).

GIS and visualization. Thematic maps are the major component of DSS; they function as a information support for management. Visualization of the statistical reporting for the whole country on use, protection, and reproduction of forest resources at any level of planning and management, as well as visualization of results of modelling and forecasts, in the form of a map promotes more well-grounded and reasonable decision-making. The visualization of forest DSS is usually supported with geo-information technologies; the data of forest assessment and inventory of forests are also supported by these technologies. In Russia the broad array of GISes is used: ARC/INFO, Topol, QGIS, ArcGIS, ArcMap 9.2-9.3, WinGIS, WinPLP, WinPLP (+TILF), MapView SVG, GRASS, LesGis, GIS Integro). At the same time, many DSS and models have realized three-dimensional dynamic visualization of forest strata and landscapes. In some systems there are elements of the spatial analysis.

Various Knowledge Management (KM) techniques were used to develop computer-based tools for forest management support in Russia. The main feature of the KM's applications was a wide use of attributive databases, reference databases, and simulation models together with web-based techniques in the "up-to-date" reviewed tools. Problem structuring was done by a wide usage of database technologies to encode available knowledge for computer storage and processing and to simplify access to the data. Simulation modelling and expert systems were mainly used to support the problem modelling and analysis. Visual analytic techniques such as statistical graphics, interactive maps, geo-visualization of spatial and spatio-temporal data were mainly used to support the problem-solving and decision-making.

Public participation allows state authorities, first, to better understand the interests of different social groups and, second, to reach a concerted position on the critical problems of forest management planning. Now forest management authorities in Russia are ready to cooperate with the public in fire fighting, forest planting, taking care of plantations, joint forest protection raids, joint publications in media, creation of commissions on the most important issues. The Pskov Model Forest was among the first forest projects in Russia to practically demonstrate community involvement in forestry decision-making. The principles of building relations with local residents include, among others, availability of information about project activities, consideration for local interests, and cooperation in forest management planning: Forest Plan of the Constituent Entity, Forest Management Regulations, and Forest Development Plans. A number of mechanisms and procedures for involving the community in forestry decision-making have been tested since the project startup in 2000 (Romanyuk and Chernova 2001).

21.3.2 Case study and practical realization

The most successful in practical realization DSSs for forest management planning processes on a national level and medium-term (R2 type) in Russia provide (1) support of administrative decisions in the field of monitoring of forest fires, (2) assessment of sanitary and forest pathology conditions of forests and the forecast of forest pathology conditions, and (3) support of identifying, preventing, and struggling against illegal logging and other violations of forest law.

For example, FSUE Roslesinforg uses up-to-date level information technology and software that provides procedures for the formation, collection and processing of forestry information, helps to promptly submit the analytical data for decision-making in strategic management, modelling and forecasting, and tactical management at the federal level. At the present time, the information system FOREST REGISTER has more than 1,100 reports on remote monitoring of forests, over 2,600 reports on assessing the effectiveness of protection, preservation, reproduction and use of forests, over 1,300 reports about determination of the qualitative and quantitative characteristics of forests, more than 300 reports of documented information and state forest register, more than 3,800 reports of statistical monitoring, and more than 7,200 forms of budget drafts (www.roslesinforg.ru).

Another successful case study is the Information System of Remote Monitoring of the Federal Forestry Agency (ISDM-ROSLESHOZ). The project development began in 1995 within the framework of Remote Monitoring of Forest Fires projects. Works were carried out by a big consortium of institutes of the RAS, Rosleskhoz, Federal Hydrometeorology and Environmental Monitoring Service and some other organizations. The System was put into commercial operation in 2005. According to the experts, ISDM-ROSLESHOZ became a unique system of ecological monitoring in Russia. It is working nationwide in real-time mode with use of satellite data, data of thunderstorm position finding systems and GIS technologies for forming daily reports and administrative decision-making. This system is currently used by more than 200 organizations of forest management, timber industry, Federal Service for Supervision of Natural Resource Usage (Rosprirodnadzor), Emergency Control Ministry and others. The range of users of the system intensively grows (www.aviales.ru).

We want to note that this system, even being in commercial operation, has been constantly developing; it receives new features, possibilities, and tasks resulted foremost from improving of forest management system in Russia. As an example: on the basis of ISDM-ROSLESHOZ the Information Sub-System ROSLESOZASCHITA for Remote monitoring pest outbreak centres was created, which is intended to provide information support for the regional and federal centres of FSBI Roslesozashchita. These centres are working on forecast, preventive maintenance and struggle against the main species of forest pests. Currently, the system is in the stage of approbation of its base elements for the purpose of estimation of working capacity of the system, definition of priorities and main tasks of information support of the FSBI Roslesozashchita at federal and regional levels. The developers are FSBI Roslesozashchita, Centre for Problems of Ecology and Productivity of Forests of RAS, and the Space Research Institute of RAS. The System of Remote Pest Monitoring (www.rcfh.ru) used a new approach in organization informational support for administrative decision-making responsible for preventive measures and elimination actions against forest pests.

The example of a successful DSS solving type R3 problems is the FORRUS-S (FORest of RUSsia-Stand), which has been developed for simulation modelling of forest ecosystems dynamics. The program package FORRUS-S consists of the model of natural development of multi-species uneven-aged stands, the model of exogenous influence (including silvicultural activities) and a set of accessory programs (standard GIS, reference databases, modules recoding input and output information, etc.). An up-to-date set of reference databases supports the forecasting of forest ecosystem dynamics for mixed uneven-aged coniferous and broadleaved forests in the middle and southern taiga of European Russia (Chumachenko 1993; Chumachenko et al. 1997, 2000, 2003a). All that is based on long-term research in pristine (old growth or untouched) natural forests in Russia. The system simulates the main processes occurring in forests: growth, death, germination of new individuals. FORRUS-S has been used for the design of the Forest Development Plans for Nagorskoe and Slobodskoe forestry in the Kirov region.

Giving more details on FORRUS-S, we want to point to the fact that modelling is performed separately for each cohort (a cohort is a group of individuals of same species and same ontogenetic state). Each cohort is described by a set of biological parameters stored in specially compiled reference databases (biometrics of tree crown, demand for light, gaps in the canopy, crown transparency to light, seed dispersal distance, sprouting ability, growth tables, potential stand quality index, etc.). Growth increment, thinning, and natural regeneration are modelled with a five-year step. Since photosynthetic active radiation (PAR) is the main limiting factor for the middle and southern taiga, it is recalculated at each step while other factors as soil richness and humidity are considered constant throughout the modelling cycle. All these specific details of this model allow it to forecast dynamics of mixed uneven-aged stands, which are typical for Russia.

The model utilizes the principle of subdivision of the space into discrete three-dimensional elements. This approach makes it possible to consider the available PAR in the zone of active growth in a tree canopy, and also to take into account spatial heterogeneity of growth conditions such as relief and soil characteristics. The modelled area can be up to several thousand hectares big. A number of external modules simulating silvicultural measures can be enabled or disabled at any modelling step. FORRUS-S allows the modelling of various scenarios of silvicultural activity including: (1) natural stand development, (2) complete cycles of silvicultural measures according to the current regulations and specifications of the Russian Forest Service, (3) silvicultural measures with infringement of technology specifications (heavy upper thinning and removing the best trees, clear cutting with destroying natural regeneration without planting). A set of tools was developed for analysis of various output databases and forecast maps produced by means of GIS-technology. The model utilizes the standard input data that are traditionally used in forestry in the Russian Federation (taxation site descriptions, forest stand maps) and which are available for virtually all Russian territory. A comparative analysis of forecast modelling under alternative scenarios of forest management is an effective way of planning continuous, economically profitable and ecologically responsible forest use on regional and local levels. Scenario modelling allows the solution of various subtasks, depending on economic (presence of timber processing enterprises, road networks, etc.) and landscape-geographical (presence of valuable large forests, non-wood resources, etc.) properties of the region, availability of labour, technical resources, etc.

DSS FORRUS-S helps solving tasks of type R3 (medium-term – tactical /optionally long-term - strategic, forest level, spatial with neighbourhood interrelations, multiple objectives, market non-wood products, market wood products, market services, non-market services, more than one decision-maker / stakeholders) forest management planning problems like:

1) forming a medium (long)-term plan of forest road network development;
2) working out a medium (long)-term plan of timber processing clusters development for the region (the list of types of enterprises, their capacities and spatial positions);
3) designation/allocation of the most ecologically valuable sites (level of Reserves and National Parks);
4) calculation of carbon sequestration by forest stands of the region or forestry district.

At the same time, DSS FORRUS-S can solve tasks of type R5 (medium-term – tactical / optionally short-term – operational, stand level, spatial with neighbourhood interrelations, multiple objectives, market non-wood products, market wood products, market services, non-market services, more than one decision-maker / stakeholders) forest management planning problems like:

1) calculation of economic availability of every parcel in a forest;
2) calculation of harvest volume on economically accessible parcels in the forest;
3) planning of clear cutting, taking into account silvicultural requirements;
4) planning of site allocation for reforestation;

5) calculation of potential harvest volumes of non-wood resources (mushrooms, berries, hunting and so forth);
6) designation/allocation of the most ecologically valuable sites (level of Specially Protected Areas of FMU).

Another examples of successful DSS solving tasks of R3, R5, and R6 types are the systems for maintenance of harvesting and transport operations (Gerasimov at al. 2008, 2010, 2011; Syunev 2004). They constitute a separate sector of DSS development. Today we know about:

1) GIS-based DSS for planning and optimization of harvesting and transport operations is a tool for planning and optimizing industrial and fuel wood supply chains associated with cut-to-length operations at a logging company level for Russian conditions. The logistics system is designed to support strategic (choice of harvesting method, choice of transport method, equipment investments), tactical (harvest unit scheduling, transport delivery plan, choice of equipment utilization level), and operational (detailed harvesting plan, truck routing) harvesting and transport decisions.

2) GIS-based DSS for planning and optimization of forest road networks is a tool for planning and optimizing forest road networks associated with cut-to-length operations at a logging company level for Russian conditions. The system is designed to support decisions for improving forest road infrastructure and decreasing costs of industrial and fuel wood transportation in the specific soft soil conditions of Russia. The system supports strategic harvesting decisions (forest infrastructure investments).

3) The purpose of the Multi-criteria simulator for optimization of wood harvesting operations is to find out the effect of using the multi-objective simulation technique for logging technology and machinery optimal design and/or selection. This task is important for supporting forest machinery designers in providing them with the necessary knowledge for carrying out the first drafts without a pilot machinery model. One part of the procedure for the improvement of machinery performance criteria is a multi-objective algorithm for thinning regime optimization. The system is designed to support strategic harvesting decisions (choosing of harvesting method and equipment investments).

At the present time, scientific models describing the growth and renewal of separate trees or their cohorts on the basis of the physiological processes connected with the water balance and balance of nutrients in a given habitat have been developed. They can be used for some aspects of forest management planning like the EFIMOD-DLES.
EFIMOD-DLES is an example of a Russian DSS solving tasks of the R1 type forest management planning problems: long-term - strategic / optionally medium-term - tactical, forest level, spatial with no neighbourhood interrelations, multiple objectives, market wood product, non-market services, single decision-maker. Long-term (strategic) tasks are:

1) long-term planning of the silvicultural operations;
2) prediction of timber volume;

3) prediction of carbon budget: carbon accumulation in the biomass of trees and soil organic;
4) matter and carbon dioxide emission;
5) assessment of biodiversity dynamics;
6) evaluation of climate change, increase in nitrogen deposition, and natural disturbances (e.g. windfalls, fires);
7) assessment of the management impact on the forest ecosystems.

At the same time the EFIMOD-DLES is designed for solving tasks of type R3 (medium-term – tactical - dimension) forest management planning problems, like the following:

1) planning of management options (thinning cuttings, clear cutting, reforestation, etc.);
2) assessment of the impact of prescribed management options for every forest site;
3) calculation of potential harvested growing stock for every forest site.

EFIMOD-DLES is a tool to forecast carbon and nitrogen flows in ecosystems of mixed uneven-aged forests of middle and southern taiga with strong feedback mechanism between soil and stand. It provides a description and spatial analysis of mixed stand dynamics in boreal and temperate forests at different management and external impacts. The system takes into account timber harvest effects, the dynamics of ecosystem and forest understory biodiversity, climate change effects, nitrogen deposition effects, and natural disturbances (fires, windfalls, etc.). The package consists of several blocks: (1) stand-level forest ecosystem model EFIMOD (Komarov et al. 2003), (2) model of soil organic matter dynamics ROMUL (Chertov et al. 2001), (3) statistical climate generator SCLISS (Bykhovets and Komarov 2002), (4) batch processing unit (Shanin et al. 2011), (5) biodiversity calculator BioCalc (Khanina et al. 2007), and (6) spatial analysis and visualization toolkit CommonGIS (Andrienko and Andrienko 1999; Chertov et al. 2005).

The model can simulate different interventions in the forest: harvest at various times, planting plantation, thinning, selective cutting, natural regeneration, converting forest into agricultural land and vice versa. The system allows planning for the medium-term (tactical) and long-term (strategic) with annual temporal resolution (monthly resolution for soil organic matter dynamics). The EFIMOD-DLES facilitates forest management planning through construction of different scenarios including both silvicultural operations and natural impacts and comparative analysis of these scenarios. The system considers forested area as a set of individual sites, which are different in forest type, environmental conditions, species composition and age structure, and strategy of management. Scenarios take into account the specific parameters of individual forest sites and assess, therefore, the spatial discontinuity of the whole simulated area (Shanin et al. 2011).

21.4 Discussion and conclusions

The key principle of modern forest policy is sustainable, multipurpose forest development and management. Multipurpose forest development includes not only the production functions of forests, but also maintaining their global ecological value through protection of soil and water resources, preservation of biodiversity and the ecosystem functions of forests. In order to solve the practical problems of forest management by helping users to build a flexible strategy and tactics for ecologically responsible management, DSS for forest management planning processes should:

- have tools that allow the consideration of local and regional ecological and socio-economic conditions (by means of various knowledge bases, databases, and other tools);
- have forest models adequate to a task (or models additional to it: the forecast of pest outbreaks, distribution of fires, pollution, and radionuclides, and so forth);
- consider the spatial placing of objects during planning and have tools for spatial analysis;
- solve multi-criteria tasks: be able to balance interests of various groups of users, helping to find compromises;
- have working algorithms and methods of data analysis;
- have a block of scenario modelling in order to analyze alternative or compromise variants of planning;
- provide managers with the grounded decisions or information materials in support of the decisions (demonstrative charts and forecast maps);
- have a user's guide and methodical recommendations for DSS use, support tutorial functions.

Probably, a more perspective way for DSS development in Russia, with its very varied forest growing characteristics, is not an elaboration of the “universal Russian model” for forest management but the development of a “model platform” (de Coligny et al. 2010; Pretzsch et al. 2008). This “model platform” could be a basis for selecting necessary sub-models for solving the user’s particular problem.

Most of Russia’s DSS and tools for DSS that we have analyzed in our report have not been used in the practice of Russian forestry. Our analysis shows that at the present time mostly the individual elements of the DSS (Excel sheets, databases, small programs and so forth) have been used in practical forestry planning. Meanwhile, Russian academic science has accumulated excellent forestry knowledge and has developed world-known process-based models of forest growth, spreading of forest fires, pest dynamics, forest-soil interactions, good soil-water-atmosphere (SWAT) models, etc. They have been applied to certain territories for solving some of the problems of these areas. The peculiarity of the development of DSS and their elements in Russia is the prevalence of fundamental, academic works over practical applications used in forestry practice (the ratio is 70:30 for the collected base of metadata on DSS in Russian forestry). On the one hand, it can be explained with the usual sequence of steps required for DSS development: at first, the fundamental regularities should be found, then the mathematical apparatus adequate to object/process/problem, information technologies and decision methods should be selected and created, then these technologies will be adapted for local conditions and only at the last stage the tool/system would be adjusted for particular application/user. We have a remarkable example of a project that was realized this way - ISDM-ROSLESHOZ (see above).

Another reason for the low percentage of practical applications in Russia is the lack of access to actual trustworthy information on forest resources. This remark concerns all the above most ‘practical’ DSS for R5 and R4 types - the local level DSS for operative and tactical planning. We would like to especially underline the fact that seems rather ordinary: the quality of resource management and, as a special case, the quality of forest planning based on DSS depends on the timeliness and quality of input data, i.e. on the initial information about the condition of the resources. Moreover, the data needed to develop a management plan (e.g. operation costs or product prices and etc.) frequently are not available in a ready form. In the most cases a potential customer and/or DSS developer don't have the relevant data about forest resources, and this is the main obstacle for the development of forestry planning DSS in Russia. This issue concerns both parametric and spatial data. It would be wrong to say that such data doesn't exist in Russia at all - actual good quality data exists for 30-40 % of forested territory of Russia, by expert estimations. At the same time the existing databases and created GIS on forest resources are not open to public access, and their price in most cases makes them unavailable both for developers and for potential customers of forest planning DSS (leaseholders, timber industrials etc.).

This absence of important information hinders both the development of theoretical models for DSS and the process of creation of DSS. At the same time, access is restricted to the majority of the reference data on characteristics of trees, forest soils, and other data, collected during years of research at institutes of RAS and on the permanent inventory plots of Rosleshoz organizations. These data could serve DSS developers for the creation of reference databases, verification of models and so forth. Thus, the absence of this element, of a culture of knowledge management (hereditability of the information), also negatively affects the efficiency of the development of DSS for forest management planning. Not the last reason for the insufficient presence of DSS in Russian forestry is the lack of orders for DSS development, which is caused by low awareness about the possibilities of modern DSS, and the low IT competence of the people who make decisions about opportunities for IT projects for forest management planning work.

The analysis of the tender documentation on research projects within the framework of Rosleshoz in recent years shows the absence of requests for DSS development from managers at regional and local levels. It may probably be also caused by their qualification level, which is insufficient for statement of such problems and further use of DSS.

There is almost no modelling of ecosystem processes such as “forest-soil”, “forest-water”, processes of gene pool dynamics of tree populations, formation of plantings attractive for recreation and others. The reason for that is the lack of problem statements and of order placement for corresponding DSS due to weak inter-branch interactions.

Besides, the process of planning and decision-making in Russian forestry has a mostly insular/non-public nature due to historical reasons. A legal basis for public participation in forest management and a potential necessity for the creation of corresponding DSS only appeared after the introduction of the new Forest Code (2006).

According to our opinion, the development of DSS technologies in Russia should take the following steps:

1. Working out a regional zoning of forest policy problems in different Russian regions using multipurpose approach. Different regions possess different dominating factors in Russia. For example, for the old low production forests from inaccessible areas it is not economically reasonable to organize timber production and their management should be focused on forest fires prevention or on decreasing the total amount of greenhouse gases for the area as a whole. Such problems exist in Europe also, but Russian peculiarities differ from European ones.

2. For every forest zone a set of scenarios should be developed, taking into account the forest policy and economic values. Not only production functions of woods, but also their global ecological value, preservation of biodiversity and ecosystem/biospheric functions of forests should be considered. In order to solve the practical problems of management and to help users to build a flexible strategy and tactics for ecologically responsible management for each zone, the set of scenarios should:

- solve multi-criteria tasks – be able to balance interests of various groups of users, helping to find the compromises;
- have working algorithms and methods of data analysis;
- have a block of scenario modelling to analyze alternative or compromise variants of planning.

The development of sets of scenarios is a scientific task by itself. It can be accomplished by uniting specialists in forest policy, forestry, regional economics, etc.

3. The development of scenarios should be accompanied by the development of tools that allow:

- the consideration of local and regional ecological and socio-economic conditions (by means of various knowledge bases, databases and other tools);
- forest models adequate to each task: the forecast of pest outbreaks, distribution of fires, pollution and radionuclides, and so forth;
- the consideration of the spatial placing of objects during planning and to have tools for spatial analysis.

So the models should be reconstructed into standardized model components, and pieced together to form a new modelling system with the desired characteristics. The development of the modelling system can be greatly facilitated by using libraries of reusable model components (Mikhailov et al. 2010).

4. The next step is the creation of a framework that can be used as the basis for the assemblage of mathematical models with discrete spatial and temporal resolution, databases and solvers. This framework should facilitate the combining and comparative testing of different approaches to simulate forest ecosystems on a local scale (individual forest stands). The system should be flexible and scalable enough to allow the modelling of other natural systems with various spatial scales. This work could be done using the component-based approach which is the next stage of modular development after object-

oriented ecosystem modelling (He et al. 1999). A component-based system of models can be built on different levels:

- The development of new models as combination of already existing models. For instance, TRIPLEX model (Liu et al. 2002) has a component structure gathered from three different models: 3-PG, TREEDYN3 and CENTURY.
- The development of special frameworks (Knox et al. 1997; May and Conery 2003; Wenderholm 2005; de Coligny et al. 2010; and others) or common protocols (Gregersen et al. 2007) of data exchange which allow the combining of models created by different research groups.
- Use of DSS as the basis of model integration (Potter et al. 2000).

We can demonstrate the development of such a platform using as an example DLES - Discrete Lattice Ecosystem Simulator (Mikhailov et al. 2010). The advantages and disadvantages of existing implementations of component-based systems were taken into account while developing DLES, which is focused on the simulation of complex ecological systems with a discrete spatial and temporal step. DLES allows the taking into account of some specific problems coming from the development of individual-based forest stand models, such as the programming of local interactions between trees (shadowing, redistribution of soil nutrition), matching of spatial and temporal scales, etc.

DLES has an open modular architecture. It uses COM-interfaces. DLES allows the combination of various sub-models into a unified system, presetting the system by the sets of initial data, carrying out the simulation experiments using different scenarios and saving the results obtained from these experiments. DLES is based on a modular concept. Any module is the functionally completed and self-sufficient system unit. Modules can be of the following types:

- The system kernel is the basic module that provides interaction between components and their ‘team-work’ through performance control and support for the data exchange;
- The shell provides the user interface; it transfers user commands to the system and receives the results of modelling to display;
- models (sub-models) are the implementations of algorithms which simulate certain processes in the ecosystem; the sub-models receive initial data and return the results of the simulation;
- the tools are shell extensions (for example, tools for statistical analysis and data visualization).

Each module is realized as a dynamically linked library or executable file which contains an operating algorithm implemented in machine-language code. The specific feature of the system is that modules can be written in different programming languages; the only requirement is that the language should support COM-interfaces.

Thus, the model system is a complex of components and the relationships between them. The kernel integrates all components into the unified system using information that is contained in the scheme of the model system. The scheme is the description of the model system, which includes the list of all sub-models, their execution order and the description of relationships between components. The scheme editor is a special program for easy and safe editing of the model system scheme. We presume three levels of DLES users:

- model developers create sub-models based on the specifications provided;
- scheme administrators construct new schemes or modify existing (they can, for example, add or remove components);
- users can use existing schemes, changing only files with input data to customize simulation experiments.

5. The results of different models linked with GIS and databases should be interpreted by foresters together with policy-makers. They have to:

- provide managers with the grounded decisions or information materials in support of the decisions (by forming demonstrative charts and forecast maps);
- have a user's guide and guidelines for DSS use, and also support tutorial functions.

This step should be done in parallel with the training of foresters who are main users of DSS. It should be one of specific tasks which will facilitate DSS application in Russia. To be nevertheless optimistic, it should be noted that there are working DSS and some excellent prototypes of DSS for forest planning in Russia.

We want to particularly note that Russian forests have some distinctions compared to European countries. We should emphasize that almost all Russian forests are uneven-aged, mixed forests, to which simple dynamic models developed for European plantation forestry can not be applied. That is why DSS development in Russia must create its own experience and apply existing large reference databases and knowledge, including process-based models, databases, and remote sensing methods for constructing country-specific DSS.

References

Alexandrov, G. 2007. Carbon stock growth in a forest stand: the power of age. Carbon Balance and Management 2:4. [www.cbmjournal.com/content/2/1/4].

Alexandrov, G. 2010. Richards Growth Curve. In: The Wolfram Demostrations Project). [http://demonstrations.wolfram.com/RichardsGrowthCurve/]

Alexandrov, G., Yamagata, Y. 2002. Net biome production of managed forests in Japan. Science in China (Series C), 45:109-115.

Alexandrov, G. and Matsunaga, T. 2008. Normative productivity of the global vegetation. Carbon Balance and Management 3:8. [www.cbmjournal.com/content/3/1/8]

Alexandrov, G. and Matsunaga, T. 2009. Carbon Sink Archives. CGER-D041-2009. Tsukuba, NIES. CGER-REPORT.

Andrienko, G. and Andrienko, N. 1999. Interactive maps for visual data exploration. Int. J. Geogr. Inf. Sci. 13:355-374.

Brezgin, V. and Filatova, T. 2002. The information system for evaluating the ecological functions of forest ecosystems. In: Natural resource potential of Asian Russia and adjacent countries: how to improve use. Irkutsk: Institute of Geography SB RAS. Pp. 118-119.

Burstein F. and Holsapple, C.W. 2008. Handbook on Decision Support Systems 2: Variations. Springer. 798 p.

Bykhovets, S.S. and Komarov, A.S. 2002. A simple statistical simulator of soil climate. Eurasian Soil Sci. 35:443-452.

Chertov, O.G., Komarov, A.S., Nadporozhskaya, M.A., Bykhovets, S.A. and Zudin, S.L. 2001. ROMUL – a model of forest soil organic matter dynamics as a substantial tool for forest ecosystem modelling. Ecological Modelling 138 (1-3):289-308.

Chertov, O., Komarov, A., Mikhailov, A., Andrienko, G., Andrienko, N. and Gatalsky, P. 2005. Geovizualization of forest simulation modelling results: a case study for the «Russky Les» forest. Computers and Electronics in Agriculture 49:175-91.

Chertov, O., Komarov, A., Loukianov, A., Mikhailov, A., Nadporozhskaya, M. and Zubkova, E. 2006. The use of forest ecosystem model EFIMOD for research and practical implementation at forest stand, local and regional levels. Ecological modelling 194:227-32.

Chumachenko, S.I. 1993. Basic model of dynamics of multispecies uneven-aged forest coenosis. Problems of Ecology and Modelling of Forest Ecosystems. Moscow Forest Institute, Moscow. Pp.147-180. (in Russian).

Chumachenko, S.I., Syssouev, V.V., Palyonova, M.M., Bredikhin, M.A. and Korotkov V.N. 1997. Simulation of stand dynamics with account of forestry impacts. In: Sustainable development of boreal forests - Proceedings of the 7th Annual Conference of the IBFRA (August 19-23 1996, St.Petersburg). ARICFR, Moscow. Pp. 177-184.

Chumachenko, S.I., Syssouev, V.V., Palyonova, M.M., Bredikhin M.A. and Korotkov V.N. 2000. Simulation of heterogeneous uneven-aged stands dynamics under human-induced disturbance. In: Disturbance in Boreal Forest Ecosystems: Human Impacts and Natural Processes. Gen. Tech. Rep. NC-209. U.S. Department of Agriculture, Forest Service, North Central Station, St. Paul, MN. Pp. 104-112.

Chumachenko, S.I., Korotkov, V.N., Palenova, M.M. and Politov, D.V. 2003a. Simulation dynamics of long-term stand dynamics ar different scenarios of forest management for coniferous – broadleaved forests. Ecological Modelling 170(2-3):345-361.

Chumachenko, S. and Zobkov, V. 2003b. FORRUS-S: 3DVisualization System as tool of visual analysis of forest inventory data and modelling results. MGUL, Mytischi. 23 p.

de Coligny, F., Dufour, S., Dreyfus, P., Courbaud, B. and Auclair, D., 2010. CAPSIS: Computer-Aided Projection for Strategies In Silviculture.in Falcao. AO, Rosset. C (eds.) Proceedings of the Workshop on Decision Support Systems in Sustainable Forest Management. Lisbon, April 2010. OP2. 6 p. [www.fc.ul.pt/dsfm2010/docs/presentations/paper_6.pdf]

Forest Code of the Russian Federation. 2007. Moscow:OS-89. 80 p. In Russian.

Gerasimov, Y., Sokolov, A. and Karjalainen, T. 2008. GIS-based decision-support program for planning and analyzing short-wood transport in Russia. Croatian Journal of Forest Engineering 29(2):163-175.

Gerasimov, Y. and Sokolov, A. 2010. Decision-support system for harvesting planning in Russia. In: The 43rd edition of the International Symposium FORMEC, July 11-14, 2010, Padova, Italy. 8 p.

Gerasimov, Y., Sokolov, A. and Catharov V. 2011. Development of optimal network design of logging roads. Information Technology 1 (68):39-43.

Gusev, Ye.M. and Nasonova, O.N. 2003. Modelling heat and water exchange in the boreal spruce forest by the land-surface model SWAP. J. Hydrology 280:162-191.

Gusev, E.M. and Nasonova, O.N. 2010. Modelling of heat and water transfer between land and atmosphere. Moscow. Nauka. 327 p.

Gregersen, J.B., Gijsbers, P.J.A. and Westen, S.J.P. 2007. OpenMI: Open Modelling Interface. Journal of Hydroinformatics 9 (3):175-191.

He, H., Mladenoff and D., Boeder, J. 1999. An object-oriented forest landscape model and its representation of tree species. Ecological Modelling 119(1):1–19.

Isaev, A.S., Khlebopros, R.G., Kiselev, V.V., Kondakov, Yu.P., Nedorezov, L.V. and Soukhovolsky, V.G. 2009. Forest insects' population dynamics. Eurasian entomology journal. Novosibirsk. V. 8. App. 2: 115 p. (In Russian)

Kaplina, N. 2009. New tree stem taper function as basis for growing stock and assortment estimation. In: Forest, Wildlife and Wood Sciences for Society Development. Conference proceedings. April 16-18, 2009. Prague, Czech Republic. CULS, Faculty of Forestry and Wood Sciences. Pp. 111-117.

Khanina, L., Bobrovsky, M., Komarov, A. and Mikhajlov, A. 2007. Modelling dynamics of forest ground vegetation diversity under different forest management regimes. For. Ecol. Manage. 248:80-94

Knox, R.G., Kalb, V.L., Levine, E.R. and Kendig, D.J. 1997. A Problem-Solving Workbench for Interactive Simulation of Ecosystems. IEEE Computational Science & Engineering 4(3):52-60. doi:10.1109/99.615431

Kolobov, A.N. 2009. Individual-based model of wood communities' dynamics. Izvestiya Samarskogo Nauchnogo Centra RAN 11- 1(7):1477-1486. (in Russian)

Komarov, A., Chertov, O., Zudin, S., Nadporozhskaya, M., Mikhailov, A., Bykhovets, S., Zudina, E. and Zoubkova. 2003. EFIMOD 2 - - A model of growth and elements cycling in boreal forest ecosystems. Ecological Modelling 170 (2-3): 373-392.

Korovin, G.N. and Karpov, E.A. 1995. Model of forest stock dynamics for optimization of forest management // Monitoring problems and modelling of forest ecosystem dynamics. Ekoles. Moscow. Pp. 140-156. (in Russian)

Liu, J., Peng, C., Dang, Q., Apps, M. and Jiang, H. 2002. A component object model strategy for reusing ecosystem models. Computers&Electronics in Agriculture 35:17-33.

Litinsy, P.Ju. 2007. 3D-modelling of vegetation structure and dynamics in taiga landscapes. Petrozavodsk. Karelian Scientific Center of RAS. 107 p. (in Russian)

Malysheva, N. 2010. GIS - a useful tool for assessing the quality of regional forest management. ArcReview - Modern GIS technology 3 (54):19-21.

Mathematical modelling in ecology. 2009. Proc. of the 1st National Conference with the international participation, June, 1-5, 2009. Pushchino. IPCBPSS RAS. 322 p.

Mathematical modelling in ecology. 2011. Proc. of the 2nd National Conference with the international participation, May, 23-27, 2011. Pushchino. IPCBPSS RAS. 304 p.

May, H.K. and Conery, J.S. 2003. FOREST: A System for Developing and Evaluating Ecosystem Simulation Models. SCSC. Pp. 119-127.

Mikhailov, A.V., Shanin, V.N. and Bezrukova, M.G. 2010. A Component Approach to Development of Forest Ecosystem Models. Lesovedenie 2:69-76. (in Russian)

Mokhirev, A.P. 2007. Basis for forest road net design on an example of Nizhnee Priangarye Forestry. PhD Thesis. Krasnoyarsk, 176 p. (in Russian)

Oltchev, A., Cermak, J., Gurtz, J., Kiely, G., Nadezhdina, N., Tishenko, A, Zappa, M, Lebedeva, N, Vitvar, T., Albertson, J.D., Tatarinov, F., Tishenko, D., Nadezhdin, V., Kozlov, B., Ibrom, A., Vygodskaya, N. and Gravenhorst, G. 2002. The response of the water fluxes of the boreal forest region at the Volga's source area to climatic and land-use changes. J. Phys. Chem. Earth. 27 (9-10):675-690.

Olchev, A., Ibrom, A., Priess, J., Erasmi, S., Leemhuis, C., Twele, A., Radler, K., Kreilein, H., Panferov, O. and Gravenhorst, G. 2008. Effects of land use changes on evapotranspiration of tropical rain forest margin area in Central Sulawesi (Indonesia): modelling study with a regional SVAT model. J. Ecological Modelling 212:131–137.

Olchev, A., Radler, K., Sogachev, A., Panferov, O. and Gravenhorst, G. 2009. Application of a three-dimensional model for assessing effects of small clear-cuttings on radiation and soil temperature. Ecological Modelling 220:3046–3056.

Potter, W.D., Liu S., Deng, X. and Rauscher, H.M. 2000. Using DCOM to support interoperability in forest ecosystem management decision support systems. Computers and Electronics in Agriculture 27: 335-354.

Pretzsch, H., Grote, R. and Reineking B. 2008. Models for forest ecosystem management: a European perspective. Annals of Botany 101:1065-1087.

Romanyuk, B. and Chernova, E. 2001. Public Involvement in Forest Planning. 8 p.

Romanyuk, B., Zagidullina, A. and Knize, A. 2002. Conservation Forest Management Planning in Russia. Moscow. 16 p.

Romanyuk, B., Knize, A., Shinkevich, S., Zakharov, G. and Kudryashova, A. 2005. Thinning Schedules for Intensive Forest Management. 79 p.

The Russian Forests 2010. 2010. Moscow, VNIILM. 50 p.

Shanin, V, Komarov, A, Mikhailov, A. and Bykhovets, S. 2011. Modelling carbon and nitrogen dynamics in forest ecosystems of Central Russia under different climate change scenarios and forest management regimes. Ecological Modelling 222(14): 2262–2275.

Syunev, V.S. 2004. New information technologies as instrument of optimal selection of logging machines. Lesnoj jurnal 1:23-27. (in Russian)

Verhunov, P. and Chernyh, V. 2007. Inventory of the forest. Textbook for students. Yoshkar-Ola, MarSTU. 398 p.

Voronov, M., Usoltsev, V. and Chasovskikh, V. 2010. The study methods and development of information system of definition and mapping of the deposited carbon by forests in the environment Natural: Monograph. Ekaterinburg: USFEU. 160 p.

Usoltsev, V.A. 2007. Biological productivity of North-Eurasian forests: methods, data base and applications. UrO RAS. Ekaterinburg. 636 p.

Wenderholm, E. 2005. Eclpss: a Java-based framework for parallel ecosystem simulation and modelling. Environmental Modelling & Software 20:1081-1100.

22 The design and use of forest decision support systems in South Africa

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22.1 Introduction

22.1.1 Boundary conditions for forestry in South Africa

South Africa's plantation and natural forests account for 1.1% (1,274,869 ha) and 0.4% respectively of the country's total surface area with more 80% of this area FSC-certified (PAMSA 2004). Economically viable expansions of commercial plantation are constrained by the country's water-scarcity and only 16% of South Africa's surface is climatically suitable for plantation forestry (Van der Zel 1989). Of this, large areas are not available for tree planting because of steep slopes, and associated high planting and harvesting costs and competition with other land-uses; e.g. agriculture, viticulture and horticulture. Land availability for further afforestation is limited to about 20% of the current plantation area (DWAF 2005).

Planted stock currently consists of 51% softwood and 49% of hardwood. Common hardwood species are *Acacia mearnsii, Eucalyptus grandis,* and hybrids, while *Pinus patula, P. elliotii* and *P. radiata*, are the dominant softwood species. Plantation forestry provides raw material for pulp and paper manufacturing, sawmilling and furniture manufacturing. Softwood is mainly used for structural purposes, with only approximately 3.7% of all sawlogs produced from eucalypts (FSA 2004). Clearcutting is practiced in South Africa with typical rotation periods for sawlog production between 25 and 30 years, while pulpwood is produced in cycles of 7-12 years (eucalypts) and 12-15 years (pines).

An important difference when compared to the northern hemisphere is the high degree of vertical integration of the industry in South Africa and hence wood production is rather driven by demand than by supply, with the resultant consequences for decision support requirements. This is reflected in the dominant role production plays in the process, since supplying the companies' timber and pulp processing facilities is the primary objective.

Forestry is currently taxed according to water consumption, based on climatic, edaphic and other tree parameters (Gush et al. 2002).

Most plantations are privately owned. However most of this area (48.1% in 2003) is in the hands of a few large corporate owners (Figure 1), with a further 21.2% to be privatised in the near future (PAMSA 2004). Drastic demographic and landownership changes are expected due to land claims and the promotion of the broad-based black economic empowerment (BB-BEE) (Ham et al. 2010). These processes will re-allocate land currently owned by big forest companies to communities. These communities are largely without forest management expertise or experience. This situation can seriously impact an already constrained wood supply in South Africa and even further if no appropriate measures are taken to support the management decisions of these potentially new forest owners.

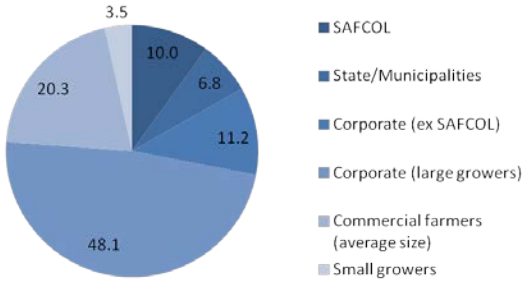

Figure 1. Plantation ownership in South Africa (Godsmark, 2010)

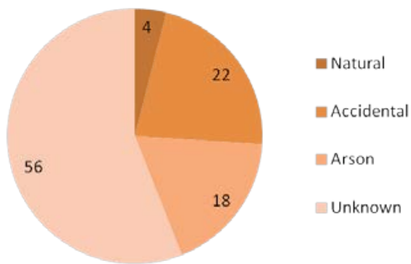

Figure 2. Causes of fires in South Africa (FES, 2010)

22.1.2 Problem types

Management currently focuses on a singular wood/pulp production-oriented perspective which is supported by existing decision support (DS) tools that have been viable and efficient over the years. Forest management typically follows a top-down approach where the strategic demand of timber is matched with available land, wood types and species. The demand is identified from current pulp and sawmill capacities of the larger growers. Site/species matching and management practices are based on this demand as well as with environmental, geographic and social limitations at the local level. Companies have standard procedure manuals based on past scientific research which are used as guidelines. Information regarding spatial parameters is captured and stored in spatially enabled databases (GIS). An important aspect is that the decision process is only supported to a certain degree and stops with providing relevant facts for decision-making. Thus most decisions are made by the forest managers. Typical spatial levels range from the stand (5 - 20 ha) to the forest (5,000 – 20,000 ha). The following most prevalent problem domains correspond with the problem types defined in Table 2 and Table 3.

1) **Title deed / lease management (TDM)** is a spatial problem which typically requires a geographical information system (GIS) in order link cadastre data and long-term contracts to spatial planning entities.
2) **Forest Inventory** (FI) is prerequisite for informed planning since it provides a *status quo* information of the stocks, with regards to stocking area, standing volume, increment, age and diameter distribution. An evaluation of the accuracy of this data is often desired and in particular the data flow towards yield regulation is important for a seamless planning process. Often road infrastructure assessment is integrated in this problem domain.
3) **Growth and yield projection** (G&Y) is geared towards providing accurate projections of volume and product yield from inventory information, and is a key element of long-term sustainability and operational planning. Typically, statistical stand growth simulators are used for this task.
4) In **harvest scheduling/planning** (HS) the amount of harvestable timber is spatially and temporally attributed to compartments to meet a predefined objective. This is a typical optimization problem which can be e.g. solved by linear programming, simulation or meta-heuristic techniques.

5) **The Annual Plan of Operations (APO)** encompasses all necessary operations for the coming year such as stand establishment (planting), silvicultural operations (weed control, fertilizing, pruning, thinning), as well as harvesting and transport. Usually these operations are integrated with budgeting and progress control in an accounting system, where the corresponding financial transactions are recorded.
6) **Tactical planning** (TP) is done for a longer time period, where market information and seasonal or mid-term constraints from other factors can be taken into account (e.g. work load balancing) to plan equipment configuration, logistics, as well as road maintenance and construction.
7) **Land claim management** (LCM) became an issue when, after the political change in 1994, the new government, committed itself to reverse the deprivations imposed by the previous government, and entitle people, unfairly dispossessed of land since 1913, to either restitution or to fair compensation (DIDIZA 2006). Multiple decision-makers are thus consulted which will include stakeholders from the communities, commercial forestry sector, and possibly government. This has introduced a wide range of novel management planning problems.
8) **Afforestation management** (AM) is a must in South Africa since any afforestation requires a "Stream Flow Reduction Activity License", plus other government consents as a legal pre-requisite, this also includes authorisation from a number of provincial and national public departments and a site inspection and legal notices (Howard et al. 2005).
9) Proactive and reactive **Fire Management** (FM) is a key issue in South African forest planning because plantation damages are mainly fire related (Table 1) and only a small proportion of occurring fires has natural causes (Figure 2).

Table 1. Total Damage in South Africa 2008/2009 (FES 2010)

	Fires count	**ha**	**Weather ha**	**Diseases ha**	**Insects ha**	**Animals and Rodents ha**	**Total Ha**
Softwood	780	13082	254	586	97	443	**14462**
Hardwood	1084	6723	883	66	522	153	**8347**
Total	**1864**	**19805**	**1137**	**652**	**619**	**596**	**22809**

10) **Delineation** (DLN) is a process in which wetland and riparian zones are excised from commercial areas (FSA 2004). The need for a decision support system (DSS) which integrates with the spatial (GIS) data at a compartment level could support the task of determining what compartment would need to be delineated and to what extent.
11) **Theft management** (TM) is a necessity in South Africa because timber theft is common and occurs mainly in plantations that have settlements in close proximity and is typified by blatant timber theft for financial gain and tree removal for home building. As forests are generally not fenced or guarded, this theft continues largely unchecked.

22.1.3 Objective of this report

The objective of this country report is to identify the prevalent forest management planning problem types that are prevalent in South Africa. Another objective is to summarise the existing DSS, describe their key features and analyse how they address the most prevalent country-specific problem types. This allows the identification of the need for further DSS development. The purpose of this chapter is not to provide an exhaustive overview but rather to concentrate on the most relevant problems. Thus several problem types were aggregated to keep an overview, where in reality they would consist of several individual management problems. Table 2 defines the problem types encountered in South Africa according to FORSYS typology.

Table 2. Classification of forest management planning problems in South Africa according to the FORSYS dimensions

Problem type*	Spatial Scale	Temporal Scale	Spatial Context	Objectives	Parties Involved	Goods & Services
1. TDM	Forest level	Operational	Spatial w Neighbourhood Interrelations	Multiple	More than one decision-maker/stakeholder	Non-Market Services
2. FI	Stand level	Operational	Spatial w Neighbourhood Interrelations	Multiple	More than one decision-maker/stakeholder	Market Wood Products
3. G&Y	Forest level	Operational	Non-Spatial	Single	Single decision-maker	Market Wood Products
4. HS	Stand level	Operational	Spatial w Neighbourhood Interrelations, Non-Spatial	Multiple	More than one decision-maker/stakeholder	Market Wood Products
5. APO	Stand level, Forest level	Operational	Spatial w Neighbourhood Interrelations	Multiple	More than one decision-maker/stakeholder	Market Wood Products, Non-Market Services
6. TP	Stand level, Forest level	Tactical	Spatial w Neighbourhood Interrelations	Multiple	More than one decision-maker/stakeholder	Market Wood Products, Market non-wood products
7. LCM	Stand level	Tactical	Spatial w Neighbourhood Interrelations	Multiple	More than one decision-maker/stakeholder	Non-Market Services
8. AM	Regional/ National level	Strategic	Spatial w Neighbourhood Interrelations	Multiple	More than one decision-maker/stakeholder	Market Wood Products, Non-Market Services
9. FM	Regional level	Tactical	Spatial w Neighbourhood Interrelations	Single	More than one decision-maker/stakeholder	Market Wood Products, Non-Market Services
10. DLN	Stand level	Operational	Spatial w Neighbourhood Interrelations	Single	More than one decision-maker/stakeholder	Market Wood Products, Non-Market Services
11. TM	Stand	Strategic	Spatial w	Single	More than one	Non-Market

	level, Forest level	Neighbourhood Interrelations	decision-maker/stakeholder	Services

* Corresponds to problems identified in section 1.2

22.2 Materials and methods

Information for this report was gathered by questionnaires, interviews with experts from the forest industry and academic institutions. It also relies on the analysis of DSS in South Africa by Lämås (2010) and published reports and articles, as well as information available on web pages. A questionnaire was designed in Excel and distributed to forestry companies in South Africa via email. The questionnaire was designed to assess which tools were used by which companies to address specified problem types, as well as establish how well these tools performed. A set of problem domains were identified and included in the questionnaire in order to determine how companies were resolving these issues. Additional space was provided for users to insert any other problem domains.

The existing FORSYS problem type definitions were entered into an Excel grid. The questionnaire results were analysed, and in addition if an entry did not have a corresponding problem type definition, one was added to this grid. The problem types were then aggregated to Table 2.

22.3 Results

Table 3 provides an overview on existing DSS in South Africa. In the following section current DSS are briefly described and matched to prevalent problem types as identified in section 1.2.

Table 3. The main DSS tools applied in the South African forest industry for the various problem types.

Problem types addressed	**DSS**	**Models and methods**	**Accessibility**	**KM techniques (if applicable)**	**Methods for participatory planning (if applicable)**
1, 7	ARC-GIS, Esri	GIS system	commercial	Spatial database	Visualisation of spatial plans
8 (partly)	ATLAS, Sappi	Rule-based site-species matching	proprietary	na	None
2,3, 4, 5	COMPAS	Statistical-based simulation model, Simulation-based harvesting scheduling	commercial	Database management system	None
6 (partly)	FESA	expert system for harvest benchmark & costing	public domain	Database a	Base for negotiation with

Problem types addressed	DSS	Models and methods	Accessibility	KM techniques (if applicable)	Methods for participatory planning (if applicable)
					contractors
3	FORSAT, KLF	Inventory Database Statistical stand growth simulator, with cut to logs simulation (dynamic programming)	proprietary	Interface to database	None
2, 3, 4, 5, 6	Microforest, Syndicate	Simulators for harvest scheduling Statistical simulation model for Growth and Yield	commercial	Database management system	None
6 (partly)	SAFCA2	Expert system for harvest costing	public domain	Database	Base for negotiation with contractors
2, 3, 4, 5, 6	SAPPI consists of FMS Harvesting manager Modelmanage r	Inventory Database (GMS) Simulation-based harvest scheduler, OR optimizer Statistical Stand growth model	proprietary	Database	None
4, 5, 6 (Scenario tool)	SIMSAW	rule-based sawing simulation	public domain	Na	None

Arc-GIS from ESRI and Mondi GIS are the standard GIS system for many spatial planning issues in forestry in South Africa. However, several companies are currently testing open source alternatives, such as QuantumGIS, to reduce costs. Main applications are title deeds management, site-species matching and road management.

ATLAS is SAPPI's proprietary DSS for site-species matching. The rule-based approach based on statistical correlations between tree growth and edapho-climatic site parameters is used as a specialist tool in silvicultural planning and also afforestation management.

COMPAS (Computerised Plantation Analysis System), presented by Wessels and Kassier (1985) is a DSS developed in the 1970s and 1980s for the South African Forestry Department to manage state-owned plantations of SAFCOL. It contains growth models for a number of pine and eucalypt species (COMPAS PCPROJ), a harvest scheduling system (COMPAS HSS), a data editing and processing module, a discounted cash flow model and a model for working plan report writing. It also caters for long, medium and short-term planning.

Stellenbosch University/Forest Engineering South Africa (FESA): The costing model was developed by Stellenbosch University with funding from FESA, an association that deals with forest engineering development in South Africa. The expert system uses the main equipment or harvesting methods common in harvesting in South Africa and calculates a basic cost for a set of variables and conditions – similar in some aspects to the South African Forestry Contractors Association (SAFCA) model, but more comprehensive as it caters for system balancing. The programme is freely available on the internet (FESA 2011).

FORSAT: An in-house growth simulation system from Komatiland Forests with the objective to develop silvicultural programmes and test options in scenario-simulations. FORSAT has a focus on pine sawlog production in a plantation setup (Kotze 2004). It has the capability for stand-based scenario analysis and features routines for volume and taper calculation, pruning and crosscutting and some further wood quality-related sub-models (Kotze and Malan 2005, 2007).

MICROFOREST: A widely used DSS in the forestry industry developed and provided by Syndicate Database Solutions Ltd. The programme is an integrated plantation and natural resource management system encompassing inventory, modelling, planning, scheduling, operations and logistical aspects and covers the life-cycle of forestry operations. A web description is available (Syndicate 2011).

SAFCA: A costing model developed by the SAFCA. This Excel model is quite simple and relatively easy to use. It has harvesting, silvicultural and machine costing sections and is also used for basic budgeting. The programme is freely available (SAFCA 2011).

SAPPI FOREST MANAGEMENT SYSTEM (FMS): This system integrates information obtained from Sappi's two other DSS which were developed in-house and is very similar to Microforest in its functions, i.e. the Model Manager and Harvest Simulator. The Model Manager is a growth model system, while Harvest simulator is a programme that describes different harvesting systems, equipment, projected cost and productivity outputs. These two systems are integrated into the FMS which is a database containing the information necessary for plantation management.

SIMSAW (V.6): SIMSAW is a sawing simulator which predicts the costs, board recovery and the total recovery by value and volume, based on inputs such as the machines and sawing patterns that are used (Wessels et al. 2001). It tests production standards and production scenarios. SIMSAW also simulates log quality in terms of knotty core defect and board grades resulting from each log and production scenario. This simulator is freeware and used by a number of sawmills for testing sawing patterns (CSIR 2011).

22.4 Discussion and conclusions

Typical production-oriented decision support for commercial forestry companies is provided on a high standard and level of integration with financial systems. The market of current DSS shows a strong concentration process towards one product (MICROFOREST), while older software is phased out gradually (COMPAS). In general it is hard to find detailed information on methods and models applied in the currently used DSS. Forest management in South Africa evolved rapidly during the last 40 years, from a strong wood production centred focus to a more multi-criteria forest management system which accounts for extended socio-economic and ecological considerations. The inclusion of community interaction issues, non-timber forest use, and marketable and non-marketable forest products (ecosystem services) together with specific South African socio-economic issues increase the pressure on the forest companies to more participatory and multi-criteria planning at all spatial and temporal scales of forest management. Currently this challenge is tackled with an increasing amount of new staff dealing with community interaction, but not yet with efficient multi-criteria DSS.

It is obvious that the South African decision support tools are still focused on the singular goals of optimum wood and fibre production, conducted by large-sized companies and do not match the new realities of supporting current complex multi-criteria decision-making yet. Existing DSS are mainly designed to provide DS for the industry, not for other spatial and economic scales. The necessary DS at the regional and national planning levels are not provided for by existing systems, nor the urgently needed support for small-scale and community-based forestry. Problem types 7-11 are not or only insufficiently addressed by current DSS.

(7) Currently, no tool has been specifically developed to deal with **Land claims.** In MicroForest, land claim areas remain in the system until the land has officially been transferred to new land owners. If companies have entered into lease agreements with the new owners, then this land is handled as a regular lease agreement by the system. GIS is a standard tool to map these categories. In all cases, systems do not cater for the special clauses and requirements stipulated in these quite unique lease agreements.

(8) The need for **Afforestation licences** forces forest companies into multi-criteria decision-making. Usually a regional planning level is addressed. Both aspects are not addressed in the current DSS. A plethora of legislative requirements has to be met (Ham et al. 2010) including social (e.g. archaeological and cultural heritage, BB-BEE) and environmental aspects (e.g. water consumption, biodiversity, food security). These steps involve different public departments and usually a participatory process with the local population. The regional, governmental interaction follows strict protocols and can be seen as a definition of boundary conditions for commercial forestry in a certain region. Currently no tools or systems have been developed to manage this process. The task of managing licences is usually done by a specialist within the forestry company, who typically uses Excel spreadsheets in performing the task. These SFRA licences permit a defined area to be planted within a water catchment area, and therefore it seems plausible that a DSS integrated with the spatial aspect of a compartment register could be used in determining the optimal way in which plantable area could be utilised and managed. However, it has to be mentioned that GIS systems are valuable tools in managing and visualising this information and models like ATLAS support the aspect of species selection for a certain site.

(9) **Fire Damage** is not directly addressed in current forestry tools in use in South Africa which deal with the capture and management of plantation damage data. This is generally through the use of an edit screen. This data is, however, not currently used by the systems to perform any form of analysis (e.g. hotspot analysis and preventative actions), and do not currently fulfil the role as DSS. Also here GIS systems are used to map fire damage as a first step to DS.

(10) **Delineation** is addressed by MicroForest and FMS. These tools allow users to maintain and manage physical data and attribute data captured into the system related to the delineation activities, but do not perform any DS roles in this regard. GIS is used for the spatial description of delineated areas.

(11) No **theft management** DSS has been developed to date in South Africa. In the MicroForest tool, theft losses are recorded in the compartment notes section, but again, this only provides an interface in which compartment attributes are maintained, and no DS functionality exists.

The comparative analysis of DSS and prevalent problems in forest management in South Africa revealed a gap between the largely production-oriented existing DSS and the multi-criteria problem matrix that needs to be addressed in the future. South Africa is unique in various aspects such as its contribution to poverty alleviation while being submitted to strict regulations and land use restrictions. Forestry is able to make a considerable contribution to poverty alleviation and BB-BEE process in rural areas but on the other hand South Africa is a water-scarce environment that only allows for a relatively small amount of the area of the country to be farmed intensively, with large areas too dry, also for commercial forestry. Thus an inherent competition for suitable land between land use forms is prevalent. Considering global change and its possibly negative effects on forestry (Seifert et al. 2011) DSS are needed to provide a broadened perspective towards a truly multi-criteria assessment of forest management objectives and also towards the inclusion of forest management in a strategic landscape management on a regional level.

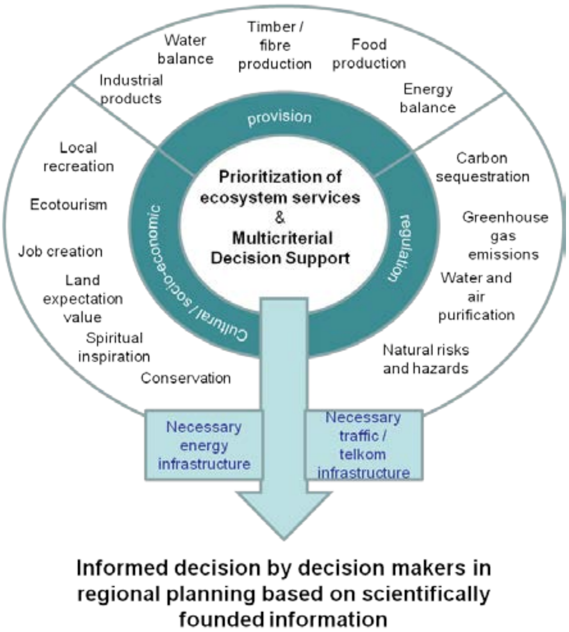

Figure 3. Ecosystem services addressed in the Green Landscapes DSS that is currently developed at the Department of Forest and Wood Science, Stellenbosch University.

To meet these challenges, the University of Stellenbosch has initiated a "Green Landscapes" initiative, with the objective of developing a spatial DSS (sDSS) for evaluating the effects of different land-use management forms (with forestry as a central pivot) and their spatial arrangement on a concise set of ecosystem services (Figure 3). A multi-criteria decision approach (MCDA) or a constraint optimization is applied to integrate and prioritize the effects of management, based on implemented policies. The DSS will have a scenario simulation capability to support "if...then" planning according to a multiple path management concept (von Gadow et al. 2008). By embarking on this multiple paths management paradigm, the developed system will provide flexibility to react to environmental or socio-economic changes, and also changes in governance.

This approach is novel to South Africa and paves the way for scenario-oriented multi-criteria planning. It opens possibilities for regional planners who have to integrate a much wider use of land for different objectives and balance a complex matrix of benefits and negative effects. This development is an important step towards a participatory planning approach since the DSS will support the abstraction and visualisation of complex interactions on different temporal, spatial and socio-economic levels. Thus non-experts can be incorporated in the discussion much more efficiently.

22.4.1 Conclusions

Currently applied South African DSS are mainly geared towards optimized wood and pulp production and have proven to be highly efficient and reliable to support decisions for this objective. They have a high degree of acceptance in the forest industry and a comparably high degree of integration in the management processes of the companies. However, they fail to address the increasing needs for multi-criteria decision-making, integrating participatory decision processes and a broad availability for decision-makers apart from forest management in companies. DSS in South Africa do currently not include DS support such as MCDA to prioritise different solutions. At the moment these integration tasks are done by the human expert and are only supported by qualified background information. Current attempts to develop advanced scenario analysis and DSS tools to incorporate a MCDM seem to be a promising way of facilitating a much broader and at the same time more participatory planning approach to complement the existing DSS.

References

CSIR, 2011. http://.ffp.csir.co.za/products/simsaw.html (website accessed August 2011)

DIDIZA A.T, 2006. Land and Agrarian reform in South Africa: 1994-2006, Presentation by the minister of agriculture and land affairs at the international conference on agrarian reform and rural development, Brazil, March 2006

DWAF (Department of Water Affairs and Forestry), 2005. Final scoping report. The development of a strategic environmental assessment of the zone of afforestation potential in the Eastern Cape. Study undertaken by CES Joint Venture for DWAF, Pretoria.

FES, 2010. Report on Commercial Timber Resources and Primary Roundwood Processing in South Africa. Compiled on behalf of the Directorate: Forestry Technical and Information Services, by Forestry Economics Services CC

FESA, 2011. www.sun.ac.za/forestry (website accessed August 2011)

FSA, 2004. South African Forestry and Forest Products Industry Facts. FSA 2002/2003 data set.

Godsmark R.P, 2010. South African Forestry and Forest Products Industry Facts. FSA 2002/2003 data set

von Gadow, K.; Nuutinen, T.; Kellomäki S., 2008. Adaptive design of forested landscapes. In: von Gadow K., Pukkala T (Eds) 2008. Designing green landscapes. Springer

Gush, M.B.; Scott, D.F.; Jewitt, G.P.W.; Schulze, R.E.; Lumsden, T.G.; Hallowes, L.A.; Görens, A.H.M.; (2002) Estimation of Streamflow Reduction Resulting from Commercial Afforestation in South Africa. Water Research Commission Report TT 173/02.

Ham, C.; Ackerman, P.; de Wet, J.; du Toit, B.,; Geldenhuys, C.; Ham, H.; Howard, M.; Mortimer, J.; Seifert, T.; Wessels, B., 2010. Sawlog Strategy and Implementation Plan for South Africa - Report compiled for the FAO National Forest Programme Facility and the Department of Agriculture, Forestry and Fisheries.

Howard, M. et al 2005. Small Scale Timber Production in South Africa pg 67-69

Kotze, H., 2004. FORSAT- A stand-level forestry analysis tool. Proceedings of the Precision Forestry Symposium, Pietermaritzburg, South Africa.

Kotze, H.; Malan, F. 2005. Progress in the prediction of growth and wood quality of plantation-grown Pinus patula sawtimber in South Africa. Proceedings “Connections between Forest Resources and Wood Quality: Modelling Approaches and Simulation Software. IUFRO WP 5.01.04 Waiheke, New Zealand.

Kotze H.; Malan F.; 2007. Further Progress in the prediction of growth and wood quality of plantation-grown Pinus patula sawtimber in South Africa. Proceedings of “Forest Growth and Timber Quality: Crown Models and Simulation Methods for Sustainable Forest Management.” Portland OR, USDA TYechnical Report PNW-GTR791. 113-123.

Lämås T., 2010. On South African forestry and forest decision support systems. Reciprocal Short Term Scientific Mission Report. COST Action FP0804 FORSYS.

Paper Manufacturers’ Association (Pamsa), 2004. Draft Background Information:South African Forestry, Pulp and Paper Industries. Pamsa: Rivonia.

SAFCA, 2011. http://www.safca.co.za/index.php/costing-model (website accessed August 2011)

Seifert, T.; Ham C; Jacobs, S.; Kunneke, A.;du Toit, B.; 2011. Impact of Climate Change on Forests and Forestry in South Africa. Second National Report on Climate Change to the IPCC.

Syndicate, 2011. http://www.syndicate.co.za/files/microforest.html (website accessed August 2011)

Van der Zel, D.W.; 1989. Strategic forestry development plan for South Africa. An evaluation of past influences. An analysis of the present forestry sector. A plan for projected development of the forest industry. Compiled for Department of Environmental Affairs. Perskor: Pretoria.

Wessels, C.B.; Dell, M.P.; Price C.S.; 2001. SIMSAW 6 User Manual. CSIR Report ENV-D-I 2001-11.Durban, South Africa.

Wessels, N. O. and Kassier, H. W. 1985. A computerised system for forest management and silvicultural planning and control in even-aged plantation forestry. South African Forestry Journal 132: 62-64.

Annex 1. Forest management planning tools survey: questionnaire template

WHAT SYSTEMS ARE IN USE FOR THE FOLLOWING FORESTRY FUNCTIONS:	If NO, Need for Relevant System? [0 = not critical, 10=very critical]	If YES, System Details (Name and Vendor)	Period System in Use (Years)	Dependency on System? [0 = not dependant, 10=very dependant]	System Performance [0 = very badly, 10= very well]	Which dimensions are catered for by the system? Please click on the cells below for a description of the dimension — Temporal Scale: Long term (strategic)	Temporal Scale: Medium term (tactical)	Temporal Scale: Short term (operational)	Spatial context: Non Spatial	Spatial context: Spatial with Neighbourhood Interrelations	Spatial context: Spatial with NON Neighbourhood Interrelations	Spatial Scale: Stand Level	Spatial Scale: Forest Level	Spatial Scale: Regional/national level	Parties Involved: Single decision maker	Parties Involved: More than one Decision Maker	Objectives: Single	Objectives: Multiple	Goods & Services: Market non wood products	Goods & Services: Market wood products	Goods & Services: Market services	Goods & Services: Non market services	How well does the system cater for/make provision for the following scenarios? [0 = very badly, 10= very — Land Claims	Community Leases	Out Growers	Delineation	Market Changes	Adding/Removing	Plantation Fires	Other Plantation Damages	Theft	Suggested System Enhancements	What other required functionality is not currently catered for by the system?	Comm
Nursery																																		
Nursery Management																																		
Planning																																		
Annual planning (APO)																																		
Enumeration Management																																		
Yield regulation																																		
Growth and yield simulator																																		
Road management																																		
GIS																																		
Remote Sensing/Image Interpretation																																		
Budgeting and Finance																																		
Annual budgeting																																		
Compartment level costing																																		
Silviculture																																		
Operations management																																		
Site species matching DSS																																		
Nursery Seedling Ordering																																		
Harvesting and Transport																																		
Harvest scheduling																																		
Tactical harvest planning																																		
Transport scheduling																																		
Wood quality control																																		
Other Systems of Interest																																		

23 Computer-based tools for supporting forest management in Spain

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23.1 Introduction

In Spain the forest surface occupies 27.5 million ha (54% of the total surface of the country; SECF 2010). However, only 36% of the total surface of the country is forested (i.e. with a percentage of canopy cover >= 20%); the remaining 18% is treeless or just covered by few trees. Forest ecosystems in the country can be classified according to the Atlantic and Mediterranean climatic zones (see Fig.1). Forests in the Atlantic region are characterized by its high wood productivity, which often relates to the practice of short rotation forestry (e.g. *Eucaliptus sp*, *P. radiata*, *P. pinaster*, *Populus sp*). Forests in the Mediterranean region are characterized by its complexity and average low productivity (long drought periods in summer). These conditions, combined with other factors such as topographic contrasts, often lead to no management (management is not profitable).

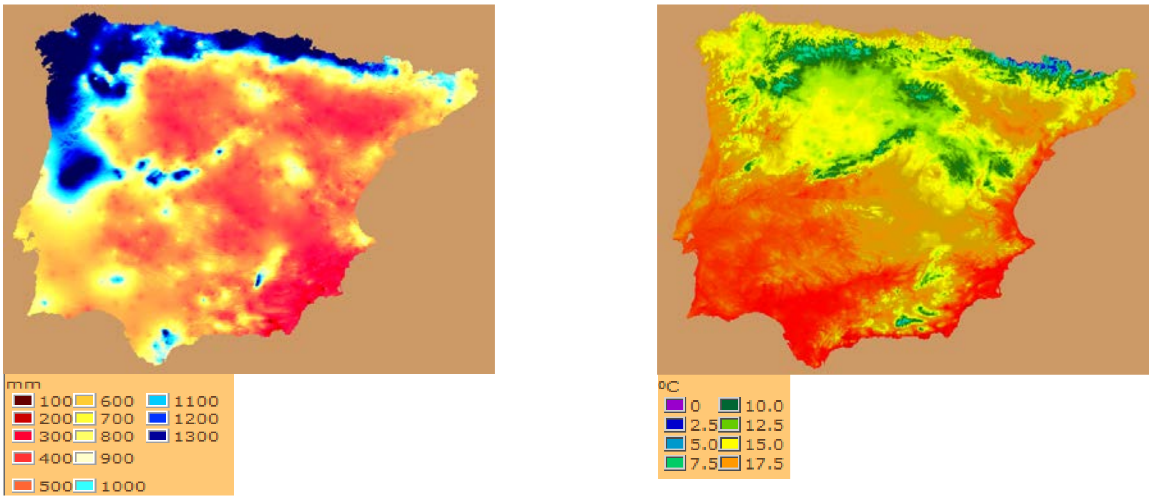

Figure 1. The Atlantic and Mediterranean climatic zones of the Iberian peninsula approximately shown by annual precipitation (left) and mean annual temperature (right) maps (Ninyerola et al. 2007a; Ninyerola et al. 2007b). The highly productive Atlantic zones relate to N-NW regions close to the Atlantic coast where annual precipitation and annual mean temperature range above 1000 mm and 5 °C, respectively.

Due to its location and climatic conditions, Spain presents large diversity in forest ecosystems. Around 20 dominant tree species can be identified, for example: *Q. ilex* (dominates in 14% of the forested area), *P. pinaster* (12%), *P. halepensis* (11%), *P. sylvestris* (9%), *P. nigra* (6%), *F. sylvatica* (4%), *Q. suber* , *P. pinea*, *Q. faginea*, *Q. pyrenaica*, *Castanea sativa*, *Juniperus thurifera*, *Q. robur*/*Q. petraea*, *P. uncinata*, *Pinus canariensis*, etc. Much of the forested area is also occupied by mixed forests. The growing stock (m^3/ha) increased 19.7% during the period 1996-2009 (SECF 2010) due to the lack of management. In Spain 41.3% of the annual growth/cutting budget is harvested (the average in the EU27 is 59%; SECF 2010). The majority of timber production is harvested in the Atlantic region (around 70% of the total production in the country).

Spanish forests (especially those in the Mediterranean region) are characterized by the existence of multiple goods and services. A representative list may be: timber, grazing, fire-wood and biomass, carbon sequestration, cork, resins, aspart, berries, mushrooms, aromatic and medicinal plants, hunting, fishing, biodiversity and protected areas (27.6% of the country's surface is protected by the National Network of Protected Natural Areas and the Natura2000 Network; SECF 2010), protection-regulation (erosion), recreation and amenity. The multiplicity of goods and services is also one of the main drivers in forest management planning (Table 1).

Abiotic (forest fires, erosion, drought, storms, etc.) and biotic (insects, diseases) natural hazards are also important drivers in forest management planning. Out of these, *forest fires* have usually the strongest impact on the ecosystems and therefore require special attention. Regarding this, it is remarkable that around half of the total investment in the forest sector (at the country level) during the period 2002-2008 was allocated on forest fires prevention and extinction (Foresdat, 2009). Forest fires are characteristic of Mediterranean forest ecosystems (long summer drought periods, high temperatures, strong winds) and have had significant negative impact in recent years, especially large fires (> 500 ha). In this context, sustainable forest management is not feasible if forest fires are not kept within a normal range. Extreme climatic conditions present a big challenge, but appropriate management measures regulating the abundance and continuity of fuels (silviculture, establishment of firebreaks) are crucial for prevention. Erosion is another relevant risk. Most forests in the steepest alpine and subalpine slopes are public protection forests.

Another challenge for sustainable forest management and planning in Spain is coping with *climate change*, especially in a Mediterranean context, where climatic conditions are already harsh. For instance, improving the water balance or creating appropriate forest stand structures that reduce vulnerability to increasing climate-driven risks (i.e. forest fires and droughts, etc.) may appear to be the most relevant management objectives in certain Mediterranean areas.

Forest ownership in Spain is characterized by a high degree of fragmentation (many properties smaller than 5 ha). This is often a challenge for regional planning and needs to be addressed by the establishment of forest associations. Approximately one-third of the Spanish forest surface is public (mostly forests from the municipalities, only a small proportion belongs to the state). In principle the legal framework allows free access to properties, and urban communities often search for recreation in nature (in private properties, permission from the owner is required in some case). Some activities are regulated (i.e. mushroom picking in some forests or provinces) or prohibited (e.g. camping, off-road motor biking, etc.), but many other activities are not regulated. These activities may cause damages, and forest owners often claim for the establishment of new forest policies that regulate some activities and evaluate possible compensations (i.e. the evaluation of forest externalities).

Similar to forest systems in the country, considerable variation in management planning problems can be found (see classification of forest management planning problems in Spain according to FORSYS dimensions, Table 1). Due to the common fragmentation of forest ownership ***stand level planning*** is very common and mainly relates to small private properties (<5ha, 1 or few stands). Typically the forest owner acts as a single decision-maker and one or two objectives are considered. Concerning goods and services, timber or/and biomass apply to problem *S_2* in Table 1, timber and mushroom production can be an example of problem type *S_3*, and the combination of timber with biodiversity or fire risk are common cases of problem *S_4*. At this spatial level the temporal dimension of planning may vary considerably. In small properties of the northern Atlantic regions (where short rotation forestry takes place) less than 10-year planning periods (problem *S_1*) may occur, while in many other cases strategic planning (10-20 years or longer) is usually considered.

Table 1. Classification of forest management planning problems in Spain according to the FORSYS dimensions

	Problem types [a]													
Dimensions	**S_1**	**S_2**	**S_3**	**S_4**	**L_1**	**L_2**	**L_3**	**L_4**	**L_5**	**L_6**	**L_7**	**L_8**	**L_9**	**R_1**
Temporal scale														
Long-term (strategic, more than 10y)		x	x	x	x	x	x	x						x
Medium-term (tactical, 2-10 years)	x								x	x	x	x		
Short-term (operational, 1y)													x	
Spatial context														
Non-spatial	x	x	x	x										x
Spatial with no neighbourhood interrelations							x	x			x	x		
Spatial with neighbourhood interrelations					x	x			x	x			x	
Spatial Scale														
Stand level	x	x	x	x										
Forest/landscape level					x	x	x	x	x	x	x	x	x	
Regional/national level														x
Parties involved														
Single decision-maker	x	x	x	x		x	x			x		x	x	
More than one decision-maker / stakeholders					x			x	x		x			x
Objectives														
Single	x													

Multiple		x	x	x	x	x	x	x	x	x	x	x	x	x
Goods and services														
Market non-wood products			x		x	x	x	x	x	x	x	x	x	x
Market wood products	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Market services					x	x	x	x	x	x	x	x	x	x
Non market services				x	x	x	x	x	x	x	x		x	x

[a] Problem types are named according to its spatial scale (*S*tand, *L*andscape, *R*egional). For a given spatial scale different problems are numbered consecutively.

Landscape level planning is conducted on public and private forests (>5ha):

- In the case of *private forests* it is important to distinguish between forests that belong to the pulp and paper industry (the national company ENCE manages around 70,000 ha in Spain, which implies a much smaller proportion of the total forest surface than in other countries such as Portugal) and forests belonging to non-industrial private owners. Private forests may relate to a single decision-maker (particular forest owner or industry, problem *L_2*) or to multiple decision-makers (*L_1*, *L_4*), for example in the case of private communal forests in Galicia where participatory planning between the owners takes place. Communal forests, or Montes Veciñais en Man Común (MVMC) are a specific form of communal land tenure and a singular legal category in Galicia (Northwest Spain). MVMC extend over one third of the area of the region (Gómez-Vázques et al. 2009). In other cases the administration is in charge of managing communal private forests (*L_2*, *L_3*).

  In properties where short rotation is used, the planning period may be less than 10 years (tactical planning, problems*L_5*, *L_6*, *L_7*, *L_8*) or one year (operational planning, type *L_9*). Relevant examples of forest systems that require intensive yearly planning are the forests of the pulp and paper industry, forests near a bioenergy plant, or the agrosylvopastoral systems "Dehesas". Dehesas occupy 2 million ha, mostly in the south of the country (generally in plateaus and valleys) and originate from thinnings in *Q. ilex*, *Q. suber* and *Q. coccifera* forests. Typically in arid summer conditions, the presence of trees prevents excessive soil temperatures and reduces the transpiration of the vegetation. Rainfed agriculture is usually practised in the uncovered surface, extensive cattle are fed with grasses, and trees provide fruits, fire-wood, timber, and cork.

- In landscape-level planning of *public forests* it is important to differentiate between forests with a single decision-maker (e.g. municipality, problems *L_2*, *L_3*) and forests with multiple decision-makers (*L_1*, *L_4*). Forests with multiple decision-makers are represented by communal forests (e.g. belonging to several municipalities in the Pyrenees) or by forests where some protected (nature conservation) area is included (then multiple stakeholders are involved in decision-making). Planning periods longer than 10 years are the most common in public forests.

Because forest systems in Spain are strongly characterized by its multi-functionality, landscape level planning (also regional planning) in most cases addresses all types of goods and services. Non-wood services/risks such as forest fires and biodiversity/habitat protection are almost always relevant objectives and therefore neighbourhood interrelations between stands (problem types *L_3*, *L_4*, *L_7*, *L_8*) need to be considered. However, there are cases in which neighbourhood interrelations are not crucial (e.g. if fire risk in the area is low etc.). In those cases spatial criteria with no neighbourhood interrelations (i.e. location) are implemented (problem types *L_1*, *L_2*, *L_5*, *L_6*).

The role of ***strategic regional planning*** was emphasized in the latest National Forest Plan (DGCN 2002). In recent years the development of strategic forest plans at the county level has been promoted by the autonomic governments, and it is expected to continue gaining importance. Some of the main objectives of these plans are: ensuring the achievement of pan-European sustainability criteria at different space-time levels, integrating forest management with the management of protected areas and with land-use in general, and addressing the common fragmentation of forest ownership by promoting forest owners associations, communal forests and participatory planning. Planning periods for regional strategic plans may range between 10-30 years, and usually a revision of objectives takes places every 10 years (*R_1* in table 1).

In 2006 only 12.7% of the forest surface (18.9% in terms of forested surface; SECF 2010) was regulated by an updated forest management plan (68.5% of the planned/regulated surface was public and 31.5% private). The main reason for this is the lack of profitability during the last decades (since 80s, 90s), mainly in the Mediterranean regions. The current national forest plan (DGCN 2002) aims to promote forest management planning at the national, autonomic (main administrative regional entity; Spain is divided in 17 autonomies), county and local levels (forest, stand), according to the current pan-European objectives of multi-functionality.

The largest part of the produced management plans is still based on classical approaches, i.e. cutting budget regulation methods (sometimes with some variation, see e.g. Madrigal Collazo 1995) usually based on poor/limited growth and yield models (yield tables that only apply to fully-stocked even-aged forests that sometimes are too old and not representative; simple models only based on tree size, etc.) that cannot be used in simulations. In fact economic efficiency objectives (e.g. NPV) are often not considered for doing the plans. This leads to a deficiency in formulating and evaluating alternative management regimes. Timber is the main objective and other objectives are integrated qualitatively, but not explicitly in the calculation/planning procedure. These methods are not goal-based methods, i.e. management proposals are not derived from the management goals set for the particular forest (Trasobares and Pukkala 2007). Modern multi-objective planning based on (1) the identification of decision-makers and their management goals, (2) the simulation of alternative treatment alternatives for stands, (3) the solution of a planning model (using information from simulations and information on management goals) by using an optimization tool, and (4) the use of sensitivity analysis tools for testing the solution, is required for this.

Though still not established in forest planning practice, in the last 10-15 years numerous tools for supporting modern planning have been actively developed in Spain. For example, several stand-level dynamic simulation tools enable the simulation of alternative management schedules for a broad range of stand types (see e.g. Sánchez-González 2007; Río et al. 2005; Calama et al. 2007; González et al. 2009). Some stand simulation tools have also been used in stand-level planning/optimization (Palahí and Pukkala 2003; Trasobares and Pukkala 2004; González et al. 2008, Palahí et al. 2009). At the forest/landscape level, various research studies on multi-objective forest planning (mainly for even-aged management systems) have been developed using real forest data (see e.g. Diaz-Balteiro and Romero 1998; Diaz-Balteiro and Romero 2003; Diaz-Balteiro et al. 2006; Bertomeu et al. 2009; Diaz-Balteiro et al. 2009a). The resulting planning models used mathematical programming (e.g. dynamic programming, heuristics) and multi-criteria analysis (e.g. Goal programming; Analytical Hierarchy Process) for integrating the preferences of decision-makers in the planning model. Besides, a method for aggregating expressed individual preferences has been adapted and applied to elicit social weights in the context of a real forest management problem (Diaz-Balteiro et al. 2009b). Finally, fully developed multi-objective decision support systems (integrating simulation, decision-making and sensitivity analysis tools) have been developed and applied at different spatial scales focusing on key issues such as fire risk prevention and habitat conservation (Palahí et al. 2004a; González et al. 2005).

The main objectives of this report are:

- To produce an inventory of computerized tools to support the forest management problem types prevalent in Spain.

- To include a summary description of the key features of these tools such as architecture, use of models, methods, knowledge management, and participatory functionalities, with a focus on how the tools came about (development and institutional context) and their success in addressing the key planning problems in the country.

- To evaluate the lessons learned in the assessment of decision support systems (DSS) in the country and define a possible roadmap for a successful transfer of these tools to practitioners in the coming years.

23.2 Materials and methods

The existing data and information on forest management planning and DSS in Spain were classified (and afterwards evaluated and used) as follows:

- Technical and scientific publications.

- Text books and publications on traditional forest planning (e.g. Dubordieu et al. 1993; Madrigal-Collazo 1995; González Molina et al. 2006).

- National and autonomic forest plans (e.g. DGCN 2002; Gobierno de Cantabria 2006), General instructions for forest management planning (e.g. Junta de Castilla y León 1999; Junta de Andalucía 2004).

- Publications and forest management plans developed by the autonomic forest services or private forest owners associations. See for example the various publications and reports of the Forest Planning Centre for private properties in Catalonia, CPF (www.gencat.cat/dmah/cpf), or several forest management planning manuals published in some Autonomous Communities (e.g. Martinez Sánchez-Palencia et al. 2011).

- Web pages:
  - Ministry of Environment: www.marm.es/es/biodiversidad/servicios/banco-de-datos-biodiversidad/informacion-disponible/default.aspx
  - TRAGSA: www.tragsa.es/es/sus-empresas/Paginas/tragsatec.aspx
  - INIA (forest species maps): http://sites.google.com/site/sigforestspecies/home/mapas-de-especies
  - Foreco Technologies SL: www.forecotech.com/
  - Universidad Santiago de Compostela: http://solar.usc.es/saddriade
  - Spanish Global Biodiversity Information Facility (GBIF) Node: www.gbif.es/index_in.php
  - Digital climatic atlas of the Iberian Peninsula: www.opengis.uab.es/wms/iberia/espanol/es_presentacio.htm
  - The use of spatial web services based on ISO and OGC standards (based on the EU directive INSPIRE, http://inspire.jrc.ec.europa.eu/) deserves special attention here. The Ministry of Environment publishes broad cartography related to forest systems and management through Web Map services (see www.marm.es/es/cartografia-y-sig/servicios/servicios-wms/default.aspx#para2). In addition, the administrative organization of the country in 17 autonomies also led to the establishment of specific regional servers (see e.g. http://cma.gva.es/web/indice.aspx?nodo=69939&idioma=V for Valencia)

In addition, a ***questionnaire*** (via email) was sent to the main forest management planning experts and DSS developers in the country (universities, research and technology institutes, regional forest services, public and private companies). The main objectives of the questionnaire were: (1) to identify the main planning problems in the country (according to the FORSYS dimensions); (2) to identify the main decision support tools and systems and relate them to the planning problems; (3) to collect information about the involvement of potential users and stakeholders in the development of the systems; and (4) to collect information about the use of the systems in practical applications.

The obtained results are assumed to be a good representation of the current situation, prevalent forest management planning problems (already presented in the introduction), and the available tools for supporting management planning in Spain, because the main experts and representatives from most of the requested institutions replied to the questionnaire.

The objective (supported by all tool developers) is that all selected tools will be included in the FORSYS Wiki page for Decision Support Systems (DSS) (www.fp0804.emu.ee/wiki/index.php/Main_Page).

23.3 Results

In this report we distinguish between decision support systems (DSS) and computerized tools (CT). We consider decision support systems to be those tools that integrate the main processes of decision-making (i.e. enable: 1. Selection of management objectives and its relative importance; 2. Simulation of a decision space based on a set of management alternatives; 3. Planning problem definition and solving; and 4. Evaluation of the solution using a sensitivity analysis). For those tools that only support some of the processes (e.g. a stand-level simulator of management schedules) we will use the term computerized tool (CT).

Because stand-level planning (i.e. find an optimal management schedule for a given stand and planning period according to the objectives of the decision-maker/s) on small private properties (<5ha, 1 or few stands) is the most common planning case in many regions of the country (e.g. Galicia, Catalonia), it is not surprising that many of the existing CT and DSS address this spatial level (Table 2). Management problems (already described in section 1) S_1 and S_2 (one or two wood products objectives, strategic and tactical temporal scales) are addressed by various tools. Often they are stand-alone CTs for the simulation of alternative management schedules, based on growth and yield model (G&YM), volume/assortment functions, and biomass functions. Examples of this type of tools are GesMO© simulator (Castedo-Dorado 2004; Diéguez-Aranda 2004; González et al. 2009 available in Diéguez-Aranda et al. 2009 and www.usc.es/uxfs/), PINASTER (Rodríguez Soalleiro et al. 1994), SILVES (Río et al. 2005), and ALCORNOQUE 1.0 (for cork production; Sánchez-González et al. 2007). Web-based support tools such as SIMANFOR (Bravo et al. 2010; www.simanfor.org) and SAD_DRIADE (http://solar.usc.es/saddriade) may also be used for problems S_1 and S_2. SIMANFOR allows simulating management schedules from any forest inventory source. SAD_DRIADE is based on a set of pre-defined management models/schedules that the user may select and includes GIS/maps and visualization tools. A more detailed description of stand-level support tools in Spain is also available in Bravo et al. (2011).

Some stand-level simulation tools also integrate models for predicting non-wood forest values and therefore dealing with problem S_3. PINEA2 (Calama et al. 2007) includes the prediction of pine nuts yield, while RODAL-ARBOREX (Trasobares and Pukkala 2004; González et al. 2008; Palahí et al. 2009; and www.forecotech.com/), a full DSS at the stand level (selection of objectives, simulation, optimization, sensitivity analysis tools; Table 2) integrates the prediction of mushroom yield and fire risk. Problem S_4, focusing on wood and non-market forest values can be evaluated by RODAL-ARBOREX (fire risk) and GOTILWA+ (Growth of Trees Is Limited by Water; Gracia et al. 1999, www.creaf.uab.es/gotilwa+/). GOTILWA+ is a climate sensitive process-based model that enables simulating alternative management regimes. This tool permits selecting environmental objectives such as stand water use efficiency or fire risk, and nowadays is evolving to the DSS level (the simulation module has been linked to an optimization algorithm, Table 2).

Table 2. CT/DSS, KM techniques and participatory planning methods used/developed for each Forest planning problem types

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
S_1, S_2	RODAL-ARBOREX	Multi-objective (G&Y_M, biomass, CO2, mushrooms, fire risk) stand simulator Selection of objectives, Optimisation (non-linear programming) of stand management	Database, Visualization	-
	GesMO©	G&Y_M, simulation of stand management		-
	PINEA2	G&Y_M, simulation of stand management	-	-
	ALCORNOQUE 1.0	G&Y_M, simulation of stand management	-	-
	PINASTER	G&Y_M, simulation of stand management	-	-
	SILVES	G&Y_M, evaluation of thinnings	-	-
	SAD_DRIADE	Management models based on growth, management costs, economic models	GIS, Database, Visualization	-
	SIMANFOR	Web platform, G&Y_M, simulation of stand management	Database	-
S_3	RODAL-ARBOREX	Same as previous description of the tool	Same as previous	-
	PINEA2	Multi-objective (timber, biomass, CO2, cone production) stand simulator	-	-
S_4	GOTILWA+	Climate sensitive multi-objective (timber, biomass, CO2, water use efficiency, fire risk) simulation-optimisation (Particle Swarm alg.) of stand management	Database, data mining	-
	RODAL-ARBOREX	Same as previous	Same as previous	
L_1, L_2, L_2, L_5, L_6, L_7, L_8	MONTE	Multi-objective stand simulation models (wood products, mushrooms, fire risk, etc.); prescription writer; objectives/preferences selection module; planning module: model writer + optimization tool (including spatial objectives); sensitivity analysis tools	Database, data mining, Visualization tools, thematic maps, interactive dialogs	Multi-attribute utility function in objectives/preferences selection module enables group decision-making
L_4	SILVANET	Multi-objective and group decision-making model, G&Y_M	Visualization and interactive	Group decision-making techniques

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning (if applicable)
			dialogs	
	MONTE	Same as previous	Same as previous	Same as previous
R_1	ESCEN	Reads regional forest inventory sample (e.g. NFI grid); Multi-objective stand simulation models of various goods and services (timber, biomass, CO2, fire risk, diversity, etc.)	Database, Visualization tools	-
	SIMANFOR	Allows simulation of management alternatives using a regional forest inventory sample	Database	-
	SAD_DRIADE	Management models can be applied at the regional level	GIS, Database	-
L_9	Not covered			

As described in section 1, the prevalent landscape level planning problems in Spain encompass variation in terms of temporal scale, spatial context, parties involved and objectives (Table 1). To date, MONTE (Palahí et al. 2004b; www.forecotech.com) is the main tool available for landscape/forest problems (i.e. determine a specific management schedule for each stand in the forest so that a global objective is maximized). MONTE is a forest/landscape-level DSS designed to optimise forest resources and maximise forest owner benefit. MONTE is organized into various subsystems: 1) database management system; 2) multi-objective simulation system (timber, biomass, carbon, fire risk, mushroom yield, fire risk; *All landscape planning problems*); 3) planning system that formulates and solves problems using an optimisation tool (mathematical programming or heuristics; Pukkala 2002); and 4) sensitivity analysis system (visualization of forested landscapes based on the DTM of the forest, tree symbols or Virtual reality modelling). MONTE permits considering spatial objectives (i.e. neighbourhood interrelations: *Problems L_1, L_2, L_5, L_6*), for example the impact of forest management on the habitat of indicator species (Palahí et al. 2004a) or forest fires (González et al. 2005).The system may be adjusted to interpret the spatial context of stands with no neighbourhood interrelations (*L_3, L_4, L_7, L_8*) and also to tactical (*L_5-L_8*) and strategic (*L_1-L_4*) temporal scales.

MONTE can be used for solving problems with one or multiple decision-makers (module with multi- attribute utility function for participatory planning; *L_1, L_4, L_5, L_7*). *Participatory planning* may also be conducted using SILVANET (Martinez Falero et al. 2010). This software can be used for *problem L_4* and provides a tool to aggregate different preferences in order to choose the best management planning. The application requires a LIDAR-based inventory of the stands studied and yield tables. No other CT or DSS allows the integration participatory processes in management planning (Table 2). It is important to remark that to date no *tools are available for addressing Problem L_9* (operational planning landscape-level problems).

Strategic Regional planning (*problem R_1*) can be supported using simulators that project regional forest inventory samples according to optional management alternatives (e.g. NFI). ESCEN (www.forecotech.com/), SIMANFOR, and to some extent SAD_DRIADE (not simulating but assuming a given set of management models) can be used for this purpose. For example ESCEN, that uses multi-objective stand simulation models of various goods and services (timber, biomass, CO_2, fire risk, diversity, etc.), has been used for simulating alternative regional management scenarios in Catalonia. This gives the planner the possibility to analyse the overall development of the forest resource (biomass, carbon sequestration, biodiversity, etc.) and the long-term consequences of policy alternatives.

Although it is not really a tool for forest management planning, but a support tool for soil evaluation and protection, we believe it is relevant to mention the MicroLEIS DSS (http://.evenor-tech.com) here. The system incorporates a set of information tools grouped into the following main modules: i) basic data warehousing, ii) land evaluation modelling, and iii) model application software. Custom applications can be carried out on a wide range of problems related to sustainable use, optimum biomass productivity, minimum environmental vulnerability and maximum CO_2 sequestration (Anaya-Romero et al. 2011). Additionally, climate change scenarios may be considered together with other important global change elements (e.g. land use change, Muñoz et al. 2011; desertification; and agriculture intensification, Shahbazi et al. 2008), in order to develop and implement territorial strategies. MicroLEIS has more than 5,000 users worldwide (although most belong to academia).

Databases, GIS, and in some cases visualization tools (e.g. MONTE DSS), are *Knowledge Management* techniques commonly used in the reviewed support tools. In general, knowledge management doesn't play a central role in the available tools. However, its role is significant in the above described MicroLEIS DSS, and to some extent in MONTE and SAD_DRIADE.

It is of relevance for the purpose of this review report to go through the type of users, development context, and use in practical management problems of the presented support tools. Table 3 shows some of the main results obtained from the questionnaires sent to the main forest management planning experts and DSS developers in the country. In most cases the education of the users is graduate or higher level, although some tools are also used/conceived for users that are not graduates but have a minimum IT knowledge. Many of the tools resulted from research projects during the last 10-15 years (e.g. PhD thesis). In some cases the projects were also related to the public administration, industries, or consulting companies. Consequently, the tools are often used in education and most of the users belong to universities and research centres (followed by the administration and some consulting company). In many cases a rather short training time is assumed (few hours or one day),but some tools may require one week or more. The number of forest management practical applications ranges from 0 to >100. Practical applications seem to be more common in stand-level tools. It seems that users participate often in the development of the tools (at least to a preliminary identification of needs). However, in most occasions the interaction is based on possible modifications of an existing tool rather than collecting guidelines for building a new tool from scratch.

Table 3. Description of the users, development context, and practical application of the presented support tools.

Computerized tool/DSS	Education of users	Organization of users (to date)	Required training time	Number of practical applications	Project origin	Use in education	Participation of users in development
RODAL-ARBOREX	Any, provided min. IT knowledge	Administration, Industry, Consulting company, University/ Res. Centre	1 hour	>50	Research/ Consultancy (2004)	Direct use by students	Tool already existing Needs identification, development, evaluation
GesMO©	Any, provided min. IT knowledge	Administration, Industry, Consulting company, University/ Res. Centre	1 hour	>100	PhD thesis (2003)	Direct use by students	Tool already existing Evaluation phase
PINEA2	Graduate/ Postgraduate	Administration, University/ Res. Centre	1 day	<=10	Administration/PhD thesis (2001)	Demo/direct use by students	Tool already existing Needs identification
GOTILWA+	Graduate/ Postgraduate	University/ Res. Centre	1 week	0	Research (1999)	Demo/direct use by students	Tool already existing
ALCORNOQUE 1.0	Graduate/ Postgraduate	University/ Res. Centre	<= 1 day	0	PhD thesis (2006)	Seminar	Tool already existing Needs identification
SILVES	Graduate/ Postgraduate	Administration University/ Res. Centre	-	<=3	PhD thesis (2001)	-	No
MONTE	Graduate/ Postgraduate	Administration, Consulting company,	1 day	<=10	Research/ Consultancy (2004)	Direct use by students	Tool already existing Needs identification, development,

Computerized tool/DSS	Education of users	Organization of users (to date)	Required training time	Number of practical applications	Project origin	Use in education	Participation of users in development
		University/ Res. Centre					evaluation
SILVANET	Graduate/ Postgraduate	University/ Res. Centre	-	1	Research (2010)	-	-
SAD_DRIADE	Graduate/ Postgraduate	Administration, Industry, Consulting company, University/ Res. Centre	1 day	<=10	Research/ Consultancy (2009)	Direct use by students	Needs identification, design, development, evaluation
SIMANFOR	Graduate/ Postgraduate	University/ Res. Centre	2-3 hours	0	Ministry of science and innovation (2006)	Direct use by students	Needs identification, design, development, evaluation
ESCEN	Graduate/ Postgraduate	Administration, University/ Res. Centre	2-3 hours	<=3	Research/ Consultancy (2004)	Seminar	Tool already existing Needs identification
MicroLEIS	Graduate/ Postgraduate	University/ Res. Centre Administration, Consulting company,	<= 1 week	>100	Research (2009)	Demo/direct use students	Yes, but most belong to academia

23.4 Discussion and conclusions

The regular use of CT and DSS in forest management planning is still limited to a small group of users, most of them working in universities and research institutions. However, some practical use is starting to arise in public administrations and consulting companies. In most cases this relates to stand-level simulation tools, because they are simple (a few hours of training required, Table 3) and close to the basic skills/knowledge from practitioners. However, the transfer of fully developed DSS systems (e.g. landscape-level systems or stand-level simulation-optimization tools) is more challenging. These tools are more complex and rely on modern information technologies which often are unknown by practitioners, especially by those that graduated some years ago.

The survey on computerized tools developed to support forest management planning in Spain revealed the existence of a wide range of tools to support *stand-level planning*. Examples of the increasing relevance of these tools in practice are the use of RODAL-ARBOREX by the Forest Planning Centre for private properties in Catalonia (CPF, Public institution in charge of promoting and regulating forest management planning in private properties of Catalonia), the use of GesMO© by the public administration and industries in Galicia, or the use of PINEA2 by the administration.

The interaction with practitioners in the development of the tools has been identified as a key aspect for promoting practical use. The example of RODAL-ARBOREX illustrates this. Initially a preliminary version of the tool was not very successful in meeting the daily requirements of the planners in CPF. For example, the calculated variables by the tool were not exactly the same as those considered in local management plans, and some dialogs and results tables were not meeting daily work requirements. Consequently, quite intensive interaction was needed to meet the needs of the users. Up to now only the simulation module of the tool has been transferred. Dealing with the solution of an optimization problem, even when proposing an easy-to-use interface, may require longer interaction and training.

If interaction with users is promoted (seems to start taking place in most cases, see Table 3) and training is sufficient we believe that many of the already existing tools for solving problems *S_1*, *S_2*, *S_3* could be successfully transferred to practice. In addition, in the case of recently developed tools, it may be more efficient to interact with the users/stakeholders since the initial design phase of the tool. This seems to be the path adopted by some recently developed tools such as SIMANFOR (Table 3). In the case of problem *S_4* and similarly to the use of optimization tools, the integration of risk (e.g. fire, drought) and climate scenarios in the predictions may require more specific consideration. Even though a process-based tool such as GOTILWA+ already provides good self-explanatory and intuitive interfaces, special emphasis should be placed on both the design of an effective/simple user interface and training. The success of stand-level support tools may also be improved by the integration of multiple objective techniques (i.e. integrating missing models for relevant non-wood and non-market values, adding an explicit dialog for objective selection and ranking) and expert knowledge (expert recommendations displayed as metadata, i.e. knowledge management).

Few tools are available for modern landscape-level strategic and tactical planning (Table 2). Basically only MONTE is a full DSS and has been used in various pilot projects, while SILVANET appears to be a more specific tool for group decision-making. In principle this may look surprising because large variation in forest/landscape management problems (L_1-L_9) has been identified. However there are several reasons for this. For instance, DSS for landscape-level planning are conceptually more complex than stand-level tools, and require more training and knowledge on modern information technologies. This is often hard to achieve with technicians who are used to applying traditional cutting budget methods. In addition, the common high fragmentation of the forest ownership often prevents the use/establishment of a more complex planning approach.

The example of the adaptation of MONTE to various practical problems (public and private forests representative of management *problems L1-L8*) is also illustrative (and also required significant interaction with practitioners). The baseline version of the system, originally developed in a research framework, was attractive (e.g. interactive dialogues, visualization) but difficult to understand/use by the average user. In general some user interfaces were not intuitive enough for beginners and the main steps to follow were not adequately presented. To solve this, several dialogues were simplified and the main steps in planning (i.e. calculation of current state, simulation of alternatives, selection of objectives, optimization, and sensitivity analyses) were clearly introduced along the planning process. The integration of non-wood (mushroom yield) and non-market objectives (fire risk, scenic beauty, biodiversity) as well as the use of thematic maps in problems considering neighbourhood interrelations was also important in the practical adaptation of the tool. Nowadays, the current version of the tool is more accessible and for most users. Nevertheless the required training effort is still a challenge. Until DSS are regularly used in all education centres it is more realistic to expect that in each institution or group one person could learn how to use the tool in detail rather than hoping that most members will reach that level.

The lack of tools for operational management planning (optimizing time/space relationships for harvesting and transportation of products; *problem L_9*) may be explained by the small relative presence of the industry compared to other countries such as Portugal. Still, the application of this type of system could also be useful for the emerging management problems focusing on potential biomass supply for bioenergy plants (perhaps also to the agrosylvopastoral systems “Dehesas”). Therefore the development or adaptation of such tools should be considered in the near future.

Simulating regional scenarios is probably simpler than landscape-level planning. However, very few applications in regional strategic planning have been reported so far. Some initial exercises, for example projecting the NFI grid for a given region, have been developed but the required structure of the tools for this type of management problem is still not clear. To develop the recently promoted strategic regional plans one may need to combine regional simulations (e.g. using ESCEN or SIMANFOR) with analyses at more detailed spatial resolution (landscape or even representative stands). For this purpose using a GIS module and/or a link with Google Earth may supply a good basis for analyses. SAD_DRIADE provides a good example of this approach.

The following points may be of relevance for improving the existing tools and achieving significant transfer to practical use in the coming years:

- Multi-objective (spatial considerations such as fires risk or biodiversity or the development of missing models for non-wood and non-market goods and services) and group decision-making approaches for landscape and regional planning should be developed and integrated in the tools.

- The integration of GIS and visualization technologies (Google Earth) combined with knowledge management (databases on previous periods, expert knowledge) approaches may ease the solution of regional and spatial landscape problems and improve usability and attractiveness of the tools (for the users).

- The use of the tools by and through the administration (i.e. the administration prescribes the use of a given tool/set of tools for developing, for example, regional and landscape-level management plans in a given region) should be strongly promoted.

- Modern planning and information technologies concepts as well as the use of representative CT and DSS tools should become an essential item in the study plans of all universities and education institutions related to forest and natural resources management planning in the country.

Finally, another challenge for forest management and planning in Spain is coping with climate change, especially in a Mediterranean context. In such a context, forest management objectives, decision-making tools and strategies will need to adapt to potential new conditions and new demands for goods and services. There are several ways to respond to this increased uncertainty. The first option is to convert current static periodical planning into a dynamic continuous process which allows updating or re-planning when something makes the plan obsolete (a fire, a change in the management objectives, etc) or no longer justified. Another way to address risk and uncertainty is to accommodate them explicitly in the forestry decision-making process (see González et al. 2005 and GOTILWA+). This can be done by analysing the outcome of different management plans under different scenarios with known or unknown probabilities. Such approach converts deterministic planning into stochastic analysis, providing information about the alternative plans through the probability distributions of the objective variables (Gonzílez et al. 2005). Stochastic planning allows for considering the attitude of decision-makers towards risk and uncertainty.

Adaptive planning is another approach to react to risk and uncertainty. In adaptive planning, decision-makers may adapt their plan according to the changing situations because adaptive planning produces instructions on how to react to different changes; in growth predictions, management objectives, sudden droughts or forest damages from fires, etc. Relevant examples of the development of methods and DSS for copying with climate uncertainty and adaptation are being developed within the framework of the MOTIVE project (Models for Adaptive Management; http://motive-project.net/).

References

Anaya-Romero, M., Muñoz-Rojas, M. and De la Rosa, D. 2011. MicroLEIS DSS, a sustainable land use and management decision support system for maximizing carbon sequestration. European Geosciences Union General Assembly 2011.Vienna (Austria). Geophysical Research Abstracts Vol. 13, EGU2011.

Bertomeu, M., Diaz-Balteiro, L., Gimenez, J.C. 2009. Forest management optimization in Eucalyptus plantations: a goal programming approach. Can. J. For. Res. 39: 356–366.

Bravo, F., Rodríguez, F. and Ordoñez A.C. 2010. SimanFor: sistema de apoyo para la simulación de alternativasde manejo forestal sostenible. Available in www.simanfor.es (last access 15th april 2010). [In Spanish].

Bravo, F.,Alvarez-Gonzalez, J. G., Del Rio, M., Barrio, M., Bonet, J. A., Bravo-Oviedo, A., Calama, R., Castedo-Dorado, F., Crecente-Campo, F., Condes, S., Dieguez-Aranda, U., Gonzalez-Martinez, S. C., Lizarralde, I., Nanos, N., Madrigal, A., Martinez-Millan, F. J., Montero, G., Ordoñez, C., Palahi, M., Pique, M., Rodriguez, F., Rodriguez-Soalleiro, R., Rojo, A., Ruiz-Peinado, R., Sanchez-Gonzalez, M., Trasobares, A., and Vazquez-Pique, J. 2011. Growth and yield models in Spain: historical overview, contemporary examples and perspectives. Forest Systems 20(2): 315-328.

Calama, R., Garriga, E., Bachiller, A., Gordo J., Finat, L. and Montero, G. 2007. PINEA2: un modelointegrado para la gestión de las masas regulares de Pinuspinea L. en la Meseta Norte. Cuadernos SECF 23, 147-152. [In Spanish].

Castedo-Dorado F., 2004. Modelo dinámico de crecimientopara las masas de Pinus radiata D. Don en Galicia.Simulación de alternativas selvícolas con inclusión delriesgo de incendio. Doctoral thesis. Universidad de Santiagode Compostela, Lugo. [In Spanish].

DGCN, Plan Forestal Español, Ministerio de medio Ambiente, Madrid, 2002.

Diaz-Balteiro, L. and Romero, C. 1998. Modelling Timber Harvest SchedulingProblems with Multiple Criteria: An Application in Spain.ForestSci. 44(1): 47-57.

Diaz-Balteiro, L., Romero, C, 2003. Forest management optimisation models when carbon captured is considered: a goal programming approach. For.Ecol.Man. 174, 447–457 pp.

Diaz-Balteiro, L., Rodriguez, L.C.E., 2006. Optimal rotations on Eucalyptus plantations including carbonsequestration - A comparison of results in Brazil and Spain.For.Ecol.Man. 229,247–258.

Diaz-Balteiro, L., Bertomeu, M., Bertomeu, M., 2009a. Optimal harvest scheduling in Eucalyptus plantationsA case study in Galicia (Spain).ForestPolicyEcon. 11, 548-554.

Diaz-Balteiro, L., González-Pachón, J.,Romero, C, 2009b. Forest management with multiple criteria and multiple stakeholders:An application to two public forests in Spain. Scand. J.ForestRes.24: 87-93.

Diéguez-Aranda U., 2004. Modelo dinámico decrecimiento para masas de Pinus sylvestris L. procedentesde plantación en Galicia. Doctoral thesis. Universidad deSantiago de Compostela. [In Spanish].

Diéguez-Aranda U., Diéguez-Aranda, U., Rojo Aboreca, A., Castedo Dorado, F., Álvarez González, J.G., Barrio Anta, M., Crecente-Campo, F., González González, J.M., Pérez-Cruzado, C., Rodríguez Soalleiro R., López-Sánchez, C.A., Balboa Murias, M.A., Gorgoso Varela, J.J., Sánchez Rodríguez F.. 2009. Herramientas selvícolas para la gestión forestal sostenible en Galicia. Consellería do MedioRural, Xunta de Galicia. 268 pp. + CD-Rom. [In Spanish].

Dubourdieu, J., Prieto, A., LópezQuero, M. 1993. Manual de ordenación de montes. Paraninfo. Madrid.

Foresdat, 2009. Asociación Nacional de Empresas Forestales. http://www.foresdat.es/

Gobierno de Cantabria, Consejería de Agricultura, Ganadería y Pesca, 2006. Plan Forestal de Cantabria.

Gómez-Vázquez, I., Álvarez-Álvarez, P., Marey-Pérez, M.Fco. 2009. Conflicts as enhancers or barriers to the management of privately owned common land: A method to analyze the role of conflicts on a regional basis. Forest Policy Econ. 11: 617-627.

González, JR., Palahí, M., Pukkala, T. and Trasobares, A. 2005. Integrating fire risk considerations in forest management planning – a landscape level perspective. Landscape Ecol. 20 (8), 957-970.

González, J.R., Palahí, M., Trasobares, A. and Pukkala, T. 2006. A fire probability model for forest stands in Catalonia (north-east Spain). Ann. For.Sci.63: 169-176

González, J.R., Trasobares, A., Palahí, M. and Pukkala, T, 2007. Predicting stand damage and tree survival in burned forests in Catalonia (North-East Spain).Ann.For. Sci.64: 733-742.

González González, J.M., Castedo-Dorado F.,Diéguez-Aranda U., Rojo Alboreca A., Álvarez González J.G., 2009. GesMO 2009. Simulador decrecimiento y producción de rodales forestales. Universidadde Santiago de Compostela (available at www.usc.es/uxfs).

González Molina, J.M., Piqué, M.,Vericat, P. 2006. Manual de ordenación por rodales. Gestión multifuncional de los espacios forestales. Centre Tecnològic Forestal de Catalunya.

González-Olabarria, J.R. Palahí, M. Pukkala, T. Trasobares, A. 2008 Optimising the management of PinusnigraArn.stands under endogenous risk of fire in Catalonia.InvestigacionAgraria: Sistemas y Recursosforestales.17 (1): 10-1

Gracia C.A., Tello E., Sabaté S. and Bellot J. 1999. GOTILWA: An Integrated Model of Water Dynamics andForest Growth. In Rodà F. et. al. (eds) Ecology of Mediterranean Evergreen Oak Forests. Ecological Studies,Vol. 137. Springer Verlag, Berlin Heidelberg. pp 163-179.

Junta de Andalucía, 2004. Instrucciones Generales para la Ordenación de Montes de la Comunidad Autónoma deAndalucía. ORDEN de 26 de enero de 2004.

Junta de Castilla y Léon, 1999. Instrucciones Generales para la Ordenación de los Montes Arboladosen Castilla y León, DECRETO 104/1999, de 12 de mayo de 1999.

Madrigal Collazo, A. 1995. Ordenación de montesarbolados, ICONA, Madrid, Spain.

Martínez Falero, J.E., Martín Fernández, S., García Abril, A. 2010. SILVANET. Participación pública para la gestión forestal sostenible. Fundación Conde del Valle Salazar, Madrid.

Martínez Sánchez-Palencia, S., Prieto, A., Díaz Balteiro, L., Saura Martínez de Toda, S. 2011. Manual para la redacción de instrumentos de gestión forestal sostenible en Castilla la Mancha. Junta de Comunidades de Castilla la Mancha. Consejería de Agricultura y Medio Ambiente, Toledo.

Muñoz-Rojas, M., Anaya-Romero, M., Zavala, L., Jordan, A., De la Rosa, D.2011. Land Cover change and vegetation carbon stocks in Andalusia region, Southern Spain (1956-2007). Science of the Total Environment. 409, 2796-2806.

Ninyerola M, Pons X, Roure JM 2007a. Objective air temperature mapping forthe Iberian Peninsula using spatial interpolation and GIS.International.Journal of Climatology 27: 1231-1242 DOI: 10.1002/joc.1462.

Ninyerola M, Pons X, Roure JM 2007b. Monthly precipitation mapping of theIberian Peninsula using spatial interpolation tools implemented in aGeographic Information System. Theoretical and AppliedClimatology 89:195-209 DOI (2006) 10.1007/s00704-006-0264-2.

Palahí, M., and Pukkala, T., 2003. Optimising the management of Scots pine (Pinus sylvestris L.) stands in Spain based on individual-tree models. Ann. For. Sci. 60: 105-114.

Palahí, M., Pukkala, T., Pascual, L., Trasobares, A. 2004a. Examining alternative landscape metrics in ecological forest landscape planning: a case for capercaillie in Catalonia. Investigaciones Agrarias: Sist. Recur. For. 13 (3): 527-538.

Palahí, M., Pukkala, T., Pérez, E., Trasobares, A. 2004b.Herramientas de soporte a la decisión en la planificación forestal. Revista forestal MONTES. N-78-IV Trimestre. Page 40.

Palahi, M., Pukkala, T., Bonet, J.A., Colinas, C. Fischer, C.R., Aragón, J.M. 2009 Effect of theInclusion of Mushroom Values on the Optimal Management of Even-Aged Pine Stands of Catalonia. Forest Sci., Volume 55, Number 6: 503-511(9).

Pukkala, T. (ed.). 2002. Multi-objective Forest Planning.Kluwer Academic Publishers.

Río, M., Roig, S., Cañellas, I. and Montero G. 2005. Programación de claras en repoblaciones de Pinus sylvestrisL. Seguimiento de sitios de ensayo en la Comunidadde Madrid. Monografías del INIA: Serie forestal 12, 46pp. [In Spanish].

Rodríguez Soalleiro R., Álvarez González J.G. and Vega G. 1994. Piñeiro do país: modelo dinámicode crecemento de masas regulares de Pinus pinaster Aitonen Galicia (Guía para o usuario do programa PINASTER).Capacitación e Extensión. Serie Manuais Prácticos 8.Consellería de Agricultura, Gandería e Montes, Xunta deGalicia, Santiago de Compostela. 40 pp. [In Galician].

Sánchez-González M., Calama, R., Cañellas I., Montero, G. 2007. Management oriented growthmodels for multifunctional Mediterranean Forests: thecase of Cork Oak (Quercus suber L.). EFI Proceedings 56: 71-84.

SECF Sociedad Española de Ciencias Forestales, 2010. Situación de los Bosques y del Sector Forestal en España. http://www.secforestales.org/web/index.php?option=com_content&task=view&id=58&Itemid=39

Shahbazi; F., De la Rosa, D., Anaya-Romero, M., Jafarzadeh, A., Sarmadian, F., Neyshaboury, M., and Oustan, S. 2008. Land use planning in Ahar area(Iran) using MicroLEIS DSS.International Agrophysics. 22, 3, 277-286.

Trasobares, A. and Pukkala, T. 2004. Optimising the management of uneven-aged Pinus sylvestris L. and Pinus nigra Arn. mixed stands in Catalonia, north-east Spain. Ann. For. Sci. 61 (8): 747-758.

Trasobares, A., Pukkala, T., 2007. Modern tools to support decision-making in forestry. Proceedings of the Ambienta Congress in Zagreb, Croatia, 15th October, 7 pp.

24 The design and use of forest decision support systems in Sweden

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24.1 Introduction

24.1.1 Swedish forest management planning

Sweden is a country rich in forests and large parts of the country are sparsely populated. The forest area according to the traditional Swedish definition – productivity ≥1 m^3 yr^{-1} ha^{-1} – is 23 million ha (55% of land area). As many mires and mountain areas have a productivity below this limit but are covered by trees, the forest area according to international definitions is higher and equals 28 million ha. When relating to total national forest area the Swedish definition is used in the following. The forests are mainly located in the boreal zone but hemi-boreal and temperate vegetation zones are represented in the southernmost part of the country (Ahti et al. 1968). The boreal and hemi boreal zones contain few tree species and are dominated by Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and birch (*Betula sp.*). In the temperate zone deciduous species, mainly beech (*Fagus sylvatica*) and oak (*Quercus robur*) are present. Roughly the history of forests and forestry can be divided according to three regions (Lämås and Fries 1995). In the southernmost part – Götaland, the most densely populated region – a large proportion of the forests were historically converted to arable land and because of intense grazing the forest was fairly open. The forested area was probably at its lowest level by the middle of the 19th century. Reforestation programmes initiated around the turn of that century have over the years created dense forests. In Svealand – the region north of Götaland – the iron industry required large quantities of wood and charcoal until the beginning of the 20th century. To ensure the supply of charcoal and other essential wood products, forest management based on the clear-felling system was introduced in the middle of the 19th century. Because of this forest history, most sites carry their second or even third rotation. As industrialism developed in Europe and large quantities of timber were demanded, a logging frontier moved northwards in an exploitive manner through Norrland, the northernmost and, in area, largest region in Sweden. Initially, partial cuttings to a diameter limit were used. Selective cutting was practiced until the 1940s. In about 1970, lodgepole pine (*Pinus contorta*) was introduced on a large scale and is now growing on 650,000 ha in northern Sweden. Otherwise exotic tree species are used to a very small amount in Sweden. To conclude, Swedish forests are intensively used for timber production and in an international perspective Sweden is a great producer of forest products. In 2005 - 2009 the annual harvested timber volume was 85 million m^3 while the forest growth was 110 million m^3. Moreover, during the last decades forest bio-fuel extraction has expanded heavily.

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Swedish forest policy is based on few regulations and the forest legislation provides freedom for the forest owner on how to manage the forest. The most important parts in the Forestry Act concern regeneration after final felling and minimum rotation periods, but also considerations to environmental and social values. For example, the act states that considerations have to be made to reindeer herding and that consultations between reindeer herders (Sami people) and larger forest owners shall be performed annually. After the last revision of the Forestry Act in 1993 (Swedish Forestry Act 1993) silviculture is less regulated then in the former act partly because of the then prevailing trend in Swedish society towards fewer regulations.

Continuous monitoring of the forest resource through a National Forest Inventory (NFI) has been an important base for forest policy since the 1920s. When revising forest policy, e.g. prepared as Swedish Government Official Reports (e.g. SOU 1992:76), calculations of potential cutting levels or forest impact analyses using data from the NFI are typically performed. The last forest impact analysis was presented in 2008 by the Forest Agency (Swedish Forest Agency 2008) commissioned by the government. Apart from timber, forest bio-fuel and environmental aspects were important parts of the analyses.

On their own initiative, large forest companies regularly perform forest surveys and long-term planning (planning horizon typically on rotation period, i.e. roughly 100 years) in order to secure a sustainable use of the forest resource. In 1980s and 1990s a General Forest Inventory (GFI) was carried out on all private, non-industrial forest land. It was supposed that efficiency of forest production should increase, with a general increase in forestry activities, if detailed knowledge was available on the condition, and silvicultural measures needed (Swedish Forestry Board 1989). It was performed by the Forest Agency and apart from providing general forest information it aimed at producing forest management plans. Due to, amongst other things, high costs and liberalization of governmental control in general, the GFI was stopped by parliament in 1993 and at the same time the compulsory management plan for forest holdings was dropped in the Forestry Act (Lämås and Fries 1995). That is, since 1993 forest management plans are not mandatory. Forest owner associations, the Forest Agency and others now produce forest management plans when commissioned by forest owners. To what extent forest holdings have up-to-date forest management plans is, however, unknown.

Roughly 50% of the forest area is owned by 239,000 non-industrial private owners (average estate forest area 50 ha), 25% by large (forest area > 1 million ha) forest companies and the remaining 25% by public owners. Non-industrial private forest owners (NIPFs) dominate in the south while large companies are more represented in the north. Since forest land productivity is higher in the south this means that although the NIPFs own some 50% of the land they represent a larger share of the production potential and of the harvest. In the south, the average holding is 40-50 ha while it is 100-150 ha in the north. Since an average annual net income from 1 ha could be 160-230 € in the south and maybe 110 € in the north, it is evident that the normal forest owner can´t support a family from forestry income. The income from forestry is normally extra income to supplement income from a normal wage-job, agriculture or other business. It also means that it is rather common among NIPFs to attach other values than timber production to their estate - hunting and other recreation opportunities, nature conservation etc. Approximately 17% of the forest area owned by

NIPFs is certified according to the standards of the Programme for Endorsement of Forest Certification (PEFC), the Forest Stewardship Council (FSC) or some other standard (Lidestav and Berg Lejon 2011). To become certified you have to have a “green management plan”, among other things stipulating that you set aside at least 5% of the forest area for nature conservation. Since this is a long-term commitment this is a way of introducing strategic components in the “tactical” management plan.

Apart from small and medium-sized forest owners there are four large Swedish forest companies each owning more than 1 million ha productive forest land. Two of them (SCA and Holmen) are integrated industrial industries having their own paper and sawmills. Both of these companies consume more round wood than produced on their own land. The third company (Bergvik) has no mills but is closely linked to two industrial companies (Stora Enso and Korsnäs). The last one is state-owned (Sveaskog) and this company is part-owner of some sawmills but no paper mills. The forest-related parts of these companies are organized in a quite similar form, comprising of a forest headquarters and a handful of geographically organized districts. The headquarters is typically responsible for the overall functioning of forest planning systems and is responsible for strategic decisions such as short and long-term harvesting levels, overall design of regeneration methods and nature conservation issues (Eriksson 2008).

As is typical in an international perspective the planning process of Swedish forest owning companies is a three-stage procedure: (i) strategic planning encompasses the entire forest in a long-term perspective and focuses on sustainability and sets the frame for more short-term planning; (ii) tactical planning is concerned with allocating harvest and silvicultural operations to stands in the next few years and where road construction may be an issue; (iii) operational planning schedules specify resources for harvesting and deliveries, often with a timeframe of less than one year (Eriksson 2008).

A central part of planning activities within forest companies is a geographical information system and an integrated stand register. All large companies have their own tailor-made GIS typically with its own designation (e.g. *GISS* at Sveaskog and *SkogsGIS* at SCA). For tactical planning the GIS and stand register is most often used in a manual manner to form harvesting tracts suitable for logging within the next few years. In some cases a certain application in the GIS is available for tactical planning (e.g. *LSP* at SCA) incorporating information enhancing tactical planning such as stand growth information, thinning quotas, and proposed management actions. Otherwise advanced decision support tools including, e.g. optimization procedures, for tactical planning have to date been lacking, but at least one tool is now under introduction (as a module in Heureka PlanWise, see below). The GISs typically used have a number of tailor-made functions for ordering of seedlings, road maintenance and reports on performed silvicutural and harvesting activities, etc. Typically the GIS is more or less integrated with a field application (field computer and software) for operational field planning of operations.

24.1.2 Problem types

As forest is a significant national resource, regional forest analysis is a most important part as a base for policy-making. The notion of regional *analysis* is important as no actual *planning* in a strict sense is performed on this level. There are several stakeholders such as authorities (the Forest Agency, the Energy Agency and the Environmental Protection Agency), organizations (forest owners associations) and forest companies and energy producers. The Swedish forests provide many products and services. Timber and forest fuel are marketed wood products. There are also marketed, or partly marketed, non-wood products, most prominently berries and to some extent mushrooms. These are picked on a commercial basis although the forest owner – based on the Right of Common Access to a land – gets no economical compensation. Services are typically non-marketed (recreation, reindeer grazing, carbon sequestration, etc), although one prominent exception is hunting rights, which is a marketed service. Based on the many resources involved, regional analysis is truly multiple objective. As for example long-run potential harvest levels are of interest, the problem is long-term and typically the timeframe is one rotation, i.e. 100 years. There are some spatial aspects on this level. For estates larger than 50 ha the Forestry Act allows a maximum of 50% of the forest area to be younger than 20 years (the ration rule, the figures applies to estates with forest area 50 – 1,000 ha, for larger estates there are other rules). That is, when simulating harvest in regional analyses the forest state on each forest holding should ideally be known. Moreover, The Forestry Act recommends that the size of clear felling areas should be restricted (greening up constraint, the maximum clear felled area although not specified). If this is to be taken in consideration the problem is spatial with neighbourhood relations (altogether making up **problem type 1**).

Forest-level planning is mainly performed for individual (large or small) forest estates, i.e, a single decision-maker. The aim of planning is to decide – based on the overall goal of the owner – where and when to perform activities (harvests and silviculture). As there are fixed costs for road maintenance etc., it is favourable to yearly or seasonally (due to e.g. snow clearing in winter) concentrate cuttings along a few road systems. Such aspects and also greening up constraints makes the problem spatial with neighbourhood relations. For NIPF owners and small estates there are typically multiple objectives concerning e.g. market wood products such as timber and forest fuel production, market services such as hunting, and non-market services such as recreation, etc. Here, multiple criteria approaches are desirable. Although timber and bio-fuel production typically is the main objective for large and medium-sized forest companies, objectives for nature conservation and environmental objectives are also stated. The problem is typically first stated as a long-term planning problem, concerning strategies for the long-term use of the forest resource (**Problem type 2**). It is then followed by a tactical medium-term spatial problem with neighbourhood relations on forest level with a single decision-maker, multiple objectives and the same goods and services dimensions for scheduling activities on a 10-15 year perspective (**Problem type 3**). Lastly, operational planning on the forest level with spatial neighbourhood relations, a single decision-maker and multiple objectives focused on market wood products follows for scheduling harvest activities, road maintenance etc. on a yearly or seasonal basis (**Problem type 4)**.

On large and medium-sized forest holdings an even flow of income (or timber to industries) is desirable. Thereby, management actions have to be considered on an estate level and, as a consequence of decisions on the forest level, leading to actions taken for each individual stand. This decision approach contrasts to an approach where actions are first decided for each individual stand – based on individual stand analysis or schematic management schedules – and then estate-level actions are simply the aggregate of the management of individual stand. In Sweden the first approach is the typical one. Yet stand-level simulators are used for analyzing stand management approaches, e.g. for analyzing management approaches (e.g. thinning and fertilization programmes) being included in a set of potential management approaches used on forest level planning. Such stand level analyses are basically long-term, that is, the entire rotation period is to be considered, and spatial with no neighbourhood interrelations. There is a single decision-maker and focus is on market wood products such as timber and forest fuel production. Typically the net present value is the single objective for deciding stand management (**Problem type 5**). Also a schematic thinning guide is based on a desirable state at the end of the rotation and a desirable outcome of final felling.

In Sweden, forest-level analysis and planning on forest landscapes not related to specific forest holdings could concern, e.g. forest close to urban areas or analyses of stream water quality in specific watersheds. In such planning multi criteria decision analysis (MCDA) and participatory planning approaches are desirable.

24.1.3 Objectives

The objectives of this country report are to:

- present an overview of decision support systems (DSS) and other computerized tools that have been used to address typical Swedish forest planning problems;
- describe the key features of these DSS and tools;
- draw conclusions about the usefulness of existing tools for addressing the prevalent problem types and needs for further development of tools.

24.2 Materials and methods

24.2.1 Data and information available

Although the Swedish forestry sector is large in an international perspective, the number of actors developing forestry DSS are limited. The Swedish University of Agricultural Sciences (SLU), the Forestry Research Institute of Sweden (Skogforsk) and a handful of consultancies are the main actors. Apart from research and teaching SLU performs a number of environmental monitoring and assessment programmes, e.g. the NFI. SLU is also assigned a certain responsibility in research and development related to the forestry sector and has developed a number of DSS. The most prominent and presently used for long-term planning at large forest companies is the Forest Management Planning Package (FMPP). The newly developed Heureka system is intended for a broad array of users. Skogforsk on the other hand performs research and development within forest to industry timber flow analyses, and short-term planning such as harvest operations and timber transportations logistics.

Any comprehensive compilation of DSS, models and methods used in Sweden is not available at present. Nor is there any official network among developers or users on this topic. Due to the reasons mentioned above SLU – and thereby the authors – have good knowledge on available DSS and contacts with other developers and the users. Therefore, e.g. any inquiry to developers and users has not been used. People responsible for forest management planning at large forest companies were, however, interviewed via telephone.

24.2.2 Analyses and processing

The starting point for the report was the compilation of the general aspects on Swedish forest planning presented in section 1.1 and the subsequent definition of problem types presented in section 1.2. Literature on forest planning, forest legislation and forest certification standards were some of the sources used in these steps. Thereafter, information on Swedish DSS were compiled as outlined in section 2.1.

For the total number of Swedish DSS found, some criteria where used for deciding whether or not a system should be included in the report. Commercially available or tailor-made GIS used at forest companies for handling forest maps and stand register were not included although they – especially the tailor-made ones – may include some functions for decision support. A handful of computerized tools for small-scale forestry management plans were found. These forest management plans typically consist of a digital map, a stand register, a compilation of the initial state on the forest holding and stand management proposals subjectively given by the person (forest officer etc.) who has elaborated the plan. That is, no simulations of a set of potential alternatives are performed and there is no support by optimization procedures. This category of systems was mainly excluded, the most commonly used one, pcSkog, is however reported.

The DSS identified were categorized based on the main problem types identified in section 1.2 that the DSS are used to address. Although a specific DSS was intended for a specific problem type, it was frequently found that it did not meet all problem type dimensions. This mismatch between the problem types and the properties of the DSS and models used to address them will be treated further in the Results and Discussion sections.

Information on a number of Swedish DSS is available on the FORSYS Wiki (the Heureka system and its various software, the Forest Management Planning Package, the Forest Time Machine, and GAYA). The information has been entered prior to and independent of the work on this report.

24.3 Results

The DSS presently used in the Swedish forestry sector are described below. They are presented in the following order: (*i*) regional analysis, (*ii*) forest-level planning and (*iii*) stand-level analysis. A compilation of the DSS described in these sections is presented in Table 1, categorized according to the problem types they are addressing.

Among the DSS described, the ones in the Heureka suite are a unique case as the tools have a common core of models central for growth and yield modelling (Lämås and Eriksson 2003; Heureka 2010; Wikström et al. 2011). Based on this core three main applications (software) are developed. RegWise is developed for long-term large-scale (area) analyses based on e.g. data from the NFI. PlanWise is a tool for long and medium-term planning on small to large forest estates. StandWise is an interactive stand simulator for analyses of management actions and stand development for individual stands. A tool for MCDA analyses, named PlanEval is also included in the suite of tools. These four software are included in the presentations in the following sections. Moreover, a number of supporting software for, e.g. data import, are available in the Heureka suite. Since the Heureka system is recently developed, it has so far been used in a limited number of practical planning situations, for research and in education in Sweden.

Table 1. DSSs presently used in the Swedish forestry sector. They are presented in numerical order according to the problem type they – more or less adequately – address.

Problem type	Computerized tool/DSS	Models and methods	Knowledge management techniques (if applicable)	Methods for participatory planning (if applicable)
1	Hugin (does not address spatial issues or multiple objectives)	Individual tree growth and yield models. Simulation.		
	Heureka RegWise (does not address spatial issues)	Individual tree growth and yield models. Simulation.	Wiki, model database	
	LandSim	Markov-type forest growth model		
2	FMPP (does not address spatial issues or multiple objectives)	Individual tree growth and yield models. Optimization		
	Heureka PlanWise	Individual tree growth and yield models. Optimization	Wiki, model database, GIS-based tool for displaying results	
	BAS/AVB (does not address spatial issues or multiple objectives)	Stand-level growth and yield models. Simulation		
	Gaya (does not address spatial issues)	Area-based growth and yield models		
	Heureka PlanEval	Multicriteria Decision Analysis: AHP and direct point allocation	Wiki	Group decision making feature under development
	pcSkog		GIS-based tool for displaying results	
	The Forest Time Machine	Stand-level models for tree growth, forest operations, economy, biodiversity and nutrient balance. Simulation		
3	VägRust	No projections of forest development. Optimization	GIS-based tool for showing results such as need for repair, transportation flows and timing of cuttings	
4	Heureka PlanWise	Individual tree growth and yield models.	Wiki, model database	

Problem type	Computerized tool/DSS	Models and methods	Knowledge management techniques (if applicable)	Methods for participatory planning (if applicable)
		Optimization		
5	ProdMod	Interactive stand simulator. Plot level growth and yield models		
	DT	Interactive stand simulator. Stand and individual tree growth and yield models.		
	Ingvar	Interactive stand simulator. Individual tree growth and yield models		
	Heureka StandWise	Interactive stand simulator. Stand and single tree growth and yield models	Wiki, model database	

24.3.1 Regional analysis

There is a rather long history in Sweden of building DSS for regional analyses, by which we mean analyses carried out on the scale of nation or sub-regions inside the nation. The analyses focus on issues like long-term harvesting potential, consequences of changed managements strategies such as species choice, rotation periods, and thinning schemes, and are often regarded as a base for forest policy decisions. Although the region analysis is a spatial problem with neighbourhood relations it is in fact treated as a non-spatial problem in most DSS used.

Hugin was developed 30 years ago but is still in active use (Lundström and Söderberg 1996). It is intended for long-term analyses of larger geographical areas such as counties, regions or areas within a specified distance from mills or heating plants. It has been used by forest companies, the Forest Agency, various organizations and researchers. It is developed for making analyses using sample plot data from the Swedish NFI. Analysis is based on simulation controlled by a set of harvesting and silvicutural rules stated by the user. Also, the harvesting level could be stated by the user. Projected harvest levels and forest state is then a consequence of the stated conditions. That is, the system answers “What if” questions. The system is focusing on the production of timber and bio-fuel. (Developer: SLU)

Heureka RegWise is – as its predecessor Hugin – intended for long-term analyses of larger geographical areas such as counties, regions or areas within a specified distance from mills or heating plants (Heureka 2010, www.slu.se/heureka). It is mainly developed for analyses using sample plot data from the Swedish NFI but it has a structure allowing analyses on wall-to-wall data. Simulation is basically controlled in a similar way as Hugin. The system has, however, a broader scope as it also handles other products and values than timber and tree biomass. (Developer: SLU)

The **LandSim** model is a tool for simulating the development of landscape described by wall-to-wall data under different management scenarios (Ola Sallnäs pers. com.). Forest dynamics is modelled by a Markov-type growth model while dynamics of other land-cover classes is user specified. It is mainly used in research and teaching. (Developer: SLU)

24.3.2 Forest-level planning

As stated in the Introduction, forest-level planning is a <u>spatial problem with neighbourhood relations</u>. For several reasons the problem has so far not been treated as such, see the FMPP, which uses a sample of stand as a base for planning. Heureka PlanWise, on the other hand, can be applied on both a sample of stands and all stands. In the latter case, maximum opening size for clear-felling can be considered, that is, a spatial problem with neighbourhood relations.

Forest level planning on arbitrary landscapes, i.e. not related to specific forest holdings, has to date seldom been applied in Sweden. In the future this will probably take place concerning, e.g. forest close to urban areas or analyses of stream water quality in specific watersheds. (c.f. Nordström et al. 2010 and Öhman et al. 2009, respectively). Here, Heureka PlanWise and Heureka PlanEval are potential tools.

24.3.3 Large scale forestry planning

The Forest Management Planning Package (FMPP) brought about a shift in the long-term planning paradigm as it was introduced in the beginning of the 1980s (Jacobsson 1986; Jacobsson and Jonsson 1991) and the system is still used at all large forest companies. A unique idea when introduced was a system comprising the whole chain of data acquisition, calculation of initial state, projections and optimization. The input is forest data acquired by the inventory of a stratified sample stands (the stand register making up the frame, stands selected PPS within strata, area as the size variable) in contrast to former individual plot-based company surveys. The development of the system included software as well as hardware. The first electronic calipers using wireless transmission to field computers and ultrasound distance measurements instruments were developed (Jonsson 1991). Individual growth and yield models are used, implying, amongst other things, a flow of data from calipering trees on the sample plots to projections of stand development. As linear programming (LP) initially was considered too demanding compared to available computer capacity, a special optimization routine and a concept of decreasing marginal utility was instead applied. Later the LP routine developed by Lappi (1996) has been added as an optional solver. Thereby environmental and nature conservation issues, such as the area of old or deciduous rich forest at each time point can be included as restrictions. As planning is based on a sample of stands a weak link in the system is the link to the medium-term planning. (Developer: SLU)

BAS/AV) is a simulation-based system for rough and quick calculation of long-term potential cutting levels (OL Skogsinventering 2005). It uses data from a stand register and consequently area-based growth and yield models. Harvested volumes are not divided in any assortments and economic factors are not included. The stands included in an analysis can be divided into different categories based on different silvicultural treatments, and different management (rotation periods, thinning regimes, etc.) is applied on the different categories. (Developer: OL Skogsinventering AB)

Heureka PlanWise is a versatile tool for long-term planning (Heureka 2010, www.slu.se/heureka). As the other central tools in the Heureka suite, it uses single tree growth and yield models. Like its predecessor FMPP, it can operate on a sample of stands for long-term planning. When using data from a stand register for wall-to-wall analyses a list of trees with a certain tree size distribution is simulated based on the stand mean data in the register. The forest can easily be divided in a number of categories – domains – based on stand data and different management actions can be applied to each domain. Linear and mixed-integer programming problems can be formulated (ZIMPL code) and solved. At present the solvers LP_solve (freeware) and CPLEX are available. The optimization procedures can be used for both long-term and medium-term planning; certain settings for the different planning modes are enabled by the treatment programme generator. Other components are a map viewer for visualization of forest development and management actions and tools for reporting (tables and diagrams). (Developer: SLU)

Heureka PlanEval is a MCDA tool that helps a decision-maker evaluate a set of potential forest plans (Heureka 2010; Korosuo et al. 2011, www.slu.se/heureka).The starting point for PlanEval is to define the decision problem through the construction of an objective or goal hierarchy where an overall goal, criteria and attributes for these criteria are established. In the next step, the alternative plans to be evaluated are defined. A special feature of PlanEval is that plans elaborated with another Heureka application – Heureka PlanWise – can easily be imported for evaluation. Data about plans generated in other ways may be entered manually. Next, the decision-maker states his or her preferences for the criteria of the objective hierarchy and the plans, using one or a combination of the two MCDA methods available in PlanEval, the AHP and direct point allocation. The plans may be evaluated against each attribute using numbers, diagrams or maps to compare the performance of the plans. Finally, the overall and partial results of the evaluation are shown in a table as normalized values. PlanEval was developed mainly for a single decision-maker, but the tool is presently being further developed to include such mechanisms to make it more suitable for group decision-making and participatory planning processes. So far, the tool has been used for research and education in Sweden. (Developer: SLU)

GAYA is a forest simulator describing the forest dynamics according to silvicultural treatments (Nabuurs and Päivinen 1996). The simulations are based on predefined forest treatments and area-based models describing growth, mortality, prices and costs. GAYA is used both for long-term forest management planning at forest level based on information for individual forest stands, and for analyses based on sample plots e.g. from the national forest inventory. It was developed for long-term economic analysis of forest production and is used for research and education in Sweden and Norway. (Developer: SLU)

VägRust handles the short-term scheduling of stands for cutting and the planning of road investments (Frisk and Rönnqvist 2006). Using optimization the system proposes optimal allocation and timing of cuttings in relation to industrial seasonal demand, road seasonal capabilities, and costs for road upgrading. (Developer Skogforsk)

24.3.4 3.2.2 Small scale forestry planning

The small-scale forestry planning problem is typically to establish a sequence of activities for all stands within a forest holding (i.e. a relatively small number of stands). Normally the basic input information is a digital forest map with stand data. In normal cases the planning horizon is 10 years with some strategic components in the form of set-aside areas for nature conservation. A handful of such systems are available in Sweden and one example is presented below.

pcSkog is a commonly used tool to help in scheduling activities on forest estates and to assess the economic outcome of the activities (www.pcskog.se). It includes only a short-term simulation of the dynamics of the stands. At present the forest owners associations are using pcSkog as a platform for their production of forest management plans. (Developer: pcSkog)

The Forest Time Machine is a simulator designed to illustrate the long-term development of a forest area under alternative management programmes (Andersson 2005). It is based on a regular forest map with stand data. Today it is mainly used by the research community. (Developer: SLU)

24.3.5 Stand level

There is a rather strong tradition in Sweden of building empirical growth functions expressing basal area increment as the result of a multiplicative model. More or less all large-scale DSS mentioned above have these kinds of functions embedded to express the dynamics of the forests. Some of these functions are also used in stand-alone applications to generate decision-support for stand-wise management decisions. The results from this kind of application are sometimes summarized in "thinning schedule graphs" or tables. All the simulators presented below are interactive, i.e., the user controls management actions and stand development is projected period-wise (typically five-year periods).

ProdMod is a classical growth model working on plot level (area-based growth model (Ekö 1985)), simulating the development of established forests under specified management schedules (www.skogforsk.se/KunskapDirekt/Alla-Verktyg/ProdMod). The basic increment function is estimated from NFI-plot data. In ProdMod the increment function is combined with static volume functions to yield volume and diameter development. (Developers: SLU and Skogforsk)

DT is a more recently developed stand-alone stand simulator which uses a combination of area-based (Ekö 1985) and single tree growth models (Elfving 2004) to simulate the development of stands from regeneration to final felling. (Developer: SLU)

Ingvar is focused on analyses of thinning programmes. Although data for stands to be analyzed is stand mean data it uses single tree growth and yield functions (Söderberg 1986). That is, a tree list with a certain tree size distribution is simulated. It is specially designed for analyses of thinning programmes. (Developers: SLU and Skogforsk)

Heureka StandWise is the most recently developed interactive stand simulator (Heureka 2010, www.slu.se/heureka). The stand and its trees are visualized in 2D maps and 3D computer drawn pictures. Strip road can be drawn in the 2D map or systematically located in the stand. The effect of management (including even-aged and uneven-aged management, respectively) on stand development, timber and bio-fuel production, economic yield, etc. can be analyzed. (Developer: SLU)

24.4 Discussion and conclusions

The identification of the common Swedish forest planning problem types described in section 1.2 was made independently from the description of the DSS that are used to address these problems. When the inventory of DSS is then compared to the problem types, mismatches between the problem types and the tools used to address them are revealed, such as:

- Regional analysis problems are in reality spatial problems, but have been handled as non-spatial problems in most DSS, such as Hugin and Heureka RegWise.
- Regional analysis problems are characterized by multiple objectives and multiple stakeholders, but until recently the DSS used, Hugin, has mainly handled economical values from a single decision-maker perspective.
- The planning for NIPF has usually been based on a description of the forest state without any options to describe the future development.

These issues and the implications for further development of DSS and computerized tools are discussed below.

In section 1.2 we make a distinction between regional analysis and large-scale forest-level planning. Generally, the former is characterized by a setting with multiple stakeholders, multiple objectives and a long-term perspective while the forest-level planning is linked to a single decision-maker and with an aim to help him or her in deciding when and where to carry out activities. Both regional analysis and forest-level planning are regarded as relevant to the concept of DSS. Hence you can discuss what kind of decisions the different systems are supposed to support.

In the Swedish setting, the term regional analysis is normally used for analysis that forms the basis for strategic, policy-related decisions, e.g. dimensioning of wood-consuming industry or directives concerning lowest allowable final felling age. In addition, consequences of recently introduced features, such as certification schemes, are often analyzed in this context. Normally, these issues are handled by using simulating tools to illustrate, in several dimensions, future development of the forest resource under specified management schemes. In section 1.2, regional analysis was described as being a spatial problem with neighbourhood relations (problem type 1) because of the greening up constraint. However, only one of the DSS listed, LandSim, meet this specific criterion and treat the problem as a spatial problem. The reasons for this are first that the data normally used on this level is plot data from the NFI, which does not contain the information needed, and second, that the use of wall-to-wall data would bring about a large amount of data, making projections and analyses troublesome. The forest-level planning, also on the large scale, often has a different background. Usually, it is an activity carried out by an owner/manager of one specific forest holding, although the holding can be of a size of millions of hectares. The aim of the analysis is to help in deciding what activities to carry out in order to meet a stated objective, for example what kind of harvesting strategy should a company apply in order to guarantee the long-term wood supply to its industry.

In the recently developed Heureka system, a core of common models has been embedded in two different applications which differ in scope and potential use; RegWise is intended to be used in the regional analysis, while PlanWise is focusing on the large-scale management problem in forest-level planning,

Another line of discussion, inherent in the problem type classification, is what kind of processes you want to handle in your DSS. Forest growth is basically a process that can be handled and modelled on plot or stand level, while water, roads, habitats and storms are features that can be parts of landscape-level processes. Since the focus on these types of processes is increasing in policy discussions, they should also be incorporated in relevant DSS. This is a field for further development in Sweden.

Management decision-oriented forest-level planning activities are carried out on the large as well as the small scale. There are existing DSS for the large scale, i.e., tens of thousands of hectares. The FMPP has been in use for 20 years now and the PlanWise application in the Heureka system will probably gradually replace the FMPP. With the Heureka system it will be possible to explicitly model not only economical but also ecological and social values and handle multiple objectives.

To date, there have been no formal DSS for medium-term planning. GIS, more or less tailor-made for individual companies, priority functions and manual methods have been used to prepare sets of potential harvesting areas. PlanWise is the first DSS having certain functions for this planning mode. The treatment programme generator enables certain settings, and the same optimization procedures as for long-term planning can be applied.

However, for forest-level planning on the small scale (tens or hundreds of hectares), DSS are less elaborated. Still, the static forest management plan is the main instrument used in the process. The plan is typically developed out of a regular stand map by assigning treatment proposals to the individual stands. There are basically no dynamic DSS adapted to this category of users. In some cases there is no demand for such elaborated products but on the other hand, also some small-scale forest owners could take advantage of a more sophisticated DSS. There is an ongoing effort to adopt the PlanWise application to the small scale and the specific needs of NIPF owners. One topic that needs to be addressed is the relatively poor forest data available for many estates. Often the quality of the data is low and the correlation to the specifics of the individual stands is poor. Another specific feature of the small-scale forest-level planning is that, through the introduction of goal classification of the stands and certification standards, strategic components are coming into the traditionally rather short-term planning process of small-scale forest owners.

Formalized and documented participatory planning procedures are rare in Sweden and formalized tools are lacking. A few documented examples of participatory processes in forest management planning exist, e.g. the Lycksele project where a number of stakeholders and land owners participated in a process forming a plan for the forest close to Lycksele municipality (Nordström 2010). As mentioned, the Heureka PlanEval software is being further developed to support multiple stakeholder situations in multi-criteria decision analysis.

In northern Sweden reindeer herding is practiced by Sami people on vast areas. Forestry greatly influences the conditions for reindeer herding and large forest owners are obliged perform consultations with the reindeer herders prior to final felling and fellings for road building. In the last decade land-use plans for reindeer husbandry have been developed to facilitate the interaction between forestry and reindeer herding (Sandström et al. 2003). Any formal participatory planning process including such plans and other elements has so far not been established. Furthermore, the development of practical methods and tools that could be used to integrate consideration of the reindeer herding interests early in the forest planning process could contribute to improved dialogue and interaction between forestry and reindeer herding. Such tools would need to be able to address quite complex spatial problems and to take the different planning horizons of the parties into account.

Another potential area for the development of tools for participatory planning is peri-urban forestry. For historical reasons, many Swedish municipalities own forest, which is mostly located in or near urban areas (Lidestav 1989). Most of the municipalities have a green forest management plan of the same kind as private forest owners (Lundquist 2005) and the management plans incorporate recreational values into the planning, but how these values are defined is not clear. In addition, long-term strategies for the forest management are often unclear (Lundquist 2005; Lidestav 1994). Often, municipalities use external contractors to manage their forest (Lundquist 2005). The Swedish Forest Society (Skogssällskapet), a commonly used contractor, has specialized in planning for urban forests and recreation areas and offers a product called "land use plan" or "multiple use plan". These plans have a participatory element, since they are based on interviews with stakeholders. However, this kind of plan is a zoning map rather than a proper forest plan, as it does not contain any predictions of development over time.

Naturally knowledge in different forms is frequently handled within and between organizations. For example, knowledge is transferred between different modes/stages of planning in large organizations such as strategic/long-term to and from tactical/medium-term planning. The use of formal knowledge management procedures and tools seems, however, to be rare. The field of knowledge management within forestry planning research has recently attracted attention. Not only planning tools and methodology *per se* but also the organizational context where they are applied are of interest and recently a research project has been initiated in this field (Nilsson and Eriksson 2010). Serving forestry in a broader context Skogforsk in collaboration with a number of organizations (e.g. the Swedish Forest Agency and forest owner associations) has gathered knowledge on a website "Instant knowledge" (*Kunskap direkt* in Swedish, www.skogforsk.se/sv/KunskapDirekt/). The material is presented in text, instruction videos, or calculation tools. It presents guidelines on, e.g. silviculture (such as selection of proveniences) and nature conservation and cultural remnants considerations. Instruction videos are available on how to operate a chain saw, pre-commercial thinning, but also videos on, e.g. how to increase forest production. It includes a number of calculation tools, e.g. calculation of growing stock based on stand data, economic yield of fertilization, expected root rot frequency, and effects of pre-commercial thinning. Some topics are presented in "packages". One example is aspects on forestry related to water quality which includes rules and regulations, basic information on water and aquatic environments and guidelines on forestry operations.

24.4.1 Conclusions

The Swedish forest DSS and planning tools have been quite successful in addressing forest planning problems from an economical and technical perspective. Some dimensions of the common problem types, like spatial relationships on regional level, have for practical reasons not been handled in most existing DSS. The increasing focus on sustainable forest management will require further development of features for participatory planning, such as possibilities of including different values and multiple stakeholders. The increased focus on ecological and social values will demand, amongst other things, better possibilities for modelling spatial aspects in planning. In addition, there is a need for creating planning tools enabling long-term projections not only for forest companies but also for NIPF owners. Models and methods for handling risk and uncertainty are also needed in the Swedish DSS and planning tools, which so far have mostly adopted a deterministic perspective. Finally, yet another challenge to be handled is that with increasingly complex tools, higher competence and knowledge will be demanded from the users.

References

Ahti, T., Hämet-Ahti, L. and Jalas, J. 1968. Vegetation zones and their sections in nothwestern Europe. Annales Botanici Fennici 5:169-211.

Andersson, M., Dahlin, B. and Mossberg, M. 2005. The Forest Time Machine - A multi-purpose forest management decision-support system. Computers and Electronics in Agriculture 49:114-128

Ekö, P.M. 1985. A growth simulator for Swedish forests, based on data from the national forest survey. Swedish University of Agricultural Sciences, Department of Silviculture, Report 16. 224 p.

Elfving, B. 2004 Grundytetillväxtfunktioner för enskilda träd, baserade på data från Riksskogstaxeringens permanenta provytor. (Single tree increment functions based on Swedish NFI data). Swedish University of Agricultural Sciences, Department of Silviculture.

Eriksson, L.O. 2008. The forest planning system of Swedish forest enterprises: A note on the basic elements. Swedish University of Agricultural Sciences, Department of Forest Resource Management, Report 232. 8p.

Frisk, M. and Rönnqvist, M. 2006. Vägrust – planeringsstöd för prioritering av vägförbättringar. Resultat no. 14. Uppsala, SkogForsk. 4 p.

Heureka 2010. The Heureka Research Programme. Final report for phase 2, October 2005 - September 2009. Swedish University of Agricultural Sciences. 119 p.

Jacobsson, J. 1986. Optimization and data requirements - A forest management planning problem. Swedish University of Agricultural Sciences.

Jacobsson, J. and Jonsson, B. 1991. The forest management planning package. Experience from applications. Swedish University of Agricultural Sciences, Department of Biometry and Forest Management, Report 21. 38 p.

Jonsson, B. 1991. Electronic instruments and computerized devices in forest management planning. Swedish University of Agricultural Sciences, Department of Biometry and Forest Management, Report 23. 20 p.

Korosuo, A., Öhman, K., Wikström, P. and Eriksson, L.O. 2011. An integrated MCDA software application for forest planning: a case study in southwestern Sweden. Mathematical and Computational Forestry och Natural-Resource Sciences 3:75-86.

Kunskap Direkt 2011. Kunskap Direkt. Skogforsk/LRF Skoggsägarna/Skogsstyrelsen, Uppsala, Sweden. www.skogforsk.se/sv/KunskapDirekt/

Lämås, T. and Fries, C. 1995. Emergence of a biodiversity concept in Swedish forest policy. Water, Air, and Soil Pollution 82:57-66.

Lämås, T. and Eriksson, L.O. 2003. Analysis and planning systems for multi-resource, sustainable forestry - The Heureka research programme at SLU. Canadian Journal of Forest Research 33:500-508.

Lappi, J. 1996. Management optimization using JLP linear programming software. In: Päivinen, R., Roihuvuo, L. and Siitonen, M. (eds) Large-scale forestry scenario models: experiences and requirements. Proceedings of an International Seminar and Summer School, Joensuu, Finland, 15-22 June 1995. EFI Proceedings no.5, pp. 175-190.

Lidestav, G. 1989. Kommunägd skog - omfattning och skötsel av primärkommunernas skogsinnehav. Swedish University of Agricultural Sciences, Department of Operational Efficiency, Report 183.

Lidestav, G. 1994. Kommunägd skog - omfattning, användning och planering. Swedish University of Agricultural Sciences, Department of Operational Efficiency.

Lidestav, G. and Berg Lejon, S. 2011. Forest certification as an instrument for improved forest management within small-scale forestry. Small-Scale Forestry 10:1-18.

Lundquist, J. 2005. Kommunägd skog i Sverige - en enkät- och intervjustudie av de tätortsnära skogarnas ekonomiska och sociala värden. Swedish University of Agricultural Sciences, Department of Forest Products, Master thesis no. 47.

Lundström, A. and Söderberg, U. 1996. Outline of the Hugin system for long-term forecasts of timber yields and possible cut. In: Päivinen, R., Roihuvuo, L. and Siitonen, M. (eds.) Large-scale forestry scenario models: experiences and requirements, Joensuu, Finland, 15-22 June, 1995. EFI Proceedings no. 5, pp. 63-78.

Nabuurs G.J. and Päivinen, R. 1996. Large scale forestry scenario models. A compilation and review. European Forest Institute Working Paper No. 10. Joensuu, Finland. 174 p.

Nilsson, M and Eriksson L.O. 2010. How forest knowledge is used in forest planning – a case study. In: Helles, F. and Steen Nielsen, P. (eds.) Proceedings of the Biennial Meeting of the Scandinavian Society of Forest Economics Gilleleje, Denmark, May 2010. Scandinavian Forest Economics No. 43, 2010. pp 34-44.

Nordström, E.-M., Eriksson, L.O. and Öhman, K. 2010. Integrating multiple criteria decision analysis in participatory forest planning: Experience from a case study in northern Sweden. Forest Policy and Economics 12:562-574.

Öhman, K., Seibert, J. and Laudon, H. 2009. An approach for including consideration of stream water dissolved organic carbon in long term forest planning. Ambio 38(7): 387-393.

OL Skogsinventering 2005. BAS/AVB – ett enkelt konsekvensberäknande system. Stencil 2005-01-21. 22 p.

Sandström, P., Pahlén, T.G., Edenius, L., Tømmervik, H., Hagner, O., Hemberg, L., Olsson, H., Baer, K., Stenlund, T., Brandt, L.G. and Egberth, M. 2003. Conflict resolution by participatory management: Remote sensing and GIS as tools for communicating land-use needs for reindeer herding in northern Sweden. Ambio 32: 557-567.

Söderberg, U. 1986. Funktioner för skogliga produktionsprognoser. Tillväxt och formhöjd för enskilda träd av inhemska trädslag i Sverige. (Functions for forecasting of timber yields. Increment and form height for individula trees of native species in Sweden. Swedish University of Agricultural Sciences, Section of Forest Mensuration and Management. 251 p.

SOU 1992:76. Skogspolitiken inför 2000-talet, Allmänna förlaget. Stockholm, 343 p.

Swedish Forestry Board 1989. Översiktlig skogsinventering. Program. Skogsstyrelsen, Jönköping.

Swedish Forest Agency 2008. Skogliga konsekvensanalyser 2008. SKA-VB 08. Skogsstyrelsen Rapport 25.

Swedish Forestry Act 1993. Lag om ändring i skogsvårdslagen (SFS 1979:429), SFS 1993:553, Stockholm, 9 pp.

Swedish University of Agricultural Sciences 2011. Heureka homepage. Swedish University of Agricultural Sciences, Department of Forest Resource Management, Umeå, Sweden. www.slu.se/heureka

Wikström, P., Edenius, L., Elfving, B., Eriksson, L. O., Lämås, T., Sonesson, J., Öhman, K., Wallerman, J., Waller, C. and Klintebäck, F. 2011. The Heureka forestry decision support system: An overview. Mathematical and Computational Forestry och Natural-Resource Sciences 3:87-94.

25 The design and use of forest decision support systems in Switzerland

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25.1 Introduction

Our characterization of the Swiss forestry conditions covers five aspects: (1) natural conditions of the forests, (2) owner structure, (3) institutional framework, (4) silvicultural systems, and (5) operational structures.

Switzerland consists of a heterogenous cultural and political mosaic, e.g. four national language groups, 26 cantons and about 2,500 political communities. About 30% of the total Swiss area (41,000 km²) is covered by forests, whereas agricultural areas have a share of about 37%. We characterize five typical forest regions: the Jura region in the north (~20%), the plateau region between the Lake of Constance and the Lake of Geneva (~20%), the northern slopes of the Alps (~20%), the central Alps (~30%), and the southern slopes of the Alps (~10%). These five areas have specific characteristics in terms of forest cover, standing volume, tree species composition, and forest owner structure (Table 1).

Table 14. General figures of the forest in Switzerland and its five main forest regions (based on Brändli 2010)

	Forest cover (area%)	Stock m^3/ha	Main tree species (vol%)				Public forest (area%)
			Beech	Spruce	Silver fir	Larch	
Jura	41	377	31	29	21	0	75
Central Plateau	25	410	25	34	16	1	59
Northern Slopes of the Alps	35	464	16	53	22	0	51
Alps	26	321	7	59	6	14	76
Southern Slopes of the Alps	52	241	17	29	5	15	80
Switzerland	**31**	**364**	**18**	**44**	**15**	**6**	**71**

The forest ownership structure of Switzerland's forests is characterized as follows: the Swiss Confederation and the 26 cantons own about 5% of the area, the political communities about 29%, private forest owners about 29%, and community allotments about 37% (BAFU 2010). About two thirds of Switzerland's forests therefore belong to a "community forestry" type of ownership and management. The different types of community allotments are historical property rights arrangements, consisting of a clearly defined set of owners, each of which holds a share in the total land use, but no geographically delineated property. The average area for ownerships is 270 ha for public owners and 1.3 ha for private owners, which illustrates the extremely small-scale structure of Swiss forestry.

Switzerland is a Confederation of 26 cantons, each of which has its own constitution, parliament, government and courts. As a consequence, Swiss forest governance consists of the federal level, and a cantonal level. The Confederation's legislation provides only basic principles and guidelines, whereas implementation and operational legal rules are a matter of the canton's legislation. The federal act on forests defines five goals: (1) to conserve the forests in terms of area and spatial distribution, (2) to protect the forests as a close-to-nature ecosystem, (3) to make sure that the forests are providing a set of ecosystem goods and services, particularly protection, welfare, and recreation services, (4) to support and maintain the forest sector, and (5) to ensure that human life and important assets are protected against avalanches, landslides, erosion, and rock fall. The last goal makes an explicit statement that the forest administration is not only responsible for the management of forests, but also for the management of hydrological catchments. This perspective effectively has an impact on the variety of decision support systems that can be found in Switzerland. The 26 cantons are responsible for the implementation of the management policy that conforms to the legal framework of the Confederation, which is implemented with a forest planning system and public authorizations of tree cutting. Cantonal authorities have been developing forest development plans (FDPs) at the regional level, aiming to identify ecosystem goods and services requirements, to solve conflicts of use, and to spatially locate areas that have to provide special ecosystem goods and services. Forest management plans (FMPs) are elaborated at the forest owner's level, aiming to define the owner's strategy, and to define a tactical action plan that complies with the forest development plan and the legal requirements (Bachmann 2005).

Switzerland has its own silvicultural tradition, usually characterized with two specificities; the "single selection system", sometimes referred to as a "plenter system" and the "group selection system", which both may be characterized by structure management silviculture (Kimmins 1997). The group selection system follows three principles. First, the growth and development potential of the individual trees principle aims to foster individual trees with a high development potential. Second, the biological control principle aims to influence stand and tree development over the whole stand lifecycle. Third, the principle of spatial order aims to initiate regeneration in the "transportation watershed" to minimize tree and stand damage (Leibundgut 1949; Schütz 1994; Schütz 1999; Schütz 2002). The first principle, the focus on the site-specific development potential of individual trees, results in specific characteristics of silvicultural techniques. First, there is no fixed rotation cycle time. Second, there is no standard regeneration scheme, and therefore strip, shelterwood and small patch cuts are used in reaction to particular, site-specific regeneration conditions. Third, there is no systematic geometrical pattern for cutting units, because cutting units "follow" silvicultural requirements (Leibundgut 1949). The single-tree system is used for the management of multilayered, uneven-aged stands. The characteristic of this system is that there is only one type of silvicultural intervention, concurrently deploying tending and regeneration measures. However, Switzerland is definitively not a country of uneven-aged management, as usually assumed in foreign countries, because only 17% of the forest area has been classified accordingly (Brändli 2010).

At the operational level there are about 650 forest enterprises owned by forest owners and about 470 contractor enterprises, that are rapidly becoming important. The total number of employees is about 5,700; 3,800 of whom are employed by forest owner enterprises and 2,000 by contractor enterprises. Contractor enterprises are the backbone of forest mechanization and operational innovation, which explains their increasing importance. The annual harvesting level is about 5 million m³, about 45% of which is cut in the plateau region, about 25% on the northern slopes of the Alps, and the remaining 30% in the central and southern Alps and in the Jura region (BAFU 2010; Brändli 2010). Switzerland is a high labour cost country, and the operational conditions are unfavourable due to challenging terrain conditions, patchy ownership structures, and extremely high legal constraints, such as the prohibition of clear-cutting, of herbicide, fungicide and insecticide use.

25.1.1 DSS approach and decision problem types in Switzerland

Kenneth Boulding - a well-known systems scientist - once made a famous statement: "the world moves into the future as a result of decisions, not as a result of plans" (Boulding 1974; Boulding 1975). He stressed that any type of management activity has to start from the decision to be made, and that planning has to result in supporting decision-makers in a way that affects and improves those decisions. The concepts involved in decision support systems emerged in the 1970s under the term "management decision systems" (Sprague and Carlson 1982), which became known as interactive computer systems that help decision-makers solve unstructured problems by providing data and models. However, there was a considerable debate on the essence of the decision support system until Sprague and Carlson published their famous textbook in 1982. Sprague (1993) characterized decision support systems with four attributes: (1) decision-focused, (2) flexible and adaptable, (3) real-time user controlled, and (4) considering personal decision-making preferences of individuals. Later, he specified that decision support systems lie at the intersection of two major evolutionary trends - data processing and management science, which means model-based problem-solving and decision-making (Sprague 1987). The model component has therefore been a key ingredient that makes a significant difference between management information systems and decision support systems.

Following Sprague's first "decision-focused" characteristics, we are looking at decision support systems from the point of view of typical decision problems of forestry (Figure 1). Our framework consists of the decision object dimension (vertical) and the context dimension (horizontal). The decision object dimension identifies typical objects, upon which decisions are made such as the country, the canton / region, the catchment, the enterprise (respectively, the management unit), the cutting unit, the stand, or the tree level. The decision context dimension characterizes classes of activities, such as the spatial assignment of ecosystem products and services (requirements definition), infrastructure development, silvicultural operations (biological production), and harvesting operations (technical production). All in all, we defined 10 decision problem types (Figure 1).

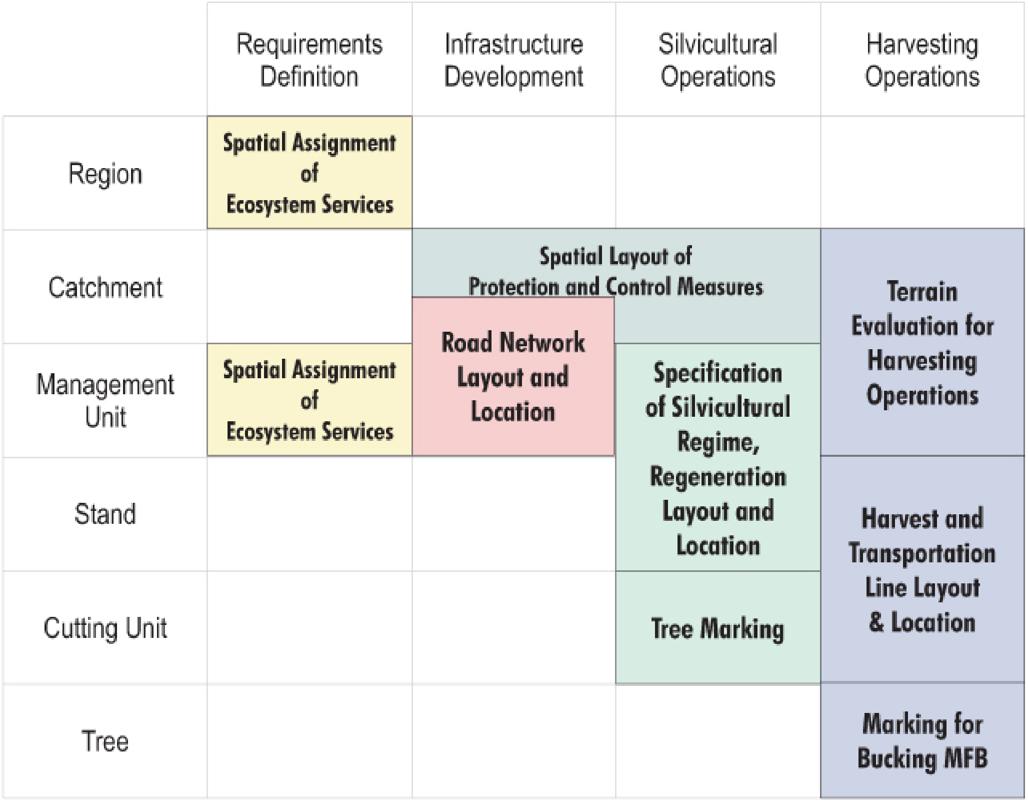

Figure 1. Decision-focused, conceptual framework for decision problems in forest management, consisting of a decision object dimension (vertical), and a decision context dimension (horizontal).

The requirements definition context aims at defining the requirements for a system that can provide the services to users and other stakeholders in a defined environment. A **first decision problem**, the spatial assignment of ecosystem services at a regional level, is a policy process to identify interests, particularly in four domains: use for fibre, use for protection services, use for biological conservation, use for recreation and leisure. The forest development plan is the tool to handle this problem by gathering stakeholder needs and requirements and to transfer those into spatially explicit "forest management requirements". The **second decision problem**, the spatial assignment of ecosystem services at the management unit level, is a strategy process of forest owners to define the portfolio of services that will be provided on the mid-term horizon. This process is part of forest management plan.

The infrastructure development context aims at developing both "ecostructures" and technical infrastructures at the catchment level. A **third decision problem**, the spatial layout of protection and control measures against natural hazards defines the contribution of the forest and the corresponding forest management requirements, as well as the complementary engineering measures outside the forest. This problem is typical for mountain forestry, which has its roots in forestry as "integrated catchment management". After the huge devastation of the forest in the 19th century, forest legislation addresses not only forest management, but also catchment management for erosion, torrent and avalanche control. The **fourth decision problem**, road network layout and location, consists of long-term investments with considerable economic and environmental consequences. It is assumed (Heinimann 1998) that about one third of the total cost of forest production is driven by road network costs.

The silvicultural operations decision context: (**5th**) the specification of silvicultural regimes, (**6th**) the layout and location of regeneration activities, and (**7th**) tree marking.

The harvesting operations context consists of three classes of decision problems: terrain evaluation for harvesting operations, harvest and transportation line layout and location, and marking trees for bucking. In mountainous terrain, the first problem, terrain evaluation (**8th**), looks at delineating terrain units for ground-borne, cable-borne, and airborne harvesting systems. Non-sound delineation of ground-borne terrain results in soil disturbance, erosion, and increased sediment delivery two streams. The second problem, harvesting and transportation line layout (**9th**), is particularly important for cable-borne terrain, because the layout pattern of cable roads affects both the economic efficiency and environmental soundness of harvesting operations. Finally, the third problem, marking trees for bucking (**10th**), has two main objectives, first to maximize the economic value of products, and second, to satisfy customer requirements for the assortment mix fullfilment.

Table 2 characterizes 10 problem types with the 17 COST FORSYS problem dimensions (FORSYS, online).

Table 2. Characterization of the 10 Swiss Problem types with the 17 COST FORSYS problem dimensions.

	Problem types in Switzerland									
Dimensions	1	2	3	4	5	6	7	8	9	10
Temporal scale										
Long term (strategic; > 10 years)	x	x	x	x	x	x	x			
Medium term (tactical; 2-10 years)						x		x	x	
Short term (operational; 1 year)									x	x
Spatial context										
Spatial with neighborhood interrelations			x	x		x			x	
Spatial without neighborhood interrelations	x	x			x			x		
Non spatial							x			x
Spatial Scale										
Stand level						x	x			x
Forest level		x		x	x	x		x	x	
Regional/national level	x		x	x						
Parties involved										
Single decision maker (DM)		x	x	x	x	x	x	x	x	x
More than one DM/stakeholders	x	x								
Objectives										
Single										
Multiple	x	x	x	x	x	x	x	x	x	x
Goods and services										
Market non wood products										
Market wood products	x	x		x	x	x	x	x	x	x
Market services										
Non market services	x	x	x	x	x	x	x	x	x	

The purpose of this paper is twofold: first, to capture decision support systems developed in Switzerland and to classify them according to the 10 Swiss decision problem types (Figure 1, Table 1). Second, to identify innovative aspects to cope with spatial complexity and to improve the efficiency and effectiveness of forest management. Those goals are in line with the memorandum of understanding.

25.2 Materials and methods

Switzerland is a small country, so the research and teaching organizations that have been developing decision-support tools are well known. These are: (1) the Institute of Terrestrial Ecosystems ITES at ETH Zürich, (2) forest management groups at the Swiss Federal Institute for Forest, Snow and Landscape research WSL, and (3) the Swiss College of Agriculture, a unit of the Berne University of applied sciences SHL. Therefore, we identified four people out of the three organizations to jointly work on the present state-of-the-art report, two of which are affiliated to the ETH, and the other two affiliated to WSL and SHL, respectively.

The decision tool survey process was organized in three phases; an intelligence, a refinement and an analysis phase. The first phase, intelligence, aimed at developing a shared understanding on decision support systems, at characterizing the problem types for Switzerland, at identifying decision support tools, and at doing a preliminary assessment of their key characteristics. We came to the conclusion that the term "decision support system", as defined in the literature (Power 2000; Power 2008; Sprague 1987; Sprague 1993) and in the memorandum of understanding (COST 2008), both need some clarification. Therefore, we defined two types of systems. First, we defined decision support systems (DSS) in a narrow sense as tools that are characterized by their focus on a clearly defined decision-making problem and by their "classical" structure, consisting of a database, a model base, and a user interface (Power 2008). Second, we defined management support tools (MST) as tools to support management activities aside from decision-making, such as scenario analysis, alternative assessment, trade-off analysis, etc.

The second phase, refinement, consisted of the compilation of a 600-character abstract and the gathering of structured information, which was stored and processed with a database. Safety attributes are used to characterize the tools and covering domains such as target user groups, availability, software engineering characteristics, etc. (for details see Appendix I).

This third phase, analysis, aimed at classifying the tools and at identifying innovative methods to cope with spatial and temporal complexity, and to improve affectivity and efficiency as outlined in the memorandum of understanding (COST 2008).

Currently, one DSS (WIS.2) is described on the WIKI of the COST FORSYS Action (see http://fp0804.emu.ee/wiki).

25.3 Results

25.3.1 Overview of decision support tools in Switzerland

We identified 18 tools (Table 3, see section 3.2) that support sustainable forest management. Eight are decision support systems (DSS) (Arabic numbers) in the sense that they give advice to decision-makers. Ten are management support tools MST that support scenario analysis and the assessment of alternatives (in Latin letters).

Figure 2 presents those tools arranged in our decision framework. The requirements dimension context is supported by the WIS.2 system on two spatial levels; the regional level, and the management unit level. For the second decision context, infrastructure development, we identified three tools {6, 7, 8} supporting computer-aided road network layout CARoLa, computer-aided control measures layout for natural hazards CACoMLa, and cost benefit analysis for road network alternatives RoNet-KNA. For the third context dimension, silvicultural operations, we identified the WIS.2 system and the CACoMLa tools that we already listed for the requirements context and the infrastructure context respectively. Additionally, there are eight management support tools (Bont 2005), five of which are "scenario-type" {FSBM, ForClim, LandClim, MASSIMO3, SiWaWa}, and three of which are "assessment-type" {PFM, PPW, WVK}. For the fourth context dimension, harvesting operations, we identified four DSS {TerEval, OffREval, CAHaTLa, MFB-Excel} and two MSTs {HeProMo, SORSIM}.

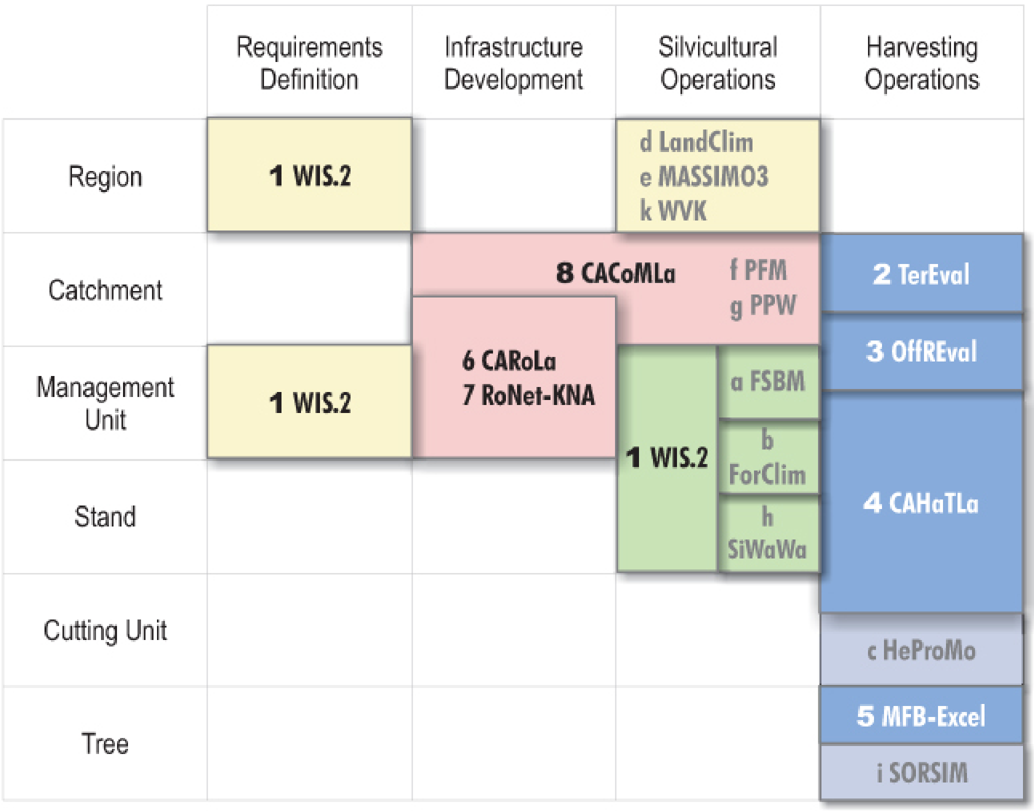

Figure 2. Decision Support Systems and Tools developed in Switzerland. DSS (Arabic numbers) and DST (latin letters) are presented in a two-dimensional framework, consisting

of a decision context dimension (horizontal) and a spatial scale dimension (vertical). Acronyms: see the following sections and Appendix II.

All of the DSS were developed at ETH Zurich; six at the Chair of Land Use Engineering and one at the former Chair of Silviculture. Seven out of the eight resulted from PhD projects, starting with (Lüthy 1998). The eight DSS are briefly described in the following sections; they are numbered, and the numbers are used as references in Figure 2. Appendix II provides a short description of the 10 MSTs, which are numbered in Latin from a to k.

25.3.2 DSS related to the spatial assignment of ecosystem services, the specification of silviculture regime and regeneration layout

WIS.2 is a DSS for monitoring and implementing goal-oriented, sustainable management of forest ecosystems, especially with regard to (1) the integral management of significant spatial and temporal scales in forest ecosystems; (2) the consideration of multiple ecosystem goods and services in silvicultural management; (3) the implementation of silvicultural interventions, following the Swiss silvicultural tradition. It has been using a top-down approach, starting with the entrepreneurial strategy, and ending at short and mid-term interventions at stand level. WIS.2 structures the overall decision process across multiple scales and provides decision support for each decision to be taken by organizing and connecting available data and models. Since the end of the project (Rosset 2005a), more than 10 case studies in management units have been carried out in four different cantons, as well as in Thailand. WIS.2 is currently available as a prototype running on MS Access and ArcGIS View. There are plans to develop a commercial product (for more detailed information c.f. Rosset and Schütz 2003; Rosset 2005b; Rosset et al. 2009a; Rosset et al. 2010). WIS.2 also helps to formalize ecosystem services with silvicultural requirement profiles considering stands (what characteristics to influence?), site and forest road system conditions (location priorities?). These profiles and the spatial assignments thereof represent the interface between the biological production context and the requirements definition context (Figure 1) at either the forest owner or authority level.

25.3.3 DSS related to terrain evaluation for harvesting operations

TerEval - Terrain evaluation for harvesting operations: TerEval addresses the decision problem of how to delineate areas suitable for ground-borne, cable-borne and airborne harvesting operations for a given geographical area. This decision is heavily affecting the economic efficiency and environmental soundness of operations, since many “high impact” logging operations are the result of poor terrain elevation decisions. In the mid-1990s, the forest engineering group at ETH developed a spatial decision support system (SDSS), providing the following capabilities (Lüthy 1998). Firstly, it delineates terrain units suitable for ground-based and for cable-based operations and units that are inaccessible. Secondly, it refines cable-based terrain units for uphill and downhill yarding considering different yarder configurations, particularly in terms of the available length of the skyline. The system was implemented on a UNIX-based ArcInfo, based on terrain evaluation algorithms that were specifically designed for this system. The system reached field prototype maturity and was never operationally used by practitioners. However, the methodology and the algorithms are used for large-scale terrain elevation in the Canton of Schwyz, which was found on a contract basis for the local Forest Service (Meyer 2001).

- **OffREval - Off-Road Trafficability evaluation System:** Trafficability is the capacity of the vehicle to operate in specific terrain conditions. It depends on vehicle configuration, soil properties and slope gradient. The purpose of the trafficability evaluation system is to predict trafficability spatially-explicitly for a given terrain unit for a specific harvesting vehicle. The system consists of three components: first, the spatial database with a digital terrain model and a forest stand map; second, a model base, consisting of mobility models, a soil moisture model, and soil bearing capacity model; third, a user interface to specify the system parameters and to visualize output. The system was implemented on an ArcInfo system with interfaces to some proprietary software components. The system was verified and validated for the research and teaching forest of ETH Zürich, and reached the maturity of the field prototype. Future work could implement such a system and harvesting vehicles to enable the operator to obtain real-time information on trafficability, which would then be an ingredient to improve the environmental soundness of operations tremendously (Eichrodt and Heinimann 2001; Eichrodt and Heinimann 2002; Eichrodt 2003).

25.3.4 DSS related to harvest and transportation line layout and location

- **CAHaTraLa:** The harvesting and transportation layout and location problem addresses the issue of how to explicitly pinpoint the spatial range of off-road transportation lines for different modes of terrain-transportation, for example skid trails, skid roads, and cable roads. A recent decision support system, which is currently under development at the forest engineering group at ETH Zürich, addresses the problem of how to locate cable roads for a given road network and specific forest stand conditions. The system is based on a digital elevation model, representing the terrain conditions, the digital representation of the road network, and a stand map. The problem is represented as a mixed integer problem, and the analysis and the numerical representation was implemented in a Matlab environment with interfaces to both geographical information systems (ArcGIS) and standard solvers (CPLEX). Preliminary results are very promising, providing layout solutions that are more effective, show higher economic efficiency, and concurrently provide an opportunity to consider environmental constraints. **CAHaTraLa** is currently under development (see Bont 2010; Bont 2011a; Bont 2011b).

25.3.5 DSS related to marking for bucking

- **MFB-Excel:** The marking for bucking problem addresses the issue of how to cross cut the stem of a tree to concurrently extract the highest economic value and to satisfy customer needs. In 1985, Mikael Näsberg presented his thesis "mathematical programming models for optimal log bucking", which provides the algorithms that are nowadays implemented in bucking computers on harvesters. However, they are only optimizing for value and customer satisfaction, while production costs are neglected. An Excel-based decision support tool (MFB-Excel) was developed at the forest engineering group at ETH

Zürich, optimizing for profit contribution in terms of sales revenue minus harvesting cost. The tool provides taper functions for different tree species, representing the geometric properties of single stems. It can be used to explore optimal bucking strategies for specific sales revenues of assortments and harvesting methods. It is also useful to evaluate and improve bucking decisions made by rules of thumb. Comparison of rules of thumb-based bucking and optimal parking demonstrated that the profit contribution could be significantly improved by this easy-to-use decision support tool (see Bont 2005).

25.3.6 DSS related to road network layout and location

☐ **CARoLa - Computer-aided road network Layout:** Road network layout and location has been a challenging engineering problem that has been solved for a long time by rules of thumb. In the late 1990s, computer-aided approaches were developed to do this work automatically or at least semi-automatically. However, some of the underlying assumptions, such as constant construction cost for the overall geographic area, were far from reality. The purpose of the road network layout system is used to develop a spatially explicit construction cost model that represents spatial variability, and to develop and implement a spatially broad network layout procedure. The key challenge was to design a representation of all feasible road links, considering turning and slope constraints. The problem was solved as a Steiner tree problem for the objective function that consists of cost and an environmental impact component. The system was implemented as a standalone application with interfaces to standard GIS systems. The system always outperformed expert solutions significantly and has been used for exemplary role, mainly in work planning problems in mountainous terrains of the Alps (Stückelberger et al. 2004; Stückelberger 2007; Stückelberger et al. 2006a; Stückelberger et al. 2006b; Stückelberger et al. 2007).

☐ **RoNet-KNA - Cost-Benefit Analysis for Road Network Alternatives:** Investments in road networks require huge financial means and have long-term consequences. The problem, how to do cost-benefit analysis CBA for a specific road network alternative, is a challenging task to the dynamics of both costs and benefits. The purpose of the CBA project was to provide an Excel tool that calculates harvesting benefits based on harvesting productivity models and gives annuities for both costs and benefits. The system was implemented in Excel and consists of two major components: first, a user interface to specify the system parameters and to present the output; second, a model base consisting of productivity models for (1) ground-borne skidding, (2) cable-borne mobile tower yarding, and (3) cable-borne long-distance sledge yarding. The system compares a planned road network alternative with the status quo, and presents cost-benefit ratios for both, the enterprise-level, considering subsidies, and the level of public administration without subsidies. In most areas of Switzerland road networks are well-developed, and for the expansion of road networks extremely limited due to environmental constraints. This is the reason why the tool has recently not been used (Pillet and Heinimann 1998).

25.3.7 DSS related to spatial layout of protection and control measures

❽ **CACoMLa Computer-aided Control Measures Layout for Natural Hazards**: Watershed management in densely populated alpine areas aims at minimizing erosion, mass movement, rock fall, flooding and avalanche risks. Up to now, the spatial layout and design of protection measures has been following rules of thumb, whereas computer-aided layout and design tools were not available. The purpose of the automatic control measures layout project was to solve the problem of how to concurrently locate both reforestation project areas and retention dams to reduce peak flow runoff volume to a targeted threshold. The system is based on a distributed hydrological model that imitates the response of the watershed system to land-use change. The system consists of a Matlab component with interfaces to ESRI's ArcGIS and to the CPLEX solver, based on a mixed-integer problem formulation. The performance of the system was evaluated for small watershed in the Swiss Alps and outperformed expert solutions in terms of understanding trade-offs between retention dam and reforestation measures (Breschan 2011).

25.3.8 Decision support tools and decision problem types in Switzerland

Table 3 presents the 10 problem types for Switzerland and the tools they are related to, as well as information about models and methods, knowledge management techniques, and methods for participatory planning integrated in these tools.

Table 3. Decision support tools used/developed for each decision problem type

Problem Type	DSS/MST	Models and Methods	Knowledge Management techniques	Methods for participatory planning
1,2	WIS.2	silvicultural requirement profiles analysis	database, GIS	-
3	CACoMLA	automatic control measures layout	GIS, fuzzy logic, MILP Optimization (CPLEX)	-
4	CARoLa	spatially explicit construction cost model; Steiner tree problem (objectives: cost and environment impact)	database, GIS, MILP Optimization CPLEX, Graph Theory	-
	RoNet-KNA	harvesting productivity models, Cost-Benefit Analysis (CBA)	-	-
5	WIS.2	overall decision system model for the biological production system at forest level (management unit), simple growth and yield model, forest simulation model	database, GIS	-
	FBSM	growth and yield model (single-tree distance-independent model), harvesting productivity models, model for biologic and meteorological disturbance	-	-
	WVK	FBSM, HeProMo, SORSIM	database, GIS	
	PFM	Stand dynamics, disturbances, silvicultural operations, hazards risks and management costs models; cost-benefit analysis; Markov chain approach:	-	-

Problem Type	DSS/MST	Models and Methods	Knowledge Management techniques	Methods for participatory planning
	PPW	cost model of management restrictions based on potable water protection area	-	-
~6	WIS.2	simple growth model, steep edge model	database, GIS	-
7	SiWaWa	stand growth model (distance-independent)	-	-
8	TerEval	terrain evaluation algorithm for ground-based and cable-based harvesting operations	GIS, Rule-based reasoning	-
	OffREval	trafficability model based on mobility, soil moisture, and soil bearing capacity model;	GIS	-
~9	CAHaTraLa	Mixed integer problem to locate cable roads for a given road network and specific forest stand conditions	GIS, MILP Optimization	-
10	MFB-Excel	marking for bucking problem: optimization algorithm for profit contribution in terms of sales revenue minus harvesting cost	MILP Optimization	-
	HeProMo	harvesting productivity models	-	-
	SORSIM	bucking to alternative timber assortment		
~7, but at national level and non-spatial	MASSIMO3	Empirical stochastic simulation model	-	-
~5, but-non spatial	FORCLIM	gap model (establishment, growth, mortality)	-	-
~7, but very large landscape	LANDCLIM	forest growth simulation + impact of fire/wind disturbance, and forest management on forest dynamics; based on LANDIS model	GIS	-

All problem types are covered by at least one tool. None of the tools integrate knowledge management techniques except database management systems and GIS, and none of them support participatory planning.

25.3.9 Decision support tools and the COST FORSYS Problem Dimensions

Figure 3a depicts the location of our 18 tools in the 16-dimensional characteristics space (FORSYS, online), projected on the first two principle components, resulting from principal component analysis. The COST FORSYS problem characterization consists of 17 criteria, one of which is non-relevant, because all Swiss problem types have a single value only (multiple objectives). Figure 3a shows that the 10 decision problem types for Switzerland mainly cluster into three groups. The first group, consisting of Problem Types Number 2 to 5 represents long-term, spatially explicit decisions at forest or regional/national level. Problem Type Number 1 has similar characteristics with this group, although it differs in the sense that it is meant for multiple decision-makers. The second group, consisting of Problem Types Number 6, 8 and 9 represents spatially explicit, tactical decisions at the management unit level. The third group, consisting of Problem Types Number 7 and 10, represents non-spatially explicit decisions at stand level.

Figure 3b illustrates how the Swiss DSS and MSTs relate to the 10 Swiss problem types.

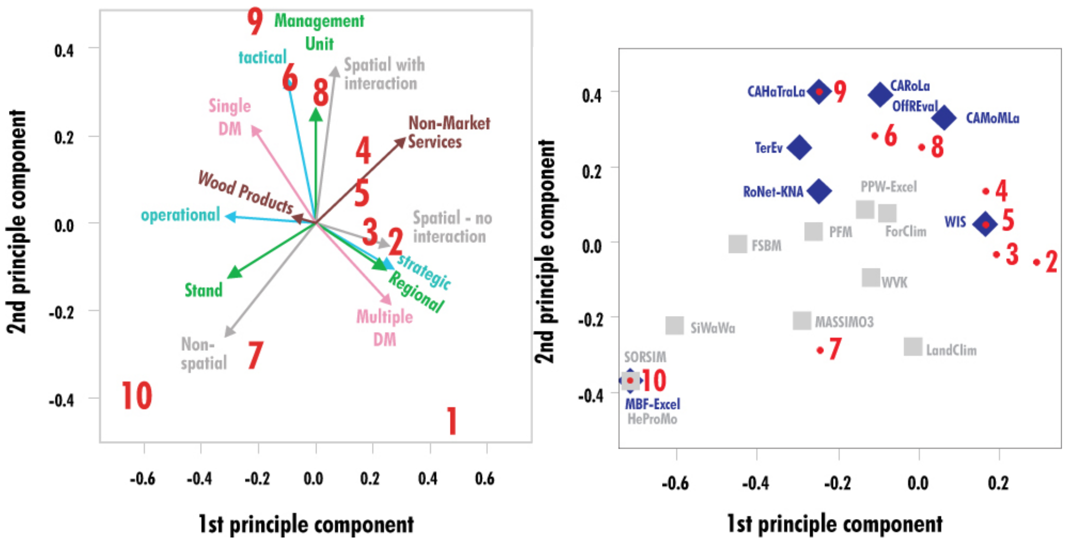

Figure 3.
a) COST FORSYS Problem Types, projected on the two first principle components. Arrows represent the 13 decisive COST FORSYS problem dimensions; Arabic numbers represent the 10 Swiss decision problems.
b) Swiss Decision Support Systems and Tools, projected on the two first principle components. Arabic numbers represent the 10 Swiss problem types, Rhomboids the 8 DSS, and squares the 10 MST.

We can identify four clusters of tools (Figure 3b). A first cluster groups around Problem Types {6, 8, 9} and consists of tools that support harvesting operations {TerEval, OffREval, CAHATLa} in the infrastructure development context {CARoLa, RoNet-KNA, CAMoMoLa}. A second cluster is located around problem types {2-5} with WIS.2 as an important tool, which has its emphasis on biological production. A third cluster exactly matches with Problem Type {10} with three tools {HeProMo, MBF-Excel, SORSIM}. A fourth cluster is located between Problem Types {5, 6, 8} and {10}, embodying eight management support tools, {SiWaWa, MASSIMO3, LandClim, WVK, FBSM, PFM, ForClim, PRW-Excel}. The projection of the DSS and MSTs on the first two principle components clearly demonstrates, that it is difficult to propose a system of problem types that matches with real-world applications, and that there is a continuum between the COST FORSYS problem dimensions.

25.3.10 Target user groups, accessibility, use and development context of the tools

The results from the database provide a general overview of the 18 tools with regard to the target user groups of the tools, their accessibility, their utilisation and the development context.

25.3.11 Target user groups

About two-thirds of the tools support decisions of forest experts, while about half of the tools address forest guards. Two tools are meant for researchers and one for the wood industry. The main target user organization type is the forest service at cantonal level with

14 tools (among which four are DSS), the second the forest enterprise with 12 tools (among which three are DSS), the third the forest authority at national level with seven tools. Forest contractors also belong to the target user organization type.

25.3.12 Accessibility

Almost two-thirds of the tools (11/18) are free of charge or cost less than 100€, and are easy to install on a standard computer (considering the target user group); two DSS belong to this category. Otherwise, the costs range from less than 1,000€ (one DSS) to more than 10,000€ (one DSS and one DST). Three DSS Tools are not accessible (in development, or based on outdated technology).

The training time for a normal user of the target group for four tools is equal to or less than one hour (one DSS), for three tools equal to or less than one day (one DSS), for three other tools equal to or less than one week (two DSS), for three tools equal to or less than one month (no DSS), and for two tools more than one month (no DSS).

There is no organization that feels responsible for the maintenance of about one-third of the tools (7/18); for one sixth no support is provided (3/18). The ETH, WSL and SHL maintain or respectively provide support for three to seven tools. Support is provided in five cases by two people, otherwise by one person. Two of the six DSS are neither maintained nor supported. People are available for the support of only one DSS.

25.3.13 Utilization

Since 2008, half of the tools (10/18) were used by practitioners to support forest management (among which only one is a DSS). A quarter (6/18) was used in up to 10 real-life problems, two tools in up to 30 and one tool in up to 100 real-life problems. Students have had the opportunity to discover six tools (demo) and work with six other tools (both times with two DSS) during their courses (ETH, SHL). More than half of the tools (10/18) were used in education during the past two years, of which three are DSS. Seven tools were used in research and development projects - one is a DSS.

25.3.14 Development context and activities

Half of the tools (10/18) are extensions of standard software (among which six are DSS) and seven tools are stand-alone desktop applications (one DSS). In only one case, there is a client-server architecture (one case is not known).

Windows is the operating platform for most of the tools (13, among which five are DSS) and UNIX for three of them (among which two are DSS). Two tools can be operated on multiple platforms. VBA was the most commonly used programming language for five tools. Other programming languages are (used in less than three tools): AML (ARC Macro Language), Visual Basic, Modula2, C++ and Borland Delphi.

About 40% of the tools (eight) integrate a GIS and all DSS do so as well, with one exception. All GIS products are proprietary ESRI software. Four tools incorporate a relational database such as MS Access (two), Oracle (one) or SQL Server (one). In six cases, optimisation algorithms were implemented (three DSS). No MCDM techniques were integrated. None of the tools integrate knowledge management techniques except database management systems.

Software Engineering techniques were used for five tools, among which one is a DSS (references mentioned are Appleman 1999; Pree 1997; Szyperski 1998; Steinweg 2000; Schönsleben 2001; Specker 2001)

About 40% of the tools were developed by a single person. This is the case for 100% of the DSS. In the rest of the cases, two to four people developed the tools (i.e. with an involvement of larger than 10% in the project). Stakeholders were mainly involved in the test phase for less than half of the tools. In three cases, stakeholders were involved in the requirement phase (none of which was a DSS), as well as in the design phase. In one case this occurred in the construction phase (one DSS), in seven cases during the test phase (one DSS), and in five cases during the new development phase (of which one was a DSS). Almost half of the tools (8/18) were updated since 2008 (of which two are DSS). Only one tool was updated for the last time prior to 2000. Three tools are currently in development (among which two are DSS).

25.4 Discussion and conclusions

The purpose of this report was, first, to determine typical problem types for Switzerland, to capture decisions and management support tools (DSS, MST) developed in Switzerland and classify them with a generic framework, and second, to identify innovative aspects to cope with the spatial complexity and improve the efficiency and effectiveness of forestry. Our investigation resulted in four major findings: first, we identified 18 tools, which cover all Swiss problem types defined in section 1, except decision-making in a multiple-stakeholder context. Second, eight out of 18 tools are systems that give direct advice to decision-makers, while 10 tools (management support tools, MST) support other management functions, such as scenario analysis and assessment of alternatives. Third, eight tools provide innovative functionality, particularly "knowledge components" or components to identify spatially explicit solutions for complex problems. Systems (1WIS.2, 2 TerEval, 3OffREval, 4 CAHaTLa, 6 CARoLa, 8 CACoMLa} were designed to manage spatial complexity, which means that they give advice in terms of spatially explicit solutions. Tools (3 OffREval, 4 CAHaTLa, 5 MFB-Excel, 6 CARoLa, 8 CACoMLa) are clearly knowledge-driven, providing optimal or at least near-optimal solutions by using mathematical optimization techniques. They also significantly improve the effectiveness and efficiency of solutions compared to expert solutions. The automatic road network layout tool's performance is at least 20% better (Stückelberger 2007) than any expert solution. This is also true for the marking for bucking tool (Bont 2005). Fourth, most of the tools only have reached "field prototype" maturity, whereas standard releases, designed for end-users, are still missing (with two exceptions: HeProMo and FBSM).

The first result, the identification of decision support tools and their contribution to solving the Swiss problem types, demonstrates that our proposed framework (problem object and problem context) helps to refine the classification of the tools based on the FORSYS problem dimensions (see example of WIS.2 and Problem Types 2-5 in section 3.3). There is an ongoing debate in the literature (Power 2000; Power 2008; Sprague 1987) on classification systems that map the variety of real-world systems. We are convinced that a combination of problem orientation (e.g. our two proposed dimensions) with five generic classes (Power 2008), communications-driven, data-driven, document-driven, knowledge-driven and model-driven, is a promising approach in developing a shared understanding of the variety of decision support tools used in forestry.

The second finding illustrates that the term decision support system is not unique, because systems are supporting different management functions. The generic meaning of DSS is that it has to be decision-oriented (Sprague and Carlson 1982), clearly supporting the decision-making function. This function itself can be split into an intelligence, design and choice phase (Simon 1999), and some of the most recent spatial decision support systems (SDSS) have been focusing on the design function (1 WIS.2, 4 CAHaTLa, 6 CARoLa, 8 CACoMLa). The set of tools that we identified are supporting other management functions, too, among which "scenario analysis" and "alternative assessment" are the most important ones.

The third finding, innovative functional aspects, demonstrates that five tools (3 OffREval, 4 CAHaTLa, 5 MFB-Excel, 7 CARoLa, 8 CACoMLa) are "knowledge-driven". In this sense, knowledge means "expertise", consisting of three aspects, (1) factual knowledge about a particular domain, (2) understanding the problems within this domain, and (3) skills to solve some of those problems (Power 2000). The key ingredient for understanding is to find an appropriate quantitative framework to represent the problem space, whereas the key ingredient for problem solving consists of a set problem-solving techniques. Spatially explicit problem formulations additionally require the representation of neighbourhood relationships between spatial entities.

The field of decision support systems in Swiss forestry is looking back on only about 15 years, and is still emerging. The most sophisticated tools are outcomes of PhD projects that are mainly aiming to develop new functionality and to prove the feasibility of new concepts. Therefore, the last mile to transfer tools from development into operational use has been missing for most of the time. Models of systems engineering provide lifecycle frameworks, defining a transition process to transfer custody of the system and the responsibility from the development team to the organization that is subsequently operating the system (Krueger et al. 2010). The successful conclusion of this process typically defines the beginning of the utilization stage. Traditionally, the public Forest Service was responsible for the development of methods and tools. In the last decade, many functions were outsourced to consultancy and contractor firms, and so it is not clear who "problem owners" are; which is particularly true for Switzerland with its federal system with 26 cantons. Additionally, the commercial interest to make prototypes mature for end-users has been marginal.

It is interesting to see that almost no tool supports public involvement and participatory decision-making. One reason for this is that about two-thirds of Swiss forests are managed as "community forests", with underlying democratic processes that have been in place for many years. Our view is that the rationale of public involvement is still not well understood yet, and that the functions of a "critical pragmatism" have yet to be further explored (see for example Forester 1989).

Finally, our investigation demonstrated that a broad set of tools is available, but that a major problem exists in transferring the tools from development to operational use. To overcome this gap, the transfer process should focus on decision-makers, people confronted directly with the decisions to be made. At the operational level, this means addressing both forest contractors and forest managers, while on the tactical and strategic level forest owners and district forest officers are the main group of interest. This dialogue will be essential to develop training programmes for already available tools and to gather user expectations and needs for future development.

References

Appleman, D. 1999. Dan Appleman's Visual Basic Programmer's Guide to the Win32 API, Publisher Macmillan Publishing Co., Inc. Indianapolis, IN, USA ©1999, 1500 p.

Bachmann, P. 2005. Forstliche Planung - heute und morgen. Schweizerische Zeitschrift für Forstwesen 156(5): 137-141.

BAFU (ed.) 2010. Jahrbuch Wald und Holz 2010. Bundesamt für Umwelt, Bern, Umweltzustand nr. 1025. 192 p.

Blattert, C. and Bürgi, A. 2011. Trinkwasserschutz-Tool -Berechnung von Mehraufwand und Minderertrag infolge des Trinkwasserschutzes im Wald. Schlussbericht ca. 80 S. Birmensdorf (in Vorbereitung).

Bont, L. 2005. Kundenorientierte Optimierung der Sortiments-Aushaltung bei der Holzernte unter besonderer Berücksichtigung des Energieholz. Diplomarbeit. Professur für Forstliches Ingenieurwesen, Eidgenössische Technische Hochschule Zürich, Zürich. 205 p.

Bont, L. 2010. A solution of the cable corridor layout problem for harvesting under steep slope conditions. 24th European Conference on Operational Research, Lisbon. July 11-14, 2010.

Bont, L. 2011a. Concurrent layout optimization of truck roads and cable corridors for timber extraction under steep slope conditions. 14th Sympsium for Systems Analysis in Forest Resources, SSAFR, Reñace, Chile. 8 - 11 March, 2011.

Bont, L. 2011b. Optimal geometric layout of a single cable road. Paper submitted to European Journal of Forest Research.

Boulding, K.E. 1974. Reflections on planning: The value of uncertainty. Technology Review, (Oct/Nov): 8.

Boulding, K.E. 1975. Reflections on planning: The value of uncertainty. Strategy & Leadership. 3 (2): 11-12.

Brändli, U.-B. (ed.), 2010. Schweizerisches Landesforstinventar. Ergebnisse der dritten Erhebung 2004-2006. Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft WSL, Birmensdof, Bundesamt für Umwelt BAFU, Bern. 312 p.

Brang, P. and Hallenbarter, D. 2007. Bewertung von Handlungsstrategien in Schutzwäldern: Ein integraler Modellansatz. Schweizerische Zeitschrift für Forstwesen 158(6):176-193.

Breschan, J.H. 2011. Automatic design of cost-effective control measures to mitigate flooding hazard in small watersheds. PhD thesis nr. 19463. Professur für Forstliches Ingenieurwesen, Eidgenössische Technische Hochschule Zürich, Zürich. 109 p.

Bugmann, H. 1996. A simplified forest model to study species composition along climate gradients. Ecology 77:2055-2074.

Bugmann, H. and Solomon, A. M. 2000. Explaining forest composition and biomass across multiple biogeographical regions. Ecological Applications 10: 95-114.

Bugmann, H. 2001. A comparative analysis of forest dynamics in the Swiss Alps and the Colorado Front Range. Forest Ecology and Management 145:43-55.

COST 2008. Memorandum of Understanding for the implementation of a European Concerted Research Action designated as Cost Action FP0804: Forest management decision support systems - FORSYS. http://fp0804.emu.ee/fp0804_mou.pdf

Didion, M., Kupferschmid, A., Zingg, A., Fahse, L. and Bugmann, H. 2009. Gaining local accuracy while not losing generality: Extending the range of gap model applications. Canadian Journal of Forest Research 39:1092-1107.

Eichrodt, A. and Heinimann H.R. 2001. Mobility of Timber Harvesting Vehicles. In: Wang, J., Wolford, M. and McNeel, J.(eds.). Conference Proceedings of the 2001 Council on Forest Engineering (COFE): “Appalachian Hardwoods: Managing Change”. West Virginia University, Division of Forestry, USA. 6 p.

Eichrodt, A. and Heinimann H.R. 2002. Modeling spatial variability of forest vehicle trafficability. In: Yoshimura, T. (ed.). Proceedings of the International Seminar on New Roles of Plantation Forestry Requiring Appropriate Tending and Harvesting Operations. The Japan Forest Engineering Society, Tokyo, Japan. Pp. 232-241.

Eichrodt, A.W. 2003. Development of a spatial trafficability evaluation system. vdf Hochschulverlag AG, Zürich, Switzerland. 165 p.

Erni, V. and Lemm, R. 1995. Ein Simulationsmodell für den Forstbetrieb: Entwurf, Realisierung und Anwendung. Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft WSL, Birmensdorf. Berichte der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft nr. 341. 89 p.

Forester, J., 1989. Planning in the Face of Power. University of California Press, Berkeley, California, USA. 283 p.

FORSYS. online. Guidelines for the Country Report. http://fp0804.emu.ee/wiki/index.php/Guidelines

Frutig, F., Thees, O. and Kostadinov, F. 2009. Holzernteproduktivitätsmodelle HeProMo: Konzeption, Realisierung, Nutzung und Weiterentwicklung. In: Thees, O. and Lemm, R. (eds.). Management zukunftsfähige Waldnutzung: Grundlagen, Methoden und Instrumente. vdf Hochschulverlag AG, Zürich, Switzerland. Pp. 441-466.

Heinimann, H.R. 1998. A computer model to differentiate skidder and cable-yarder based road network concepts on steep slopes. Journal of Forest Research (Japan). 3 (1): 1-9.

Kaufmann, E. 2001. Prognosis and Management Scenarios. In: Brassel, P. and Lischke, H. (eds) Swiss National Forest Inventory: Methods and Models of the Second Assessment. Birmensdorf, Swiss Federal Research Institute WSL. Pp. 197-206.

Kimmins, J.P. 1997. Forest ecology: a foundation for sustainable management, 2nd Ed., Prentice-Hall Inc. 611 p.

Krueger, M., Walden, D. and Hamelin, R.D. 2010. Systems Engineering Handbook (v3.2), International Council on Systems Engineering. 374 p.

Leibundgut, H. 1949. Grundzüge der schweizerischen Waldbaulehre. Forstwissenschaftliches Centralblatt. 68 (5): 257-291.

Lemm, R. 1991. Ein dynamisches Forstbetriebs-Simulationsmodell -Prognosen von betriebsspezifischen Waldentwicklungen, Waldschäden und deren monetäre Bewertung unter variablen Einflussgrössen, Diss. ETHZ Nr. 9369. Professur für Forsteinrichtung und Waldwachstum, Eidgenössische Technische Hochschule Zürich, Zürich 235 p.

Lemm, R. and Erni, V. 2009. Bessere Nutzungs- und Allokationsentscheide mit dem Sortierungssimulator SORSIM. In: Thees, O. and Lemm, R. (eds.). Management zukunftsfähige Waldnutzung: Grundlagen, Methoden und Instrumente. vdf Hochschulverlag AG, Zürich, Switzerland. Pp. 415-439.

Lüthy, D. 1998. Entwicklung eines" Spatial decision support"-Systems (SDSS) für die Holzernteplanung in steilen Geländeverhältnissen, vdf Hochschulverlag AG, Zürich, Switzerland. 260 p.

Näsberg, M. 1985. Mathematical Programming Models for Optimal Log Bucking. Linköping University. Linköping, Sweden. 200 p.

Meyer, T., Stückelberger, J., Hollenstein, K., Attenberger, M. and Hänggli, T. 2001. effor2: Holzerntekonzept für die Untersuchungsbetriebe im Kanton Schwyz. Internet Bericht. http://www.lue.ethz.ch/archive/internal_reports/IB_11.pdf

Pillet, G. and Heinimann, H.R. 1998. Kosten-Wirksamkeitsanalyse (KWA) für forstliche Erschliessungsprojekte. Bundesamt für Wald und Landschaft. Bern. 38 p.

Power, D.J. 2000. Supporting decision-makers: An expanded framework. http://dssresources.com/papers/supportingdm/sld001.htm

Power, D.J. 2008. Decision Support Systems: A Historical Overview. In: Burstein, F. and Holsapple, C.W. (eds.). Handbook on decision support systems 1, Springer, Berlin. pp. 121-140.

Pree, W. 1997. Komponentenbasierte Softwareentwicklung mit Frameworks. Heidelberg, dpunkt.Verlag. XII, 130 p.

Rasche, L., Fahse, L., Zingg, A., Bugmann H. 2011. Getting a virtual forester fit for the challenge of climatic change. Journal of Applied Ecology 48, 1174-1186 pp.

Risch, A.C., Heiri, C., Bugmann, H., 2005. Simulating structural forest patterns with a forest gap model: a model evaluation. Ecological Modeling 181, 161-172.

Rosset, C. and Schütz, J.-P. 2003. A DSS as a tool for implementation and monitoring of multiple-purpose, near to nature silviculture. In: Vacik. H., Lexer R, M.J., Rauscher, M.H., Reynolds, K.M. and Brooks, R.T. (Eds.): Decision support for multiple purpose forestry. A transdisciplinary conference on the development and application of decision support tools for forest management, April 23-25, 2003, University of Natural Resources and Applied Life Sciences, Vienna, Austria, CD-Rom Proceedings, 11 p.12: 462-470.

Rosset, C. 2005a. Système de gestion sylvicole intégrée et d'aide à la décision. Le WIS.2, un instrument informatique pour une gestion sylvicole efficiente et ciblée, durable, multifonctionnelle et proche de la nature. Diss. Nr. 16005, EPF Zurich, Zurich. 175 p.

Rosset, C. 2005b. Le WIS.2, un instrument informatique performant pour une gestion efficiente et ciblée des écosystèmes forestiers. Schweiz. Z. Forstwes. 156, 12: 496-509.

Rosset, C., Schütz, J.P., Ammann, S., Stückelberger, J. and Kunz, B. 2009a. Management von Waldökosystemen mit WIS.2 – Was trägt WIS.2 zur betrieblichen Planung bei? In: Thees, O. and Lemm, R. (eds.). Management zukunftsfähige Waldnutzung: Grundlagen, Methoden und Instrumente. vdf Hochschulverlag AG, Zürich, Switzerland. Pp. 387-414.

Rosset, C., Hässig, J., Thees, O., Lemm, R., Frutig, F. Bürgi, A., Hensler, U. and Brang, P. 2009b. Potenziale und Verfügbarkeit des Schweizer Holzes – Funktions-weise und erste Anwendung der Dynamischen Waldholzverfügbarkeitskarte WVK. In: Thees, O. and Lemm, R. (eds.). Management zukunftsfähige Waldnutzung: Grundlagen, Methoden und Instrumente. vdf Hochschulverlag AG, Zürich, Switzerland. Pp. 157-190.

Rosset, C., Günter, M. and Gollut, C. 2010. From WIS.2 to SMART-Forest - a Sustainable forest MAnagement decision suppoRT system. In: Falcao, A.O. and Rosset, C. (eds.). Proceedings of the Workshop on Decision Support Systems in Sustainable Forest Management. Lisbon, April 2010. OP5. 6 p.

Schönsleben, P. 2001. Integrales Informationsmanagement. Springer-Verlag , Berlin Heidelberg. 593 p.

Schumacher, S. 2004. The role of large-scale disturbances and climate for the dynamics of forested landscapes in the European Alps. PhD project Thesis, No 15573. Swiss Federal Institute of Technology, Zurich, Switzerland. 141 p.

Schumacher, S., Bugmann, H. and Mladenoff, D.J. 2004. Improving the formulation of tree growth and succession in a spatially explicit landscape model. Ecological Modelling 180:175-194.

Schumacher, S. and Bugmann, H. 2006. The relative importance of climatic effects, wildfires and management for future forest landscape dynamics in the Swiss Alps. Global Change Biology 12:1435-1450.

Schumacher, S., Reineking, B., Sibold, J. and Bugmann, H. 2006. Modeling the impact of climate and vegetation on fire regimes in mountain landscapes. Landscape Ecology 21:539-554.

Schütz, J.P. 1994. Der naturnahe Waldbau Leibundguts: Befreiung von Schemen und Berücksichtigung der Naturgesetze. Schweiz. Z. Forstwes. 145 (6): 449-462.

Schütz, J.P. 1999. Naturnaher Waldbau: gestern, heute, morgen| Near-Natural Silviculture: Past, Present and Future. Schweizerische Zeitschrift fur Forstwesen. 150 (12): 478-483.

Schütz, J.P. 2002. Silvicultural tools to develop irregular and diverse forest structures. Forestry. 75 (4): 329.

Schütz, J.-P. and Zingg, A. 2007. Zuwachsprognose nach der sozialen Hierarchie im Entwicklungs- und Wuchsmodell SiWaWa. In: Nagel, J. (eds.). Deutscher Verband Forstlicher Forschungsanstalten - Sektion Ertragskunde: Beiträge zur Jahrestagung 2007: 180-187.

Schütz, J.-P. and Zingg, A. 2010. Improving estimations of maximal stand density by combining Reineke's size-density rule and the yield level, using the example of spruce (*Picea abies* L.) Karst.) and European Beech (*Fagus sylvatica* L.). Annals of Forest Science 67: 507-519.

Simon, H.A. 1999. The sciences of the artificial (3rd ed.). The MIT Press, Cambridge, London. 231 p.

Söderbergh, I. and T. Ledermann. 2003. Algorithms for simulating thinning and harvesting in five European individual-tree growth simulators: a review. Computers and Electronics in Agriculture 39:115-140.

Specker, A. 2001. Modellierung von Informationssystemen. vdf Hochschulverlag AG, Zürich, 372 p.

Sprague, R.H. and Carlson, E.D. 1982. Building effective decision support systems. Prentice-Hall. Englewood Cliffs, N.J. 329 p.

Sprague, R.H. 1987. DSS in context. Decision Support Systems. **3** (3): 197-202.

Sprague, R.H. 1993. Decision support systems putting theory into practice, 3rd Ed. Prentice-Hall international editions, Englewood Cliffs, N.J.. 437 p.

Stückelberger, J., Heinimann, H.R. and Chung, W. 2004. Improving the Effectiveness of Automatic Grid Cell Based Road Route Location Procedures. In 2004 International Mountain Logging Conference. A joint FERIC, UBC, and IUFRO D3 conference, eds. I.B. Hedin and R. Krag, published on CD. Vancouver, BC, Canada. Forest Engineering Research Institute of Canada, FERIC.

Stückelberger, J.A., Heinimann, H.R. and Burlet, E.C. 2006a. Modelling spatial variability in the life-cycle costs of low-volume forest roads. European Journal of Forest Research, (125): 377-390.

Stückelberger, J.A., Heinimann, H.R., Chung, W. and Ulber, M. 2006b. Automatic road-networkplanning for multiple objectives. In Council on Forest Engineering, 2006 Annual Conference, eds. W. Chung and H.S. Han, 233-248. Coeur d'Alene, MT, USA. The University of Montana.

Stückelberger, J.A. 2007. A weighted-graph optimization approach for automatic location of forest road networks, ETH. Zürich. Diss Nr 17366, Eidgenössische Technische Hochschule ETH Zürich, Zürich,. 127 p.

Stueckelberger, J., Heinimann, H.R. and Chung, W. 2007. Improved road network design models with the consideration of various link patterns and road design elements. Canadian Journal of Forest Research. 37: 2281-2298.

Szyperski, C. 1998. Component software beyond object oriented programming. Harlow [etc.], Addison Wesley. XVIII, 411 p.

Thürig E., Kaufmann, E., Frisullo, R. and Bugmann, H. 2005. Evaluation of the growth function of an empirical forest scenario model. Forest Ecology and Management 204: 51-66

Appendix I: Description of the decision support tools - Attributes

Attribute	Description
DST_Name	Name of the Decision Support Tools
E_Mail_ContactPerson	E-mail of the contact person
Tool_As_DSS	Tool described explicitly as a DSS in project documentation: yes / no
Tool_As_DSS_References	List of references related to the definition/approach of DSS (Author and Year), if any
PT_Dim_TemporalScale; _SpatialContext; _SpatialScale; _PartiesInvolved; _Objectives; _GoodsAndServices	Main problem type dimensions related to the tool (PT: problem type, Dim: dimension; cf. definition COST FORSYS)
TargetUserGroup_EduLevel_Forester; _Engineer; _Other	Education level of the target user group
TargetUserGroup_OrgType_ForEnterprise; _ForContractor; _ForEngineerFirm; _ForServiceCantonal; _ForServiceNational; _Other	Organization type of the target user group
ReadyToUse_Costs	Ready-to-use costs, based on an average computer (hardware, software) considering the target user group, inclusive installation costs when performed by a specialist: 0, <= 100€, <= 1,000€, <= 10,000€, >10,000€
TrainingTime	Training time for a normal user of the target group: <= 1 hour, <= 1 day, <= 1 week, <= 1 month, > 1 month
OrgInChargeMaintenance	Organization in charge of the maintenance, if any
OrgInChargeSupport	Organization in charge of the support, if any
NumberPeopleInvolvedInSupport	Number of people involved actually in the support, if any
NumberKnownUtilisationRealLifeProblem	Number of known utilisations in real life problems by practitioners: 0, <=3, <=10, <=30, <=100, >100
YearLastKnownUtilisation	Year of the last known utilisation in real life problems
UtilisationInEducation	Utilisation in education, such as presentation / demo or utilisation directly by students
YearLastUtilisationInEducation	Year of the last utilisation in education
MainReferenceUtilisationResearchDev	Utilisation in research and development: main references (max. 5) of R&D project in which the tool has been used
OriginProject	Origin of the project: research institution, PHD PROJECT, public administration, private enterprise or other
DevTeamNumberMember	Developer team – number of people, with at least 10% involvement of the project
DevTeamNumberSpecialist	Developer team – number of different specialists considering their educational background
DevTeamNumberMemberCurrent	Developer team – number of people still working on the tools
DevDesignToolReference	Design of the IT-solution: main reference for the design phase of the project (e.g. software engineering)
YearLastUpdateTool	Year of the last update (minor development, maintaining the tool up-to-date to the underlying software / OS, fix errors) of the tool
YearLastUpgrateTool	Year of the last upgrade (major development, new functionalities, new version) of the tool
StakeholderInvolvement_RequirementPhase; _DesignPhase; _ConstructionPhase; _TestPhase; _NewDevelopment	Involvement of stakeholders, if any
ITTool_SystemType	System-type, such as extension (based on standard software), stand-alone desktop, client-server: desktop-client / web-client (browser), other
ITTool_OperatingSystem	Operating system, such as Linux, Unix, Windows, multiplatform, other
Database_Productname	Product name of the database implemented, if any
GIS_Productname	Product name of the GIS implemented, if any
Modelbase_Productname	Product name of the Modelbase implemented, if any
UserInterface_Productname	Product name of the GUI implemented, if any
ProgrammingLanguage	Programming language, such as VBA, c#, c, c++, java, other
IntegrationOptimisationAltgorithm	Optimisation algorithms have been implemented: yes / no
IntegrationMCDM	MCDM techniques have been implemented yes / no
IntegrationKM	KM techniques have been implemented: yes / no
Remarks	

Appendix II: Repository of management support tools in Switzerland

Name of the tool *email contact person* Brief overview: scope of the system, main decisions supported, main means of decision support, system origin and main applications (length: about 600 characters)	References (max. 5)
FBSM ***renato.lemm@wsl.ch*** FBSM is a simulation model for forest management unit. The purpose is to estimate forestry growth and yield. The input variables, such as tree species, stand age, site index, silvicultural treatment, harvesting and bucking strategy are recorded menu- and dialogue driven or imported from ASCII files. The nucleus of FBSM is a single tree distance-independent model; the single tree is treated as representative of a diameter class. FBSM was designed primarily to quantify the loss of value as a consequence of biologic and metereologic disturbances. It is working well for forecasts of timber yields, to support the long-and medium-term forestry planning and as a tool for forest value estimations.	Erni and Lemm 1995 Lemm 1991
FORCLIM ***harald.bugmann@env.ethz.ch*** FORCLIM is a gap model designed to incorporate simple yet reliable formulations of climatic influences on ecological processes while using only a minimum number of ecological assumptions. The model consists of three submodels: PLANT simulates stablishment, growth and mortality of 30 European species on small patches of land. Tree establishment rates are determined from light availability on the forest floor, growing season temperature, soil moisture, minimum winter temperature and browsing pressure. Growth is modelled based on the carbon budget approach by Moore (1989), modified by Risch et al. (2005) and Didion et al. (2009). In this approach the species' optimal growth rate is decreased based on the degree to which environmental factors (nitrogen availability, growing 120 season temperature, soil moisture) and crown size are at suboptimal levels. Tree mortality is modelled as a combination of an age-related and stress-induced component. To date this type of model has mainly been used to simulate forest dynamics in unmanaged forests. However a detailed management module for simulating even and uneven-aged management is being developed by Rasche et al. (2011).	Bugmann 1996 Bugmann 2001 Bugmann and Solomon 2000 Didion et al. 2009
HeProMo ***friderich.frutig@wsl.ch*** HeProMo provides a collection of deterministic models to estimate productivities of harvesting operations. It covers the following systems and system components: motor-manual harvesting, mechanized harvesting with wheeled harvesters; chipping, extraction with skidders, forwarders, cable systems and helicopters. HeProMo provides user-friendly interfaces, tailored to the needs of practitioners. Users define site and system specifications to get productivity and cost estimates, to do sensitivity analysis as well as the comparison of alternative harvesting systems	Frutig et al. 2009

LandClim ***harald.bugmann@env.ethz.ch*** LandClim has been demonstrated to be able to simulate vegetation dynamics accurately along steep environmental gradients in the Swiss Alps and the Colorado Front Range, USA. In addition to simulating forest growth the model also incorporates fire and wind disturbances, and forest management, and their impacts on forest dynamics. LandClim is a spatially explicit, stochastic model developed starting from the well established LANDIS model. It was designed to study forest succession determined by climate, soil properties and large-scale disturbance agents such as fire, windthrow and harvesting. The model operates over time periods of hundreds to thousands of years and at spatial extents in the range of 10-1,000 km^2. The major modifications of LandClim as compared to LANDIS are a) the incorporation of a quantitative description of forest structure by tracking density and biomass specifically for individual tree species and age classes; b) the explicit simulation of competition as well as the influence of climate and soil properties on succession and c) the modeling of the fire regime as an emergent ecosystem property based on climatic parameters and the fuel load alone.	Schumacher et al. 2004 Schumacher and Bugmann 2006 Schumacher et al. 2006 Schumacher et al. 2004 Söderbergh and Ledermann 2003
MASSIMO3 ***edgar.kaufmann@wsl.ch*** MASSIMO3 is an empirical stochastic simulation model, which is based on the sample data of the National Forest Inventory (NFI). It allows estimations of future developments mainly of standing volume, growth and cut in the forest according to forest management strategies that will be applied. The model has been developed at the Swiss Federal Research Institute WSL. It is applied by offices of the federal administration, wood industry and forest management associations as well as in the forest research.	Thürig et al. 2005 Kaufmann 2001
PFM - Protection Forest Model *peter.brang@wsl.ch* The protection forest model enables the evaluation of management strategies, i.e. combinations of preventive operations (thinning, planting) and reactive treatments after disturbances (salvage harvesting, fill planting or re-planting, construction of defensive structures), in forests protecting against natural hazards such as avalanches and rockfall. The model is based on a Markov chain approach and contains six modules: Stand dynamics, disturbances, silvicultural operations, hazard risks, management costs, and cost-benefit analysis. The model runs over a 150-year period in 10-year steps.	Brang and Hallenbarter 2007
PPW - Protect Potable Water ***clemens.blattert@wsl.ch*** Forest areas with special importance for water quality and quantity are protected by groundwater protection zones. The designation of protection zones is associated with a number of legal regulations and recommendations affecting forest management. The compliance of these requirements mean for the forest enterprises additional costs. With the “Trinkwasserschutz-Tool” a skilled person (forest manager, representative of water supplier) can calculate the additional costs and reduced revenues resulting from the legal requirements and recommendations by entering the main characteristics and management practices of a specific protection zone. The tool is based on Microsoft Excel 2007. The results will form the basis for discussions (topic: compensation payment) between forest owners and water suppliers.	Blattert and Bürgi 2011

SiWaWa ***jph.s@bluewin.ch*** SiWaWa is a new forest growth simulation model. The model operates with only two input variables, namely the number of stems (N) and the basal area per hectare (G) of a particular stand. It generates a stem number distribution curve divided into dhb classes. With an additional input – dominant height or site index – the relevant dendrometrical characteristics for the stand can be derived (stand inventory). Unlike the yield tables that are based on certain silvicultural methods, SiWaWa can be used to quantify different types of treatment for a specific stand (number, timing, type, and strength of interventions) and thus easily explore the silvicultural scope thereof. SiWaWa currently is available for three types of trees, namely spruce, beech and ash. The program exists as an Excel file. The development of a stand-alone application is planned as of end of 2011.	Schütz and Zingg 2007 Schütz and Zingg 2010
SORSIM ***renato.lemm@wsl.ch*** SORSIM is a software tool that supports bucking to alternative timber assortments. It allows the division of logs into commercial assortments based on freely definable criteria for cutting dimension (such as new timber commerce regulations). Based on the input variables tree species, breast height diameter and tree height the stem form is modelled with and without bark, the assortments are identified, the volumes and the assortment values calculated. The quality is taken into consideration as experience. The prototype provides an important basis in order to evaluate the economic value of trees or stands and to optimize assortment allocation (bucking to value or to order).	Lemm and Erni 2009
WVK - Forest Product Availability Map ***christian.rosset@bfh.ch, renato.lemm@wsl.ch*** WVK is based on company or regional forest inventories and makes use of a geographic information system (GIS). Using such forest wood energy maps users can obtain information on where it will be possible, in the near future, to harvest wood, in what amount and what type of wood product. The model calculations include varying silvicultural concepts as well as varying processing intensities and the planned use of the forest wood. Also incorporated in the model are the varying developments in the price of wood, harvesting costs and nutrient removal due to usage. The GUI of WVK is not yet developed.	Rosset et al. 2009b

26 The design and use of forest decision support systems (DSS) in Turkey

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26.1 Introduction

Turkish forests are diverse and rich in terms of forest composition, structure and functions. They include both managed and natural mixed forests, dominated by softwood such as pine, fir, spruce, cedar and hardwood such as beech, oak, alder, walnut and hornbeam (Başkent et al. 2005). According to the latest national forestry inventory, the forest area occupies 21.6 million ha (approximately 27% of the land). As a result of misuse of forest resources over centuries, however, productive forests cover only about 50.1% of the total forest area, and the remaining 49.9% carries only degraded or severely degraded unproductive forest cover as of today. Conifer forests dominate the high forests, occupying 54% of the total forest area. Deciduous forests occupy only 36% of the total forest area. The remaining 10% of the total forest area is occupied by mixed forests including softwood and hardwood species (GDO 2006).

Turkey has 75% of the plant species that occur in the whole of Europe. There are about 10,000 taxa, 3,500 (33%) of which are endemic. The country has several distinct biogeographic regions, each with its own endemic species and natural ecosystems. These include the Caucasian mountain temperate forests and alpine ecosystems of the North East Black Sea Coast; steppe grasslands of the Central Anatolian plateau; and the European and Mediterranean regions which, respectively, include probably the largest remaining stands of pristine alluvial and Cyprus forests. In addition, one of the three major flyways for millions of migratory birds, which move between the Western Palearctic and Africa each year, passes through Turkey (Konukçu 2001; Başkent et al. 2005; GDO 2006).

This paper addresses the forest management planning process according to the framework of FORSYS COST Action. In this context, it focuses on the problem types and related decision support systems addressed by the ongoing research and development initiatives. Some problems may be classified using FORSYS dimensions as single decision-maker on medium-term scale, spatial scale at forest level, and non-spatial representation of market wood products including only timber production objective (Table 1).

Table 1. Classification of forest management planning problems in Turkey according to the FORSYS dimensions

Dimensions	Problem Types
Spatial Scale	Plans are prepared at the forest level
Temporal Scale	Tactical (medium-term; 10 or 20 years)
Spatial Context	Non-spatial (actions are manually distributed)
Decision-making	One single decision-maker is involved
Objectives	The planning process addresses only one objective
Goods and Services	Management planning takes only market wood products into account. Yet, the new management plans are able to account multiple forest values.

For the 21.6 million ha of forests, 99.9% of the forest land base belongs to the state. In fact, the state both owns and manages forests across the country. So there is basically a ***single decision-maker***. The concept of state management has been dominant in Turkish forestry since 1937 and it has been accepted that forestry activities would best be undertaken by the state forest services. The main reason for accepting the state-based management system is that all society is interested in forests and any private ownership mechanism may accelerate destruction in forest resources. While a number of private forest management initiatives had been practiced over the history of Turkish forestry during the 1920s, the results were unacceptable as the control of private management was overlooked. As a result, state-based management has been established in both forest ownership and forest management activities (Başkent et al. 2005).

The management system of Turkey, essentially initiated in the 1960s with the help of European counterparts, focuses primarily on ***commodity production (wood production)***. Until the years of 2000, timber production has been the focal/single management objective. Turkey’s forests have long been exploited to meet wood supply demands and generate national income. However, as the needs of the people have changed, various forest values such as recreation, water production, soil protection and biodiversity conservation are required to be considered in forest management planning. From a forest management perspective, 80.2% of the total forest area was primarily managed for timber production; about 15.8% was allocated as conservation areas including forest recreation sites and protection forests. A small part of the total forest area (4.0%) was allocated to nature protection and biodiversity conservation including national parks, nature parks, nature conservation areas, nature monuments, seed stands, gene conservation forests, cloned seed orchards and protected areas (Başkent et al. 2005). Nowadays, forest ecosystems are managed for economical (47% of the total forest area), ecological (50% of the total forest area) and socio-cultural (3% of the total forest area) objectives (GDO 2006). The main forest values are timber production, nature conservation, soil protection, water conservation, aesthetics, ecotourism and recreation, climate regulation and biodiversity conservation. The forest resources of the country provide vital socio-economic contributions especially for local communities, which comprise around 9 million people living in approximately 19,000 forest villages.

In any case, however, a number of new initiatives as part of research and development projects have been in place across the country. For example, under the GEF-II project, the World Bank supported new a forest management planning approach, focusing on the integration of forest biodiversity into forest management plans in a few case study areas. As well, BTC Co. and some NGOs have sponsored ecosystem-based forest management planning approaches to be developed and implemented in the north-eastern part of Turkey. These new initiatives have given an opportunity towards the implementation of multiple use forest management planning approach in the country.

The planning process is centralized in Turkey in that forest management plans (strategic and tactical plans combined) are primarily prepared by the forest management planning department at the headquarters of the General Directorate of Forestry. Management plans are prepared for either ***10 or 20 years (tactical plans)*** and renewed again at 10 to 20-year intervals following a full forest re-inventory. Management planning periods are determined based on the silvicultural needs of the species. For the forests with fast-growing trees such as Calabrian pine, a 10-year planning period is used, whereas for forests with other species such as other pines and hardwood species a 20-year period is used. The plans must be prepared based on management guidelines set by the department which are a set of legal regulations.

The state forest administration in Turkey is organized across the country. At the top, the forest areas are divided into 27 forest regions, where each region is administered and managed by a regional directorate of forestry. Each region is further divided into state forest enterprises, totalling 218 across the country. Each forest industry is again partitioned into forest districts where a forest engineer is appointed to manage the forest resources. There are 1,344 management units in total. A management planning unit is defined as a geographically contiguous area of forest with certain administrative and political borders, topography, and synchronized technical activities (Başkent et al. 2005). Its size ranges from 1,000 ha to 40,000 ha, averaging around 16,000 ha but the ideal size is considered to be about 5,000 ha. The interesting issue here is that each district must have at least one management plan. It also means that forest management plans are prepared ***at forest level***.

The forest management planning process used in Turkey is ***non-spatial*** in nature, excluding the effects of forest management activities in adjacent areas. The ecological health and integrity, spatial control of forest activities and biodiversity issues are not currently part of all forest management plans. However, different management activities in any forest planning unit may often influence adjacent units. For example, the clear-cutting activity of any stand may expose neighbouring stands to wind damage, drainage problems and insect attacks. As ecological and environmental considerations are important for both society and individual forest owners or decision-makers, there is an increasing need to analyze the development of spatial structure of forests and to develop means by which spatial objectives can be explicitly included in forest management (Başkent and Keleş 2005; Başkent and Keleş 2009).

In the country report, the general framework of the current forest management planning system in Turkey was firstly explained in detail based on the problem types in FOSRYS. Secondly, the data and information available about management planning, decision support systems, models and methods used within these computerized tools were described. Thirdly, all problems relevant to FORSYS were determined at a temporal scale, in a spatial context and scale, with a participatory approach and multiple forest values and management objectives. Finally, the report will focus on the assessment of forest management planning models' success in addressing the key problem types in the Turkish forest management planning system. The contributions and shortcomings of a computer-based program of APP (developed by Turkish Forest Service) and each module of ETÇAP DSS (developed by Başkent et al. 2008c) to forest management problem solutions were described in detail, and some of the lessons learned and experiences gained during the development and implementation of ETÇAP DSS were explained.

26.2 Materials and methods

The country report has been prepared by Sedat Keleş and Emin Zeki Başkent. The information required in the preparation of the report such as the extent of forests, main uses of the forests, main stakeholders, ownership structure and legal framework were obtained from the National Forest Inventory data (Konukçu 2001; GDO 2006). The current management philosophy, regulations, socio-cultural and organizational structure, and implementation of management activities across the country were largely introduced based on a review conducted by Başkent et al. (2005).

To date, not many decision support systems have been developed in Turkey as the country has recently embraced the concept of modelling in the forest management planning process. Turkish forestry has not effectively utilized the information technologies and decision support tools in the planning process and has focused only on a simple use of some computer software. A simple utilitarian or formula-based approach has been simulated with an in-house computer program to prepare forest management plans in Turkey. While the forest management department in the Turkish Forest Service developed a sequential computer-based programme of APP, the model is just a computer program that uses an access forest inventory database to document forest management planning tables under the direction of forest management planning experts.

Therefore, an attempt has been made to develop a forest management decision support system utilizing the current management planning systems as well as simulation, optimization and combinatorial optimization-based management planning models. In Turkey, there are not many DSS ready for use in forest management planning except ETÇAP (Ecosystem based multiple use planning) model, which has just been started for development. A new decision support system (DSS) of ETÇAP for forest management planning in Turkey has been developed. The DSS is based on an ecosystem-based multiple-use forest management planning philosophy explained in detail by Başkent et al. (2008a; 2008b; 2008c).

The ETÇAP DSS was developed by Emin Zeki Başkent, Sedat Keleş and Ali İhsan Kadioğullari in 2008 as part of a research project supported by TUBITAK (Başkent et al. 2008c). ETÇAPClassical, ETÇAPSimulation, ETÇAPOptimization and ETÇAPSpatial modules within the DSS were primarily developed by Sivrikaya (2008), Keleş (2008), and Kadıoğulları (2009), respectively, as part of a project in the context of their PhD thesis supervised and directed by Emin Zeki Başkent and the programs are coded by Özkan Bingöl and Uğur Şevik. The project leader is Emin Zeki Başkent who is responsible for development and management of the model. On the other hand, some scientific papers about the system and international papers and proceedings were used in preparing the country report of Turkey (Başkent and Keleş 2009; Keleş et al. 2009a and 2009b; Sivrikaya et al. 2010a; Keleş et al. 2010; Başkent et al. 2010; Bingöl et al. 2010; Başkent et al. 2011a; Keleş and Başkent 2011). Material used in preparing the report has also been introduced to the FORSYS Wikipedia (www.fp0804.emu.ee/wiki/index.php/Main_Page).

26.3 Results

The major *"problem types"* of the current forest management planning system in Turkey are summarized as follows:

- Forest management plans are mostly *tactical level* plans and prepared at *forest level* yet provide management actions at a stand (sub-compartment) level. Each forest management unit, an average of 6,500 ha area where a forester is appointed for its management, must have a single management plan to be implemented over 10 years then must be renewed. A long-term strategic planning concept is not in place, as there is no long-term projection of forest stands and thus no long-term harvest schedule. However, since an area control method is exercised, forests are regulated based on age-class structure in even-aged stands through regenerating the same amount of area in each period and size-class distribution in un-even-aged stands. Operational plans are not prepared to accommodate transportation and the detailed implementation of silvicultural treatments. There are ad-hoc silvicultural plans that are attached into the forest management plans. So the management planning process is quasi-hierarchical and thus the link is not strongly established over temporal and spatial scales. (*Temporal and spatial scales*)

- Depending on prominent commercial trees, sites and management objectives, each forest planning unit is divided into sub-management units where harvest scheduling is prepared and thus AAC (Annual Allowable Cut) is determined. Each sub-management unit is further divided into harvest compartments, manually determined and based on topography and road networks. The maximum size limits of compartments are around 50-75 ha depending on the topography and the intensity of management issues. A compartment is used to record and track the forest management actions as they are applied on the ground. *(Spatial organization of the plan)*

- AAC is determined in two ways: final harvesting (regeneration cut) and commercial thinning. The maximum size of a harvest block (spatially contiguous areas to be harvested at the same time) is determined manually by the management team. The maximum size of harvest blocks is accepted (non-legally binding) as around 15 to 25 ha, exceptionally it may go up to 70 ha depending on the species composition, topography and silvicultural practices. There is no minimum size limit, nor are there any adjacency and opening size constraints applied to the forest management plans. Thus, in this respect, plans are not spatial. The decision mechanism about the level of commercial thinning is based on the experiences of the forest management survey team leader. The spatial layout of the thinning is determined by the capacity of the workforce in rural areas. Each year a thinning block, spatially contiguous areas with the same amount of thinning level, is scheduled for treatment. A manual decision is applied in selecting the areas to be thinned. (*Spatial context*)

- The forest management plans are prepared conventionally, based on forest management regulations, and are prepared by the General Directorate of Forestry (GDF), a solo legal state organization to manage forest resources in Turkey. The department of forest management under GDF administers all of the forest management plans across the country. Management plans are prepared either by state-owned management teams or contracted out to private forest consultants who are not well structured as yet. The forests are totally owned by the state and the management of the resources is conducted by a single organization, GDF. Frankly speaking, there is basically a single decision-maker. However, over the last couple of years, GDF has decided to cooperate with key stakeholders such as wood workers, village administrations, conservation organizations and society of Turkish foresters in recent decades. (*Decision-making dimension and participation process*)

- Before the last decade, wood production had dominated forest management planning. The basic outputs of management plans were wood products. However, over the last two decades the country has started to implement multi-objective forest management plans. Starting in 2008, the amount of carbon storage, non-wood forest products, oxygen released, water produced and soil protected have become the basic management objective components of forest management planning concepts. Among them biodiversity conservation is the most prevailing goal in forest management planning, although all forest management plans do not integrate it as yet. The forest industry is sporadically associated with GDF and thus GDF is almost free to determine forest management objectives in terms of wood products. (*Objectives dimension*)

- The GDF markets wood products in various qualities that are not part of forest management plans. Economic values of goods and services are not an integral part of forest management plans. Market issues are also not an integral part of forest management planning. There is no valuation process applied both to goods and services in forest management plans. *(Goods and services dimension)*

The DSS developed in Turkey based on major problem types determined in the FORSYS COST Action are summarized in the following table.

Table 2. Major problem types determined in FORSYS COST Action in Turkey and models and methods

Problem type	**DSS**	**Models and Methods**	**KM techniques**	**Methods for participatory planning**
Document harvest schedule for a first period (2, 10 or 20 years) at stand level. It is a non-spatial medium-term (tactical level) programme with single timber management objective	*APP*	General database management application based on query, retrieval and report.	Not applicable	Unilateral, solo state involvement
Document harvest schedule for a first period (2, 10 or 20 years) at stand level. It is a quasi spatial medium-term (tactical level) programme with single timber management objective	*ETÇAP Classic*	General database management application based on query, retrieval and report. Use of GIS to locate harvesting location.	Not applicable	Collegial with the involvement of state, a research institute and a management team
Forecast of forest development at stand level over long-term. It is a non-spatial model with multiple objectives	*ETÇAP Simulation*	Use of traditional simulation approach with object oriented programming language. Use of GIS to develop spatial database and locate treatment schedule.	Not applicable	Collegial with the involvement of state, a research institute and a management team
Forecast of forest development at stand level over long-term. It is a non-spatial model with multiple objectives	*ETÇAP Optimization*	Use of linear programming technique with object oriented programming language and GIS to develop spatial database and locate treatment schedule.	Not applicable	Collegial with the involvement of state, a research institute and a management team
Forecast of forest development at stand level over long-term. It is a spatial model with multiple objectives	*ETÇAP Spatial*	Use of traditional hill climbing and simulated annealing approaches with object oriented programming language. Use of GIS to develop spatial treatment schedule. Use of block size, opening size and adjacency constraints in harvest schedule	Not applicable	Collegial with the involvement of state, a university and a management team

The ETÇAP DSS was developed by Emin Zeki Başkent, Sedat Keleş and Ali İhsan Kadioğullari in 2008 as part of a research project supported by TUBITAK (Başkent et al., 2008c). The model includes a few modules such as AROBEM, ETÇAPClassic, ETÇAPSimulation, ETÇAPOptimization and ETÇAPSpatial. AROBEM is an empirical growth and yield model (or stand simulation model) inherent in ETÇAP DSS. It was developed to project the growth of each existing stand as there was no growth and yield model constructed for the species of the forest. The growth and yield of existing stands over the following period are predicted based on the relationship between the inventory data and the empirical yield table. It is very important to project the future stand characteristics and analyze the affects of various silvicultural treatments (Keleş 2008).

ETÇAPClassic is a GIS-based planning module focusing on classical area regulation methods. The ETÇAPClassic has been designed using Borland Delphi-7, Microsoft Office Access, MapObjects (version 2.4) and Fast Report (version 4.0). The model is programmed in an object-oriented programming language, Delphi. MapObjects was selected mainly due to its wide application and a powerful collection of GIS functions such as displaying maps, querying spatial and non-spatial attributes, and analyzing the spatio-temporal dynamics of forest ecosystems. The database was designed in MS Access with all attribute data useful in the model. MS Access was selected as it provides an array of new and enhanced objects, methods, properties, functions, statements, data types and events to enable the creation of powerful database applications with Delphi. FastReport is used for generating reports in management plan (Sivrikaya et al. 2010a). The ETÇAPClassic includes four sub-modules as Data Input, Spatial Data Management with GIS, Data Processing and Reporting (Sivrikaya 2008; Sivrikaya et al. 2010b; Sivrikaya et al. 2011).

ETÇAPClassic provides a user-friendly computer-based tool for preparing a forest management plan as well as for monitoring, assessing and reporting progresses. ETÇAPClassic has been developed as a GIS-based planning module for forest managers and decision-makers. The model includes the design and installation of a spatial database concerning the ETÇAP planning approach. The database could be established and updated with GIS-based module. It incorporates GIS-based mapping, querying and analyzing tools to make management decisions effectively. The GIS module is used effectively in the decision-making process. The decision-making dimension is collegial with the involvement of the state, a research institute and a management team (Sivrikaya 2008; Sivrikaya et al. 2010a; Sivrikaya et al. 2011).

ETÇAPSimulation is a stand-based forest-level decision support tool for assessing the effects of forest management interventions on forest dynamics and functions. The model is developed and implemented with a collection of modules and components that could be re-used when constructing new applications and models. The ETÇAPSimulation model is written in DELPHİ object-oriented programming language. The system was developed to operate on a personal computer under Windows. It is a deterministic simulation model consisting of a number of primary components; data input, actions and outputs (Keleş 2008; Keleş et al. 2009a; Keleş et al. 2009b; Başkent et al. 2011a; Keleş et al. 2011).

ETÇAPSimulation is a general purpose long-term management model that simulates the dynamic behaviour of forest ecosystems with ecological and financial understandings of forest management activities. Projections are conducted for a planning horizon (i.e. 100 years), divided into periods (5, 10, 15, etc.). It is a stand-based forest-level decision support tool. The smallest identifiable basic management area for this model is a stand. There is no limit in the number of stands to be included in the simulation. However, stands can also be grouped into homogeneous units (called analysis areas) based on a user-defined criteria. It is a non-spatial model with multiple objectives: timber production, carbon sequestration, oxygen production, soil erosion, and water production. It is a non-spatial model and collegial with the involvement of the state, a research institute and a management team (Keleş 2008; Keleş et al. 2009a; Keleş et al. 2009b; Başkent et al. 2011b; Keleş et al. 2011).

ETÇAPOptimization is a Linear Programming (LP)-based forest management planning system that consists of a matrix generator and report writer, both of which interface with a commercial mathematical programming solution package. The current implementation of ETÇAPOptimization is also a collection of modules and components which can be re-used when constructing new applications and models. The development of the model is based on both user requirements and operational specifications. ETÇAPOptimization, conventionally a large-scale ecosystem management oriented optimization tool, has been modelled using linear programming. The ETÇAPOptimization model is written in DELPHİ which is an object-oriented programming language. The system was developed to operate on a personal computer under Windows. It sets up the problem in standard MPS format for solving by a commercial LP package such as LINGO and LINDO (Keleş 2008; Keleş and Başkent 2011; Keleş et al. 2011).

The model enables the preparation of a forest management plan that is easy to update as it was developed in-house with an object-oriented approach to accommodate various management needs as they arise. The model accommodates decision-making techniques and information technologies and provides various opportunities in preparing forest management plans while enabling the process to be faster, sound and timely using relatively less amount of time and labour. The smallest and basic management area for this model is also a stand. There is no limitation in the number of stands to be included in the optimization. ETÇAPOptimization is specifically designed to schedule the management strategies of a forested area over time. It typically involves the allocation of forest area to management regimes for treatment and product outputs developed through the incorporation of concerns for multiple use and protection of environmental and ecological values. It also offers the capability to simulate management strategies across forest landscapes through time. The problem can be formulated with an objective function of timber production, water production, soil erosion, carbon sequestration, oxygen production, and their net present values. Furthermore, total net present values (NPV) of some forest values can be selected for an objective function such as the net present value of timber plus the net present value of water. There is also a wide variety of optional constraints that users incorporate in their models. As such, the model enables decision-makers to assess the trade-offs among forest values by both NPV and the absolute amounts. It is a non-spatial model and collegial with involvement of the state, a research institute and a management team (Keleş 2008; Keleş and Başkent 2011; Keleş et al. 2011).

ETÇAPSpatial is a spatial forest management planning module within the framework of the ETÇAP DSS. The system has the capability to control the spatial structure of forests based on the spatial database generated by Geographical Information Systems (GIS) and spatial parameters with other attribute data (such as empirical yield table, product assortment table, water production table). The ETÇAPSpatial was developed with object-oriented design and programming (Delphi) language, and has the flexibility to accommodate changes in model structure. It includes a simulation-ETÇAPSpatialSimulation (random ascent algorithm) and a meta-heuristics- ETÇAPCombinatorialOptimization (simulated annealing algorithm) based spatial forest management modules (Kadıoğulları 2009).

The ETÇAPSpatial is developed to generate spatially implementable harvest schedules and perform spatial analyses as part of an integrated forest management planning approach. In ETÇAPSpatial, spatial requirements are related to size, shape, juxtaposition, and distribution of management units (i.e. stands, harvest blocks, wildlife habitats and age class), minimum and maximum harvest block size limits and adjacency (i.e. green up delay) restrictions. The ETÇAPSpatial has improved the forest management planning concept using spatial simulation and simulated annealing techniques and helped analyze spatial forest structure using spatial characteristics for an implementable forest management plan. The model also accommodates GIS-based mapping, querying and analyzing tools to make management decisions effective. It is possible to develop long and medium-term forest management plans. The effects of various forest management strategies on forest ecosystem structure and functions can be understood. The spatial and temporal dynamics of forests may be understood in a better way, and economic analyses can be incorporated into forest management plans. It is a spatial model with multiple objectives like timber-water-oxygen production, soil protection, carbon sequestration and biodiversity conservation. The model is also collegial with the involvement of the state, a university and a management team (Kadıoğulları 2009).

In all modules of ETÇAP DSS Knowledge Management (KM) techniques are not applicable to develop DSS and they are not integrated in DSS applications.

26.4 Discussion and conclusions

Forest management planning in Turkey has employed both even-aged and uneven-aged management methods. Forest management objectives of all forest management plans over the country are defined and implemented according to the forest management guidelines. Single ownership of forest land (*single decision-maker*) in Turkey would suggest it would be easy to define forest management objectives. Management objectives and conservation targets have not been established under stakeholders' participation for effective management of the forest resources. Classical area regulation approaches have been widely used across the country for even-aged forests comprising mainly light-demanding trees such as pine and coppice forests. Hufnagel's size class method has been used for the uneven-aged forests comprising mainly shade-tolerant species such as fir. The production capacity is determined according to age and dominant height of stands. The current age or size class distribution is determined based on the regular forest inventory and future forest development is determined by the empirical yield tables. Using the area/size regulation method, a harvest schedule is determined to maximize wood production (*single objective*) in a single period (*tactical plan*), leaving other periods unplanned until the rotation period (Başkent et al. 2005). Management plans are prepared at a forest planning unit level (*forest level*) and the decision-making processes are carried out with a forest management team. Using a classical area or size regulation method, a harvest schedule is determined for only one period, leaving other periods unplanned until the rotation period. The Annual Allowable Cut was determined by the head of forest management team according to his/her experiences based on basic formula results such as silvicultural allowable cut and Hufnagel's formula (Başkent et al. 2005; Başkent et al. 2008a; Başkent et al. 2008b; Sivrikaya et al. 2010a).

Decision support systems have appeared to be the important tools, due to advances in information technologies, development of forest management planning approaches and expansion of the information pool. So far, however, Turkish forestry has not effectively utilized the information technologies and decision support tools in the planning process and has focused only on a simple use of some computer software. A simple utilitarian or formula-based approach (APP) has been simulated with an in-house computer program to prepare forest management plans in Turkey. The program does not use any of the operations research techniques and thus only reports or documents the harvest schedule in tables according to forest management regulations in the country. While the program prepares one period harvest schedule, it doesn't forecast future forest development nor does it utilize a spatial database to layout management actions on the ground. Therefore, an attempt has been made to develop a forest management decision support system utilizing the current management planning systems as well as simulation, optimization and combinatorial optimization based management planning models. In Turkey, there are not many DSS ready for use in forest management planning except the ETÇAP (Ecosystem based multiple use planning) model, which has just started to be developed.

Compared to the framework of ecosystem-based multiple-use forest management planning (Başkent et al. 2008a; Başkent et al. 2008b), important shortcomings include unresolved ownership, forest characterization without site, biodiversity, health and capacity inventory, conservation of various forest values not accommodated, decision-making process with operations research techniques not conducted, and structured participation has not materialized. In fact, the forest management planning process in Turkey has just started to welcome an ecosystem-based forest management concept accommodating biodiversity conservation, participation, multiple uses, and information technologies (Baskent et al., 2008a). For example, a forest management plan was developed to accommodate a black vulture (*Aegypius monachus*) protection programme in Kızılcahamam. In 2005, the World Bank-supported Global Environment Facility (GEF) project initiated the idea of biodiversity conservation (Işık et al. 1997), participation and multiple-use concepts, called the ecosystem-based multiple-use forest planning approach (Baskent et al. 2008a). The project is realized in four case study areas: İğneada Lagoons, Köprülü Kanyon National Park, Sultan Sazlığı wetlands, and Camili Bioreserve areas (World Bank 1998; Sivrikaya et al. 2007), followed by the Baku-Tbilisi-Ceyhan (BTC) Co. Pipeline environmental protection programme in the Yalnızçam forests of Ardahan, Turkey. The concept has now been successfully implemented in the İgneada, Camili, and Yanlızçam areas.

The ETÇAP DSS uses both spatial information driven from Geographical Information Systems and other data such as empirical yield tables, forest products and planning parameters as an input to model forest management activities implementable on the ground. The DSS was developed with object-oriented design and programming (Delphi) language by identifying the planning components as "classes" and the functions as "behaviours". Support for specific issues such as inventory compilation, harvest scheduling, timber-water-carbon production or prediction, soil protection, yield prediction, biodiversity conservation and spatial planning are all provided by the DSS. An interface program was developed to implement the DSS in the case study areas. The forest management DSS provides opportunities for decision-makers to test various management strategies and conduct economic analysis towards the best choice. Such an approach allows the integration of strategic and tactical planning components of hierarchical forest management planning system. The DSS will enable the preparation of forest management plans that are easy to update as it was developed in-house with an object-oriented approach to accommodate various management needs as they arise. The DSS accommodates decision-making techniques and information technologies, and provides various opportunities in preparing forest management plans while enabling the process to be faster, sound and timely using relatively less amount of time and labour. This DSS is designed to implement contemporary forest management planning processes, conduct scientific studies and exercise training activities particularly in forestry schools. As such, a DSS is indispensable to generate planning alternatives and determine an optimal management schedule among them to justify the sustainable use of forests.

The ETÇAPClassic model was successfully tested on a case study site in Sarıçdağı Forest Planning Unit in Turkey. The results showed that the ETÇAPClassic model was able to compile the sampling data from field inventory and map the results of the plan (forest stratification, age class and site maps etc.) (Sivrikaya 2008). The model was also used to prepare the management plans of Kızılcasu, İbradı, Honaz and Akseki Planning Units for even-aged, uneven-aged and coppiced forests. ETÇAPClassic has contributed to the forest management process with the help of information technologies enabling the process to be faster, sound and timely using relatively less amount of time and labour (Sivrikaya et al. 2010a).

The ETÇAPSimulation and ETÇAPOptimization models were successfully tested and applied in Yalnızçam Forest Planning Unit in Turkey. Non-timber forest values such as water production, soil protection, carbon sequestration and oxygen production were quantitatively integrated in the forest management planning process in this study. Such an approach allowed the integration of strategic and tactical planning components of hierarchical forest management planning systems (Keleş 2008; Keleş et al. 2009a, 2009b). Başkent et al. (2011a) used the ETÇAPSimulation model to project forest ecosystem development over 100 years under three forest management policies of timber-oriented forest management, multipurpose forest management, and no intervention aiming for timber production, carbon sequestration, oxygen production, soil erosion, and water production of a forest management unit in Turkey. In another study, Keleş and Başkent (2011) used the ETÇAPOptimization model to assess the long-term effects of different minimum cutting ages and some forest management policy constraints on timber production, carbon sequestration, oxygen production, soil erosion and water production in a forest management unit in Turkey.

ETÇAPSimulation and ETÇAPOptimization are ready now to be used in some forest management planning units by the General Directorate of Forestry in Turkey. In this context, the developers of the program have given some training courses about the decision support system in various platforms and times. Thus, strategic forest management plans were developed using ETÇAPSimulation and ETÇAPOptimization models and integrated into tactical forest management plans prepared by forest management teams in different forest management planning units. On the other hand, participation of various stakeholders (forest managers, local people, non-governmental organizations etc.) within the forest management planning process was carried out especially in determining potential forest values and harvested areas. Furthermore, the implementation results of ETÇAPSimulation and

ETÇAPOptimization models were tested in various forest management planning units such as Kızılcasu, Gürgendağ, Honaz and İbradı and presented at a national environment and forestry symposium (Keleş et al. 2011; Başkent et al. 2011b; Kadıoğulları et al. 2011; Sivrikaya et al. 2011). ETÇAP DSS will soon be adapted to other forest management areas after evaluation by the Forest Management Department of the Turkish Forest Service.

The ETÇAPSpatial interface program was also successfully applied in the Uğurlu Forest Planning Unit in the context of a scientific study. In this study, spatial forest management planning problems were integrated into a multiple-use forest management planning process (Kadıoğulları 2009). However, the model has not been used by the General Directorate of Forestry in Turkey yet, and we think that it will be soon adopted and used in preparing spatial forest management plans in Turkey.

Based on the main challenges, some of the lessons learned and experiences gained during the development and implementation of the ETÇAP Decision Support System in Turkey include the following:

- There is a need for a greater level of communication and coordination among the stakeholders to understand the legal, scientific, and operational status of multiple-use forest management within managed forest ecosystems. Wider forest management objectives should be formulated with the full participation of stakeholders to meet the timber and non-timber goals. Therefore, regular meetings, training sessions, and sound communication among the various institutions and the stakeholders are necessary to implement structured participation. It is quite difficult to change the traditional understanding of officials, forest management teams, and local people. The officials often lack the concept and basic understanding of biodiversity, conservation programmes, and multiple-use forest planning process as well as modelling concepts. Frequent training programmes for all responsible officers are necessary.

- Experts are needed to provide appropriate forest data for sound establishment of conservation targets, quantitative determination of forest ecosystem values, delineation of various land-use categories, and corresponding actions before finalizing the forest management plans.

- Based on the current forest management regulations, management plans are generally documents with standard tables filled or calculated by simple allowable cut formulas. Forest management plans concentrate mostly upon silviculture and wood utilization, aiming principally at obtaining maximum wood production, while less attention is paid to the social conditions of villagers as key stakeholders. What is now called participatory or joint management is still not operational or outside the implemented management principles of Turkish forests. In this respect, knowledge management techniques should be used to prepare forest management plans and develop DSS.

- Timber-oriented forest management with short-term rotation has the potential to affect the nation’s rich native biodiversity. There is no management design and modelling to prepare a strategic plan. Forests should no longer be regarded as a wood resource to be utilized and should be valued for their ability to provide many other benefits. Thus, multiple use of forest management should be practised with respect to the principles of ecosystem-based multiple-use forest management.

- Furthermore, management plans are prepared under classical area regulation without long-term insight for sustainability. Long-term forecasting of forest dynamics under management interventions is not exercised in the Turkish Forest Service thereby failing to create alternative management options to make better decisions using decision support systems such as operational research techniques. Therefore, there is a need to use decision support systems to accommodate multiple forest values as long-term forest management objectives. In this respect, ETÇAP DSS has a huge potential for the sustainable management of Turkish forests.

References

Asan, Ü. 1999. Multiple Use of Forest Resources and Planning Systems: In meeting on the Multiple Use Forest Management Planning, 5–6 May, 33–40, Bolu, Turkey.

Başkent, E.Z. and Keleş, S. 2005. Spatial Forest Planning: A Review. Ecological Modelling 188: 145 - 173.

Başkent, E.Z., Köse, S. and Keles, S. 2005. Forest management planning system of turkey: constructive criticism towards the sustainable management of forest ecosystems. International Forestry Review 7(3): 208–217.

Başkent, E.Z., Terzioğlu, S. and Başkaya, Ş. 2008a. Developing and implementing multiple-use forest management planning in Turkey. Environmental Management 42 : 37-48.

Başkent, E.Z., Terzioğlu, S. and Başkaya, Ş. 2008b. Developing and implementing participatory and ecosystem based multiple use forest management planning approach (ETÇAP: Yalnızçam case study. Forest Ecology and Management 256: 798-807.

Başkent, E.Z., Keleş, S. and Kadıoğulları, A.I. 2008c. Developing a decision support system for forest management planning. The Scientific and Technological Research Council of Turkey, Project Code: TOVAG 104O355.

Başkent, E.Z. and Keleş, S. 2009. Developing alternative forest management planning strategies incorporating timber, water and carbon values: An examination of their interactions. Environmental Modeling and Assessment 14: 467-480.

Başkent, E.Z., Kadıoğulları, A.İ. and Kırış, R. 2010. Developing Ecosystem Based Multiple Use Forest Management Model and its applicability. In: III. Congress of National Blacksea Forestry, Artvin, Turkey, Volume I, pp. 326-336.

Başkent, E.Z., Keleş, S., Kadıoğulları, A.İ. and Bingöl, Ö. 2011a. Quantifying the effects of forest management strategies on the production of forest values: timber, carbon, oxygen, water and soil. Environmental Modeling and Assessment 16: 145-152.

Başkent, E.Z., Keleş, S., Değirmenci, A.S. and Akgül, C. 2011b. Preparing forest management plans of Cide-Kızılcasu forest management planning unit using ETÇAP Decision Support System: In proceedings of I. National Mediterranean Sea Forest and Environment Symposium, Kahramanmaraş, Turkey. Pp. 1345-1355.

Bingöl, Ö., Başkent, E.Z., Kadıoğulları, A.İ. and Keleş, S. 2010. System analysis, object oriented design and programming of forest management models. In: III. Congress of National Blacksea Forestry, Artvin, Turkey, Volume I, pp. 337-347.

Erkuran, M. 2001. A National Forestry Program for Turkey, Food and Agricultural Organization (FAO) of the United Nations, Tcp/Tur/0066 (6), Consultant Report on Forestry Legislation in Turkey.

GDO, 2006. Forest inventory, General Directorate of Forestry, http://amenajman.ogm.gov.tr/.

Işık, K., Yaltırık, F. and Akesen, A. 1997. Forests, biological diversity and the maintenance of natural heritage. In: Proceedings, XI WFC, Antalya, October 13–22, Volume 2, pp. 3–27.

Kadıoğulları, A.İ. 2009. Controling spatial forest structure with meta-heuristics techniques in forest management planning: spatial planning. PhD Thesis, Karadeniz Technical University, Graduate School of Natural and Applied Sciences, Trabzon, Turkey.

Kadıoğulları, A.İ., Bingöl, Ö., Kırış, R., Sayın, M.A. and Çelik, D.A. 2011. Preparing forest management plan of Denizli-Honaz forest management planning unit using ETÇAP decision support system: In proceedings of I. National Mediterranean Sea Forest and Environment Symposium, Kahramanmaraş, Turkey. Pp. 1333-1344.

Keleş, S. 2008. Designing and developing a decision support system for forest management planning. PhD Thesis, Karadeniz Technical University, Graduate School of Natural and Applied Sciences, Trabzon, Turkey.

Keleş, S., Başkent, E.Z. and Kadıoğulları, A.İ. 2009a. Simulation based forest management planning: A framework. Kastamonu University J. of Forestry Faculty 9 (2): 136-145.

Keleş, S., Başkent, E.Z., Kadıoğulları, E.Z. and Bingöl, Ö. 2009b. Simulation based forest management planning: ETÇAPSimulation. Kastamonu University Journal of Forestry Faculty 9 (2): 124-135.

Keleş, S., Başkent, E.Z. and Küçüker, D. 2010. Preparing forest management plans using ETÇAP model: Case studies of simulation and optimization. In: III. Congress of National Blacksea Forestry, Artvin, Turkey. Pp.314-325.

Keleş, S. and Başkent, E.Z. 2011. An optimization-based model for multiple use forest management planning. Scientia Forestalis 39 (89): 87-95.

Keleş, S., Başkent, E.Z., Karahalil, U. and Günlü, A. 2011. Decision support systems in multiple use forest management planning: A case study in Edremit-Gürgendağ forest management planning unit: In proceedings of I. National Mediterranean Sea Forest and Environment Symposium, Kahramanmaraş, Turkey. Pp. 1377-1388.

Konukçu, M. 2001. Forests and Turkish Forestry, State Planning Organization Publication No: 2630, 238 pp.

Sivrikaya, F., Çakır, G., Kadioğulları, A.I., Keleş¸ S., Başkent, E.Z. and Terzioğlu, S. 2007. Evaluating land use/land cover changes and fragmentation in the Camili Forest Planning Unit of northeastern Turkey from 1972–2005. Land Deg. and Development 18: 383–396.

Sivrikaya, F. 2008. Developing forest management planning software in Turkey. PhD Thesis, Karadeniz Technical University, Graduate School of Natural and Applied Sciences, Trabzon, Turkey.

Sivrikaya, F., Başkent, E.Z., Şevik, U., Akgül, C., Kadıoğulları, A.İ. and Değermenci, A.S. 2010a. A GIS-based decision support system for forest management plans in Turkey. Environmental Engineering and Management Journal 9 (7): 929-937.

Sivrikaya, F., Köse, S. and Kadıoğulları, A.İ. 2010 b. Automation in preparing forest management plan. In: III. Congress of National Black Sea Forestry, Artvin, Turkey. Pp. 279-291.

Sivrikaya, F., Mumcu, D. and Demir, O. 2011. Preparing forest management plans using ETÇAPClassic: A case study in Akseki-İbradı forest management planning unit: In proceedings of I. National Mediterranean Sea Forest and Environment Symposium, Kahramanmaraş, Turkey. Pp. 1389-1396.

Türker, M.F., Öztürk, A. and Pak, M. 2001. Forest law and economics; ownership, scale size and economic analysis of the state forest enterprises constitute the frame of forestry sector. In: Proceedings of the 31st Annual Southern Forest Economics Workshop, March 2001, Atlanta, Georgia. Pp. 49-56.

World Bank 1998. Protected areas and sustainable resource management. TRGE44175.

27 The design and use of forest decision support systems in the USA

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27.1 Introduction

27.1.1 Forest types

About 33% of the 930,000 km^2 of land area in the US. is considered forested by the latest national assessment (Smith et al. 2009). This figure is determined by land-use category as well as forest cover, and so does not include another estimated 80-120,000 km^2 of land with forest cover but another primary land use (mostly in and around urban areas).

The USA contains nine major ecoclimatic zones (Figure 1). In the northeastern and north-central US (predominantly temperate humid zone) there are eight major forest types of at least 4,000 km^2, with Maple-beech-birch (32%) and Oak-hickory (31%) being the most plentiful. Spruce-fir (9%) and White-red-jack-pine (6%) are the most common evergreen forest types. In the southeastern and south-central US, Oak-hickory occupies the largest area, but it is followed by the Loblolly-shortleaf pine (32%). The southeast still has significant area in the Longleaf-slash pine forest type (11%), although this has declined significantly since the 1950s due to conversion to loblolly plantations and exclusion of fire. Oak-pine and Oak-gum-cypress are the next most extensive types in the south-central zone.

The central and central western portion of the country is called the Great Plains and contains relatively little forest cover. A mix of hardwoods is the most common forest type (61%), followed by ponderosa pine (25%). Forest diversity and cover increases around the Rocky Mountains; here pinyon-juniper (33%) is most common, followed by fir-spruce (15%), and mixed hardwoods and Douglas-fir (13% each). Douglas-fir dominates the Pacific Northwest coastal region (37%); ponderosa pine is the second most common (14%), occurring in the eastern portion of the zone. The Pacific Southwest becomes more arid and is occupied mostly by mixed hardwoods (40%) and mixed softwoods (26%). The one state of Alaska comprises the second largest region in the west, and it contains mainly mixed softwoods (46%) and fir-spruce forests (36%) (Smith et al. 2009).

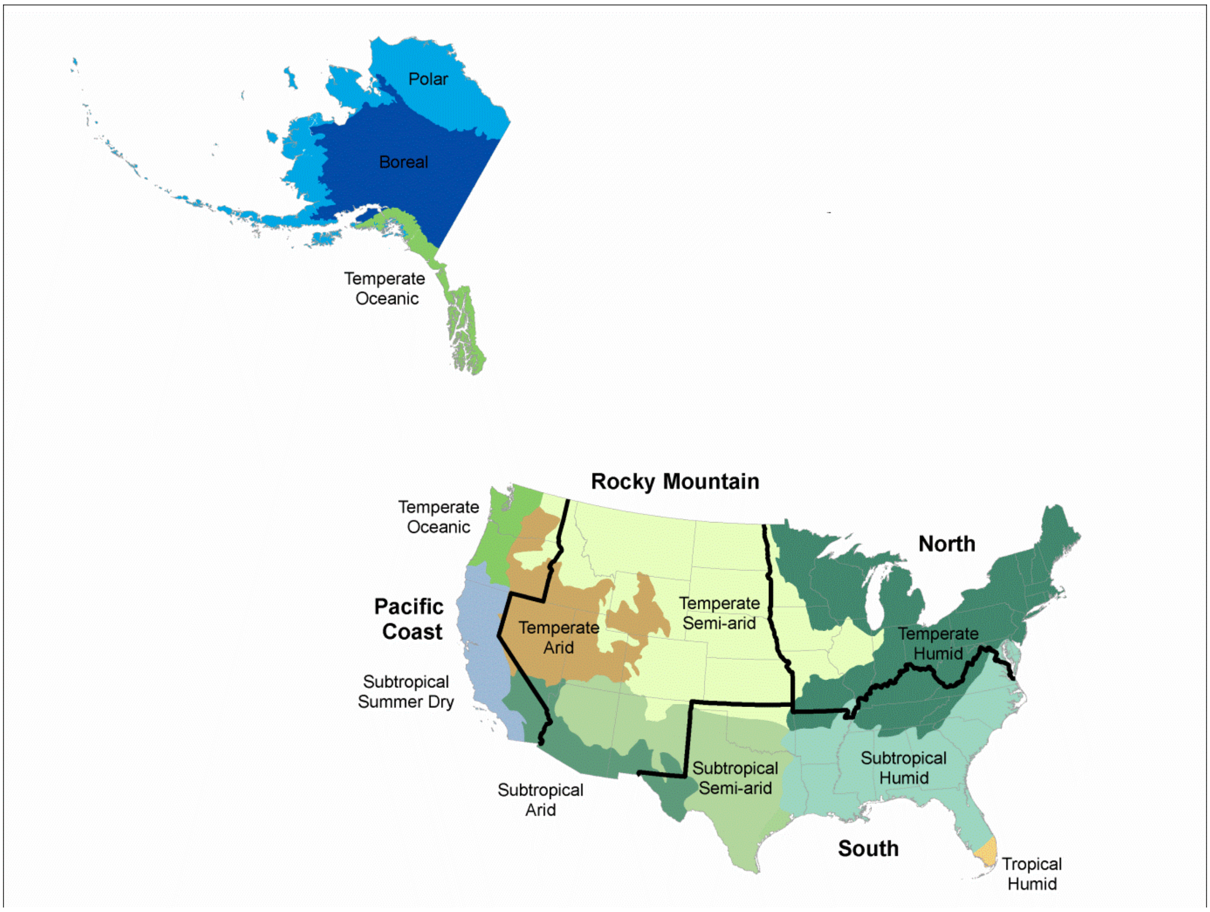


Figure 1. Ecoclimatic zones of the United States (Smith et al. 2009)

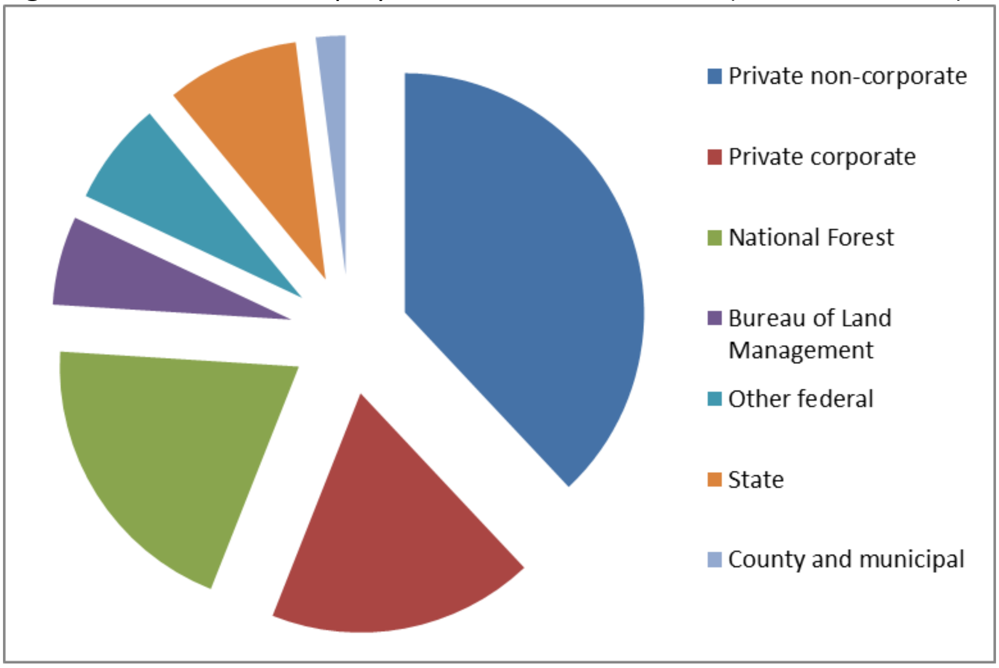
27.1.2 Forest ownership

Forest ownership in the US is diverse. 56% (1.7 million km^2) is owned by private individuals, corporations, and other private groups and 44 % (1.3 million km^2) is controlled by public agencies (Figure 2). Historical development patterns led to more private ownership in the North and South regions, while public ownership dominates in the Rocky Mountain and Pacific Coast regions (Smith et al. 2009).

Private non-corporate owners possess the largest share of forest land (38%, see Figure 2). This class includes families, trusts, non-governmental organizations, clubs, associations, and other unincorporated groups. The majority of lands (62%) within this class belong to individual families. Small private owners (0.4 – 3.6 ha) are the most numerous (61% or approximately 1.1 million owners). 18% of US forest land is owned by private corporations. These owners include forest industry and forest management companies, timber investment management organizations, and other companies that may or may not have forest management as a primary ownership objective (Smith et al. 2009).

There are 155 national forests managed by the US federal Forest Service (USFS), which comprise the largest share of public forest land (20%, 595,000 km^2). The Bureau of Land Management and other federal agencies also control significant acreages. Overall, states own 9% of forest lands in the USA. The amount owned by each of the 50 state governments varies widely, from over 20% (Alaska, Hawaii, Michigan, Minnesota, New Jersey, and Pennsylvania) to less than 1% in some states. The amount of forest land in county/municipal ownership is generally 5% or less by state, with the exceptions of Wisconsin (15%), Minnesota (12%), and a few other eastern states (Smith et al. 2009).

Figure 2. Forest ownership by area in the United States (Smith et al. 2009)



27.1.3 Forest uses and stakeholders

Forest uses are determined primarily by ownership, but they are also subject to the influence of other stakeholders. Major changes in uses, stakeholders, and their methods of influence have occurred in just the last decade (Cubbage and Newman 2006).

Private corporate owners' uses are the most homogeneous, with most focused on commercial timber production. However, a recent decoupling of land ownership from forest products manufacturing may lead to more land sales for housing development. At the same time, corporate forest managers have faced increasing pressure to improve environmental practices (social uses) through forest certification programmes emerging from environmental groups, consumers more generally, and from within their own industry (Cubbage and Newman 2006).

Family forest owners, the largest segment of the private non-corporate owner category, use their forests in diverse ways. The most popular identified uses are for aesthetic purposes (beauty/scenery, privacy, part of home); nature protection and recreation also rank high (Butler 2008). Timber production is important to only about 10% of owners, but it is a significant use for 30% of family-owned areas because it is more important for larger owners. Other non-corporate owners include clubs and associations, which are typically formed around particular recreational activities (e.g. hunting). Many non-profit land-trust organizations exist, from local to national in scope, which own land to preserve open space and provide recreation opportunities. Biodiversity conservation is the dominant purpose for which nature conservation non-profits purchase land. Other stakeholders have influence over these private lands through the promulgation of state regulations, especially related to land conversion, forest practices, water quality, and endangered species.

Public lands are the most subject to the influence of diverse stakeholders and therefore are generally managed for multiple uses, a precept which has been recognized since the establishment of the first public forest reserves by the Organic Act of 1897. Timber production on national forests became a dominant use on national forests post-WWII but has declined since the 1980s due to changes in societal preferences, environmental laws, and increasing pressure from environmental groups. Management for ecosystem health, water quality, and recreation are now all higher public priorities (Shields et al. 2002). To our knowledge, no synthesis of the uses of state and county/municipal forests exists. From our personal knowledge of a few states, we know they have multiple-use mandates similar to federal forests; however, timber harvesting rates may be higher because of their lower public profile and the more direct financing harvesting provides to state institutions (e.g. schools).

27.1.4 Forest management planning

Forest planning in the USA is organized and executed on an ownership basis. Ownership, to a large extent, determines both the objectives of forest management and the planning processes used. Federally-owned forests must comply with a distinct set of federal laws and regulations, which are different than those of state forests and private forests as well. In order to identify comparable types of planning problems across countries, the FORSYS project chose a number of criteria, including objectives, goods and services considered, decision processes, participation, and temporal and spatial scales. Based on these criteria, we have identified five generic planning problem types to describe the USA (Table 1). We have further broken down the broad problem classes into different ownerships within a class, as appropriate.

Table 1. Major US planning problem types and their characteristics

Problem type	Temporal scale	Spatial context	Spatial scale	Decision-making structure	Participation process	Objectives
Private timber-oriented	Tactical (medium-term)	Spatial	Forest	Unilateral	None	Market wood products
Private multiple use	Strategic (long-term)	Spatial	Forest	Unilateral	None	Market non-wood products Market wood products Market services Non-market services

Problem type	Temporal scale	Spatial context	Spatial scale	Decision-making structure	Participation process	Objectives
Public forests	Strategic (long-term)	Spatial	Forest	Collegial	Public	Market non-wood products Market wood products Market services Non-market services
Policy and administrative	Tactical (medium-term)	Aspatial	Regional/ national	Collegial	Stakeholder	Market non-wood products Market wood products Market services Non-market services
Broad scale cross-ownership	Strategic (long-term)	Spatial	Regional	Bargaining/ participative	Stakeholder	Market non-wood products Market wood products Market services Non-market services

The private profit-oriented forest planning type comprises most private, corporately-owned forests and some family forest owners (usually larger properties) that are oriented towards timber production. Decisions for these ownerships are made by a unilateral decision-maker (individual or company) at the scale of forest properties comprising multiple stands and generally with no public participation. Two major trends are influencing the planning in this sector. The first is forest certification. Certification standards generally require planning for longer time frames and broader scope of resources. The second trend is that there has been a recent and pervasive shift from vertically-integrated forest companies to real estate investment trusts (REITs) and timber investment management organizations (TIMOs). This shift can be inferred to change the type of planning done in a two ways. First, although strategic planning in the 50-100 year range continues to be the norm, these corporate structures must give more emphasis to shorter-term financial returns, thus placing more emphasis on medium-term planning (2-10 years). Second, there is a shift from a more exclusive focus on an even flow of timber production to a more opportunistic and broader consideration of land values (e.g. real estate development).

Private non-profit-oriented forest planning includes non-governmental organizations, such as land trusts and the Nature Conservancy, clubs and associations, and family forest owners. The diversity of these owners creates a diversity of planning problems, but in general the approach could be characterized as long-term, spatial (different areas within an ownership), small scale, with a unilateral decision-maker looking at multiple resources, considering both market and non-market goods and services. Larger non-profit organizations, such as the Nature Conservancy and Trust for Public Land have sophisticated planning processes for their own lands and have pioneered techniques in the areas of market and non-market ecosystem services. We are also including non-timber-oriented family forest lands in this category because they appear to share the same characteristics according to the FORSYS criteria. However, the level planning is quite different, with only 4% of family forest owners having a written plan, although this rises to 18% for owners of 40+ hectares (100+ acres) (Butler 2008).

As described above, 44% of US forest land is owned and managed by government organizations at three principle levels: federal, state, and local. Each level, and in fact each state and locality, operate under somewhat different laws and planning rules; however, they are similar enough in broad terms that they can be considered as belonging to one general planning problem type. These plans are generally strategic (long-term), spatial (zones within a larger ownership), and cover market and non-market wood products and ecosystem services. Formal public participation is almost always required and the decision-making approach used is collegial, in the sense that multiple participants express their preferences but a single decision-maker (agency representative, governing commission, etc.) bears the ultimate decision-making authority.

Governments also do forest planning that is not related to specific lands but rather is oriented towards broader forest policy and administration. Examples we include in this category are planning related to state forest regulations and some recent federal level efforts to consistently evaluate and prioritize lands in terms of fire, watersheds, and terrestrial ecosystems. This type of planning is more abstract than the other place-based types, but these plans do have management objectives and they frame decisions in terms of resources considered and when and where management activities can take place. These planning processes focus on the short to medium-term, are non-spatial (or very generally spatial, such as by regions), and cover market and non-market wood products and ecosystem services. Decision-making is collegial (national programme managers, state forestry boards) and includes stakeholder participation.

The fifth and final planning type we have identified is planning across multiple ownerships. In the late 1980s and early 1990s, scientists increased emphasis on the fact that natural patterns and processes do not conform to administrative boundaries. The adoption of this idea by managers became known as ecosystem management, and it spawned a number of broad-scale assessments of forest resources and more focused cross-ownership planning for certain processes (e.g. fire) and landscapes. Both government agencies and larger non-profit organizations have led these efforts. These plans are strategic (long-term), spatial (zones within a larger landscape), and cover market and non-market wood products and ecosystem services. Technically, the decision-making structure for some of these plans has been collegial, where decision authority rests with single agency decision-makers. However, in practice, since cross-ownership assessment is involved, these decisions have been much more political, resulting in more of bargaining/participative decision-making structure.

27.1.5 Objectives of the country report

The objective of this report is to synthesize trends in the diverse requirements of forest planners, in order to identify priorities for the development of DSS to meet future needs.

27.2 Materials and methods

Information about forest DSS used in the USA was developed from the published and grey literature, the internet, and in particular past surveys of forest decision support systems. In one of the latest reviews, Gordon (2006) built on previous surveys to compile a list of over 100 DSS potentially used for forest and biodiversity management, which has been integrated into an online database (University of Redlands and SDS Consortium 2011). As a follow-up to the survey, a series of case studies was compiled, which documented planning problems and DSS uses for a sample of organizations spanning the spectrum from federal to small landowners (Johnson et al. 2007). We also attempt to build on other synthetic reviews of forest DSS (Gustafson et al. 2002; IGDSNRE 1998; Mendoza and Vanclay 2008; Oliver and Twery 2000; Rauscher 1999; Rauscher 2005; Rauscher and Potter 2001; Rauscher et al. 2006; Reynolds et al. 2000; Reynolds 2005; Shao and Reynolds 2006). The following paragraphs describe resources more specific to particular owners.

27.2.1 Private timber-oriented planning

Little literature exists on planning with respect to the types of DSS used by corporate owners, probably because this information is generally regarded as strategic (trade secret) and DSS specialists in this sector are not encouraged to publish. One exception is a trip report prepared by an Australian forest planner (McLarin 2006). We also used case study information from two of the largest forest products firms (Weyerhaueser and International Paper) developed as part of Johnson et al. (2007), and we also consulted with a few colleagues with private sector experience to develop the problem type and DSS applications.

27.2.2 Private multiple-use planning

The US Forest Service conducts an annual survey of family forest owners called the National Woodland Owner Survey (NWOS). The NWOS mails surveys to approximately 6,000 randomly selected forest owners across the nation annually (www.fia.fs.fed.us/nwos/), and Butler (2008) has provided the latest summary. The NWOS asks a number of questions related to planning, including reasons for woodland ownership, management concerns, written plans, and sources of information. Not much published information is available on the use of DSS by family forest owners; however, Kirilenko et al. (2007) cite a few different efforts. Planning processes used by some of the major non-profit landowners are well documented on their websites (TNC 2011; TPL 2011).

27.2.3 Public forest planning

The most extensively studied forest planning problems in the US relate to the national forest system. The Forest Service maintains a website which describes the planning objectives (USDA FS 2010). Although no recent extensive survey of DSS use on national forests exists, two older surveys exist (Mowrer 1997; Schuster et al. 1993). Many more recent applications have reached the published literature because the research community is often involved in their implementation (Gustafson et al. 2006; Shifley et al. 2008).

Forest planning at the state level has been the subject of extensive surveys by the University of Minnesota Center for Environment & Natural Resource Policy (UMCENRP 2011). In particular, Kilgore et al. (2005; 2006) describe the practice and objectives of comprehensive forest planning at the state level, and a wider variety of planning types for the northeastern states. The National Association of State Foresters provides some information on planning (NASF 2011b). No surveys on the use of DSS tools for state or county/municipal forest planning exist, however, Johnson et al. (2007) include a few case studies at these levels, and Barker and Crist (2002) did a survey of local government tool and information use in the related field of biodiversity planning.

27.2.4 Public policy and administrative planning

Few publications on DSS use in public policy and administrative planning have appeared in the peer-reviewed literature; however, a considerable amount of information is available in government documents. State regulations are also covered in the surveys from the University of Minnesota mentioned previously (UMCENRP 2011).

27.2.5 Broad-scale cross-ownership planning

Larger, cross-ownership forest planning efforts are typically well-documented and often result in publications in the peer-reviewed literature. Johnson et al. (1999) broadly describe seven bioregional planning efforts, and Johnson et al. (2007) more specifically review DSS used in five additional cross-ownership planning efforts. Kilgore, Hibbard and Ellefson (2006) synthesized information on comprehensive state forest assessments from a 2003 survey. No synthesis has yet been performed on the results of the recent 2010 mandate for all states to produce such assessments, but individual reports are available through the National Association of State Foresters website (NASF 2011b).

27.3 Results

Table 2 summarizes the major DSS used in the USA by problem type, and Table 3 provides a reference for their abbreviations and websites. A few other related DSS are referenced in the text but not included in these tables because they fell outside the FORSYS core focus of assisting with the timing and location of forest management options.

Table 2. Planning problem types and DSS used

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning
Private timber-oriented	Remsoft Spatial Planning System	- Linear programming - Optimization heuristics - Simulation	Process structuring	Certification
	Habplan	- Linear programming - Optimization heuristics	Process structuring	
Private multiple use	NED	- Simulation - Goal assessment	Written plans	Family conversations
	LMS	- Simulation	Assessment model library	

Problem type	Computerized tool/DSS	Models and methods	KM techniques (if applicable)	Methods for participatory planning
Public forest	FVS	- Simulation	Model library	NEPA/EIS Interdisciplinary teams Internet mapping
	VDDT	- Simulation	Process structuring	
	SPECTRUM	- Linear programming - state, flow, and accessory variables	Process structuring	
	INFORMS ArcFuels Starfire	- simulation	Process structuring	
	Remsoft Spatial Planning System	- Linear programming - Optimization heuristics - Simulation	Process structuring	
	Habplan	- Linear programming - Optimization heuristics	Process structuring	
	NED	- Simulation - Goal assessment		
Policy & administrative	EMDS	- Fuzzy logic - MCDA	Knowledge model structuring	Expert workshops
	LMS	- Simulation	Assessment model library	Public rulemaking processes
Broad-scale cross-ownership	LANDIS	- Simulation	Process structuring	
	VDDT	- Simulation	Process structuring	
	HARVEST	- Simulation	Process structuring	

Table 3. DSS abbreviations and websites

Abbreviation	Full Name	Website or Reference
ArcFuels	ArcFuels	www.fs.fed.us/wwetac/arcfuels/
EMDS	Ecosystem Management Decision Support	www.fsl.orst.edu/emds/
FVS	Forest Vegetation	www.fs.fed.us/fmsc/fvs/

Abbreviation	Full Name	Website or Reference
	Simulator	
Habplan	Habplan	http://ncasi.uml.edu/projects/habplan/
Harvest	Harvest	www.ncrs.fs.fed.us/4153/harvest/harvhome.asp
INFORMS	Integrated Forest Resource Management System	www.fs.fed.us/informs/
LANDIS	LANDIS	http://landscape.forest.wisc.edu/projects/landis.htm
LMS	Landscape Management System	http://lms.cfr.washington.edu/
NED	NED	www.fs.fed.us/ne/burlington/ned
OptFuels	Fuel Treatment Optimization	www.fs.fed.us/rm/human-dimensions/optfuels/main.php
RSPS	Remsoft Spatial Planning System (Woodstock, Spatial Woodstock & Stanley)	www.remsoft.com
Starfire	Starfire	http://warnercnr.colostate.edu/starfire-home/
Spectrum	Spectrum	www.fs.fed.us/institute/planning_center/plan_spectrum.html
VDDT / TELSA	Vegetation Dynamic Development Tool / Tool for Exploratory Landscape Scenario Analyses	www.essa.com/downloads/vddt/ www.essa.com/downloads/telsa/

27.3.1 Private timber-oriented planning

This problem category captures traditional planning for the production of forest products by forest companies and larger, timber-focused individual landowners. McLarin (2006) found the Remsoft Spatial Planning System to be the most widely used, often with a linear programming approach at the strategic level and to reveal tactical scale optima, followed by heuristic or simulation runs at the tactical level to better represent spatial and other constraints. A few firms had used Habplan, a DSS developed by the National Council for Air and Stream Improvement, which is an independent, non-profit research institute that focuses on environmental topics of interest to the forest products industry. Habplan incorporates a spatial optimization heuristic and also a non-spatial linear programming module. Little mention was made of growth and yield modelling, except that one company used FVS. Other significant growth and yield simulators in the western US include Organon and FPS. Interviews with two large forest companies (Weyerhauser, International Paper) indicated that they also developed their own growth and scheduling systems to fit their individual business needs.

27.3.2 Private multiple-use planning

The use of forest planning in this sector is low. Small landowners appear to lack the time, expertise or incentive (relatively simple needs) to use DSS directly. Planning support is generally provided by state and university extension agents, and private consultants (Butler 2008), and there are some documented cases where these professionals have used DSS to help prepare landowner plans.

Johnson et al. (2007) documented the use of NED by a number of consultants in the northeastern US. NED links inventory data and external growth models to provide users with a number of alternative algorithms for translating these data into attainment measures for broad resource goals (visual quality, wildlife, water, wood production, and general ecological objectives) using a rule-based MCDA approach.

Extension agents from Washington State University have used the Landscape Management System (LMS) in forest stewardship planning short-courses to help small, private owners collect inventory data for their tree farm and simulate future economic, ecological, and aesthetic conditions. LMS integrates a number of existing tools into a common software framework, including growth and yield simulators (FVS and Organon) and visualization packages (SVS and Envision). It also links these tools to a geographic information system (ArcGIS) and provides a library of assessment routines (wildlife, carbon, etc.).

A few spreadsheet growth models also have been developed, primarily aimed at smaller landowners: WestPro for simulating uneven-aged Douglas-fir stand growth and yield in the Pacific Northwest (Ralston et al. 2003) and CalPro for California mixed-conifer stands (Liang et al. 2004). Users can choose cutting regimes by specifying the interval between harvests (cutting cycle) and a target distribution of trees remaining after harvest. The state of Texas has developed an online "Timberland Decision Support System," which provides a growth and yield simulator for loblolly pine and a timberland investment calculator (http://tfsfrd.tamu.edu/tdss/default.htm).

Because of the low level of planning by non-industrial owners, Kirilenko et al. (2007) developed an internet-based DSS called 4S (Forest Stand Software Support System, https://www.purdue.edu/apps/forestry) that is designed to be more of an educational tool than a management planning tool. It uses a picture-enhanced interface to allow the user to describe their forest (as a single stand) and then run one of three management approaches (no management, thin from below, commercial harvest). The program stores a matrix of pre-computed yields from FVS, as well as species diversity indices for wildlife and plant groups. The output report consists of these timber yields and diversity indices, but also includes links to further information and extension specialists, thus serving as a "bridge" between forest owners and forestry experts.

27.3.3 Public forest planning

27.3.4 National forest planning

Each of the 155 national forests is required to have a forest-wide plan and to update it every

15 years. Planning for these lands is unique in that it is governed by the National Forest Management Act, a federal law passed by Congress, and a "planning rule," a federal regulation derived from the Act by the USDA Forest Service (USFS) as the responsible agency. These plans are intended to provide strategic guidance (management standards, zoning). Before actions on the ground in a national forest are carried out, project-level planning is done. The basic problem structure and requirements are quite similar to forest-wide planning, except for narrower temporal and spatial scales (tactical, stand-level). In recent years, framing of the planning problem has changed from timber supply to "restoration treatments," which in turn requires more assessment tools for diverse resources and disturbances.

From 1979 to 1996, the USFS required the use of the FORPLAN DSS (and its successor, SPECTRUM), a matrix generator for input to linear programming solvers. Various growth and yield models were used to project management options. Since 1996, there has been a diversification of DSS used. One of SPECTRUM's enhancements is the ability to define and use state, flow, and accessory variables. These variables enable the simulation of ecological processes and can be used as dynamic constraints in the optimization model. Some forests are still using SPECTRUM, but as part of more ecologically-oriented vegetation analyses (see the Boise-Payette-Sawtooth National Forest Plan case study in Johnson et al. (2007)). In general, however, there has been a trend away from optimization approaches, due to difficulties in representing the complexities of the forest system, and towards more use of simulation tools such as FVS and the VDDT state-transition modelling framework. FVS has a variety of extensions, such as for fire and fuels, insects and disease, and wildlife. Other published DSS applications for national forest planning include HARVEST (Gustafson et al. 2006), LANDIS (Shifley et al. 2008), and SIMPPLLE (USDA FS 2008; USDOI BLM 2005).

Since the adoption of a national fire plan (USDA and USDI 2003) fire and fuels management has become a major planning emphasis. There has been considerable DSS development in this area; Peterson et al. (2007) document over 40 tools relevant to fire planning. Tactical planning for fire and fuels at the local level is still diverse. A national effort to improve and harmonize DSS support identified four existing comprehensive fuels treatment planning systems and diagrammed their workflows: INFORMS, ArcFuels, IFP-LANDFIRE, and Starfire (Funk et al. 2009). INFORMS, ArcFuels and Starfire all link various data sources, fire simulation models, and the ArcGIS platform. IFP-LANDFIRE is more of a procedural guidance library that helps planners integrate appropriate tools. An additional system was later identified - OptFuels is a system which integrates existing fire behaviour (FlamMap) and vegetation simulation (FVS-FFE) tools with a simulated annealing optimization system (MAGIS) for land management planning (USDA FS 2011b).

Different types of knowledge management (KM) are embedded in these DSS. FVS encapsulates knowledge of tree species growth and is essentially a model library. SPECTRUM and VDDT do not include any factual knowledge but do incorporate procedural knowledge – they provide methods for problem structuring and ways to store the generated knowledge. The fire and fuels DSS generally include both factual knowledge (in the fire and effects simulation) as well as procedural knowledge in the form of an analysis methodology.

Planning on all federal lands is subject to the National Environmental Policy Act, which requires certain procedures intended to increase public transparency and involvement in the planning process. Although the national forest planning problem requires considerable public participation, the DSS most used do not have any specific capabilities to facilitate it. The public may influence the scenarios projected, but this interaction occurs indirectly through USFS analysts. DSS, beginning with FORPLAN, have broadened participation of disciplinary experts by bringing non-timber concerns explicitly into decision options (Johnson 1987; Gordon 2006). A number of forests are now using internet-based interactive maps to share plan options and solicit input (Brown and Reed 2009). While not a DSS in sense of this project, this approach provides a promising avenue for development of more participatory DSS.

27.3.5 State-owned lands

Most state governments own and manage forest land for the benefit of their citizens. Planning for state lands varies with the amount of state ownership, types of forest owned, and the desired uses and cultural norms of the state. Little synthesis of the use of decision support technologies for state forest planning exists. However, Kilgore et al. (2005) surveyed forestry agencies in 18 northeastern states about their planning efforts and included a section on planning technologies used. They found that geographic information systems were regarded as the most important technology (mean of 3.3 on a scale of 1 to 4), followed by remote sensing (2.6), ecological, economic and resource simulation models (1.9), and decision support models (1.7). Although DSS received the lowest score, the authors added that several planners expressed the need for forest growth, harvest scheduling, and spatial models that could help them assess alternative long-term strategies.

Since no synthesis of specific DSS use by the 50 states exists (and it was beyond the capacity of our effort), we are limited to a few examples: two short case studies on Maryland and Oregon (Johnson et al. 2007) and our personal knowledge of Washington state (WADNR 2010). All three used the common strategy of using growth and yield software to model alternative pathways, which then fed into a harvest scheduling heuristic to help identify efficient strategies. Obtaining accurate growth and yield models over a range of conditions was a major challenge for both Oregon and Washington; both used FVS but had to invest considerable resources in updating inventories and calibrating the model for different areas. The Maryland case focused on a single forest property, and relied on a simpler growth projection using the single-species Tauyield loblolly pine growth model (FMRC 2011).

For harvest scheduling projections, Maryland used the Habplan DSS, and Washington used the Remsoft Spatial Planning System; both are tools used by private industry and are discussed above under private timber-oriented planning (section 3.1). Oregon contracted with a local university professor and DSS specialist to build a customized scheduling system, based on a simulated annealing optimization heuristic. The three states handled goal-setting and environmental effects differently. Maryland included a simple habitat model for the endangered Delmarva fox squirrel in their optimization goals to generate a possibility curve of harvest volume versus habitat. Oregon integrated a coarse-filter measure of old forest with complex structure into the goal statements of four of their five alternatives.

Considerable knowledge management was obviously involved in constructing the DSS in all three states. The Oregon model development process is well described in two publications (Sessions et al. 2006; Overhulser et al. 2006), however, specific knowledge management techniques are not documented.

In regard to participation, the Oregon case mentions that a major shortcoming in the first iteration was that there was little time to involve the various district and field foresters in refining the results. In the second iteration, district foresters were involved at every stage in the development of model inputs and in a feedback loop with the modellers to help check and refine the feasibility of model operations. This on-the-ground feedback was also solicited in the Washington case. All three efforts had to pass through public reviews, but the DSS were not described as playing a role in this process (although their results were certainly scrutinized).

27.3.6 Local governments

Two particular issues related to forests at the local level are protection of water supplies and the control of land use development patterns to preserve natural amenities. Planning related to these issues can be either long-, medium-, or short-term, but is generally spatial (zones within a larger forested area), and covers market and non-market wood products and ecosystem services. Public participation is generally required since the ultimate decision authority is usually a local government council.

Johnson et al. (2007) included two brief case studies on local government DSS-use related to the issues mentioned. The city of Baltimore, Maryland, used a combination of computer-based tools, primarily the ArcView geographic information system (GIS) and the NED forest DSS, to analyze risks to the long-term sustainability of their reservoir lands and to develop and evaluate alternative scenarios for management of the lands. While maintaining water quality was the primary goal, the second and third goals were maintaining and enhancing the forest habitat as a contribution towards regional biodiversity. NED inventories incorporated data needed to evaluate wildlife habitat composition and structure and the quality of habitat along first- and second-order streams. While providing a platform for the management and analysis of data on numerous key abiotic and biotic forest characteristics, the NED decision support software did not provide a mechanism for evaluating the relationships of these landscape elements. The need to understand how landscape context and current ecological processes were shaping the forest required a synthesis of tools and often required stepping outside the decision support mechanism for critical answers to conservation problems.

The second case focused on Summit County, Colorado, which has been one of the fastest growing counties in the nation, while at the same time having over 80% of its land area in a national forest (White River National Forest). Theobald and Hobbs (2002) developed a tool for evaluating the biodiversity impacts of land-use planning alternatives; it does not schedule harvests, as a traditional forest DSS, but rather projects development and associated forest and biodiversity impacts based on alternative zoning options. While tool development ceased with the project, ideas from it were incorporated into a statewide online Natural Diversity Information Source (NDIS). NDIS provides basic county-level statistics, species status lists, and internet maps of historical land-use development trends. Similar in theme, Barker and Crist (2002) did a survey of local government tool and information use related to biodiversity, which identified a need and led to the development of the Vista DSS (www.natureserve.org/prodServices/vista/overview.jsp). Vista is a MCDA tool, which evaluates the interaction between conservation elements and land-use or management policies through user-input decision rules about compatibility between uses/management and the conservation elements.

Another DSS designed for municipalities is the iTree software (www.itreetools.org), which provides urban tree managers with tools for quantifying the structure of their trees and the environmental services that trees provide. Local government interest in forest-related decision support appears more related to ecosystem services than tree growth and harvest scheduling related to traditional wood products.

27.3.7 Policy and administrative planning

27.3.8 Federal interagency planning and national assessments

Federal land management agencies developed with a culture of considerable local autonomy (MacCleery 2008). However, in the last 10 years these agencies have come under increasing pressure from federal oversight agencies to provide nationally-consistent, rational, transparent, and repeatable processes for planning and tracking agency performance on core business activities (GAO 2002; GAO 2003; GAO 2004; GAO 2007). Fire and fuel treatment have been a major focus of these national planning efforts, especially in the western US, where decades of fire suppression have led to fuel buildups. Suppression costs have escalated and yet losses from fire continue to mount.

In 2002, a federal interagency effort to standardize and support fire planning and budgeting was begun and is referred to as the Fire Program Analysis system (FPA, www.fpa.nifc.gov/index.html). The goal is to help prioritize fire management investments, including fire prevention, initial response, and fuel treatment options. One of the first pieces of this system developed was a nationally-consistent vegetation database, called LANDFIRE (Rollins and Frame 2006). The first DSS developed focused on the geographic and administrative allocation of fire-fighting resources (people, planes, etc.). An initial optimization approach was abandoned after it was judged as not sensitive to operational constraints and too vulnerable to inconsistent inputs across planning units; it has been replaced by an approach that simulates and evaluates scenarios designed by local managers (GAO 2009).

At the national level, the EMDS system has been used since 2006 to provide knowledge-based decision support for budget allocation to regions for forest-fuels treatment for the US Forest Service and bureaus of the Department of Interior (Reynolds et al. 2009). EMDS is a system for integrated environmental analysis and planning that provides decision support for landscape-level analyses through logic and decision engines integrated with a GIS system. The logic engine evaluates landscape data against a logic model to derive logic-based interpretations of complex ecosystem conditions such as wildfire potential. A decision engine evaluates outcomes from the logic model, and other feasibility and efficacy data related to fuel-treatment actions, against a decision model for prioritizing landscape treatments, based on the analytic hierarchy process and a simple multi-attribute rating technique.

Two other national-scale assessments of federal lands have more recently been initiated. In 2010, the US Forest Service completed a national assessment of watershed conditions called the Watershed Condition Framework (WCF). The WCF establishes a nationally consistent reconnaissance-level approach for classifying watershed condition, using a set of 12 indicators in a multi-criteria decision analysis approach, modelled after the EMDS methodology (USDA FS 2011c). A similar assessment for terrestrial resources is now being planned.

27.3.9 State forest regulations

In the USA, there is no federal forest practices law that applies to non-federal lands, although landowners must comply with a variety of related federal laws, such as the Clean Water and Endangered Species Acts. State governments often take primary responsibility for regulating and enforcing forest practices on private lands in their jurisdictions. While this is more of a policy-setting than planning activity, states where forest products are an important part of the economy will want to know how different levels of regulation might affect harvesting activity. We would assume that DSS have been used for these analyses in a number of states, but this type of assessment rarely makes it into the published literature. One exception is the documented use of the Landscape Management System (LMS, see private multiple use, section 3.2) by the state of Washington. LMS was used to simulate the possible impacts of new forest practice regulations over 19 scenarios representative of small private landowners. LMS was also used to create templates for alternative management plans that improved forest health while providing sustainable cash flows and that could be easily implemented by landowners regardless of computer skills (RTI 2003; RTI 2005).

27.3.10 Broad-scale cross-ownership planning

There have been intermittent attempts to conduct cross-ownership planning based more on ecological than administrative boundaries. These efforts have been variously referred to as bioregional assessments (Johnson et al. 1999) and landscape planning, with the former generally encompassing larger areas. This planning problem type is similar to policy and administrative planning in the sense that it is strategic rather than tactical. Assessments often do not define the timing and location of forest management options, but they do establish an important context in which such plans are elaborated.

27.3.11 Bioregional assessments and landscape plans

Assessment and planning at this level have used a number of DSS because of their extensive analytical demands and some have had the financial and human resources to create new DSS. The bioregional assessments described by Johnson et al. (1999) were unique efforts. The Nature Conservancy's ecoregional assessment program was one of the first to institutionalize a repeatable process over a variety of landscapes, although its process is focused on biodiversity conservation and not forest management (TNC 2006). Just in the past year, a number of new landscape management initiatives have been started by the primary federal forest management agencies: Collaborative Forest Landscape Restoration Program (USDA FS 2011a), Rapid Ecoregional Assessments (USDOI BLM 2011), and Landscape Conservation Cooperatives (USDOI FWS 2011).

The Vegetation Dynamic Development Tool (VDDT) was developed as part of the Interior Columbia River Basin Ecosystem Management Project (Hemstrom et al. 2001). It has become one of the most popular DSS for broad-scale vegetation simulation modelling because of its relatively simple and flexible state-transition modelling approach. While the basic tool is aspatial, the extension TELSA allows setting up rules for the spatial distribution of results. The VDDT approach enables structuring knowledge (statistical or expert) in models for specific vegetation types and management regimes.

HARVEST is a raster, stand-based simulation model which has been used to project the consequences of alternative harvesting patterns across ownerships (Gustafson et al. 2007). HARVEST simulates harvest practices that reset the age of forested sites to a specific age. This includes even-aged timber harvest techniques (e.g., clearcutting, shelterwood, seed tree techniques) and uneven-aged group selection, and some capability to simulate other uneven-aged techniques where such treatments predictably change stand structure, by using stand age as a surrogate for stand structure. The user specifies harvest parameters (such as harvest size, rotation age, green-up interval) by forest types and management areas over multiple time periods. Management areas are relatively large, multi-stand areas that are to be managed by specific objectives.

LANDIS is another vegetation simulation system which has been used for a number of landscape assessments (Scheller et al. 2007; Scheller et al. 2011; Scheller et al. 2005). It is a more complex tool designed to simulate vegetation over large landscapes (10,000 to 1 million ha) using an interaction of spatially explicit disturbance (wind, fire, insect, and harvesting) and succession regimes.

Knowledge management and participatory techniques are particularly important aspects for planning involving diverse stakeholders, but none of the forest DSS mentioned above include features for these needs beyond their forest modelling focus.

27.3.12 State forest resource assessments and strategies

The federal government supplies a significant amount of assistance funding to state forestry programmes. The most recent reauthorization of these funds included a new requirement for states to prepare state-wide forest assessments and strategies every five years, and the first assessments were due in June 2010 (Food, Conservation, and Energy Act). The plans are intended to address the following objectives (NASF 2011a):

- Identify and provide an analysis of present and future forest conditions, trends, and threats on all ownerships;
- Identify any areas or regions of that state that are a priority;
- Identify any multi-state areas that are a regional priority;
- Incorporate existing forest management plans including state wildlife action plans and community wildfire protection plans.

There has been no survey of the decision support technologies used in these efforts, but review of a few plans and conference presentations suggests that the principal technology application is GIS overlays of various resource layers, often using a scoring system (essentially a multi-criteria decision support approach). This overlay approach could be considered a type of knowledge management aimed at problem structuring and problem solving (identifying priority action areas).

27.4 Discussion and conclusions

The wide diversity of forest owners in the USA leads to a range of planning processes and needs in terms of decision support. Although a few textbooks (Bettinger 2009; Davis et al. 2001) and many journal articles on forest planning have been published in the past decade, there is a scarcity of published surveys regarding forest planning techniques and needs across the sectors. In fact, more synthetic information appears to exist on DSS available than the planning problems in need of support.

27.4.1 Private timber-oriented planning

From the case studies and other literature, we can see that long-time challenges to traditional harvest scheduling problems still exist. Maintaining inventory data of sufficient quality can be a challenge, especially in times of declining budgets. Accuracy related to moving from tactical to operational scales also continues to be an issue. It is becoming possible to integrate more operational feasibility factors (e.g. road access) into DSS models; however, interviews indicate that it is still a difficult process, even in advanced, commercial systems such as Remsoft's (RSPS). Involving field personnel in iterative planning seems to be a key process, but is challenging to do. Further work on knowledge elicitation and management techniques and systems could be helpful here.

27.4.2 Private multiple-use planning

Few DSS options are available for the largest land owner group, small individual and family owners. This sector is a challenge to reach, given how few engage in formal planning. However, as access to and the capabilities of home computers and internet increase, along with the familiarity of these tools to younger generations, there should be more opportunities for DSS to serve this ownership. Basic spreadsheet tools have already been developed related to growth and yield and financial planning. Moving these tools to simple web applications, linking with new visualization techniques and methods for valuing various forest goods, and possibly even structuring them in a gaming format could increase decision support use in this sector.

27.4.3 Public forest planning

The focus of forest plans, especially in the public sector, continues to broaden from trees and timber to a wide variety of ecosystem services. Federal forest planning has moved away from focus on old metrics, such as the "allowable sale quantity" to plans centered on forest restoration. States are preparing comprehensive forest resource plans, and local governments and NGOs are even more focused on non-market services. A trend toward forest management certification and emerging markets for ecosystem services are even driving private, timber-focused owners in this direction. This trend has long been recognized by the DSS community, as evidenced by numerous reviews related to ecosystem management (Mowrer 1997; Oliver and Twery 2000; Rauscher 1999; Reynolds et al. 2000; Reynolds 2005). The principle need appears to be linking the growth and scheduling capabilities of existing forest DSS to methods for valuing the broader set of ecosystem services they provide.

Links to a variety of ecosystem services have been made in many individual modelling efforts, but methods are lacking for systematically managing and sharing this knowledge. For example, innumerable forest-wildlife habitat models have been developed, but these models have not been systematized into libraries similar to those employed by growth and yield models. FVS has some of this ability in terms of adding extensions, but relatively little design and exchange of these occurs between users. The modular approach of LMS is more promising, as it appears to be providing an ever increasing number of “filters” to evaluate forest conditions for wildlife, carbon, and other resources.

Another major challenge to broadening the scope of forest DSS is how to integrate across these various resources. To a large extent analysis and reporting for different resources remain separate: wildlife is modelled and impacts calculated separately from hydrologic concerns, carbon, and so forth. It is then up to the decision-maker to try to synthesize overall impacts, often from resources reported in very different metrics. On the other hand, one of the objections to the FORPLAN model was that it forced the expression of all resources into net present value terms. Obviously there is a balancing act needed here, and DSS should provide methods for the aggregation of different resources, as well as flexibility in the level of aggregation. MCDA tools are already available to accomplish this (EMDS, Vista); NED’s multi-objective focused design has also been pioneering in this regard. However, what is still needed are easier links to forest management models and better ways to model the interactions between resources.

27.4.4 Policy and administrative planning

Policy and administrative planning can exert a strong influence over the timing and location of forest management options, and there appears to be increasing demands for rationalization and transparency that analytical tools can support. At these levels the difficulties of implementing optimization approaches appears even greater than at the individual forest level; there tend to be too many factors which are too poorly understood to accurately quantify and relate. Simulation tools, which allow policy-makers to test scenarios, have had more success. There is a dearth of information on the use of analytical tools related to state forest regulations, a very important arena for forest policy in the US that deserves further study.

27.4.5 Broad-scale cross-ownership assessments

The broadening the scope of public concerns also leads to forests not being considered on their own, but rather as pieces of larger landscapes. In this case, it is forest DSS that must be modified to fit into other modelling frameworks. Non-governmental conservation organizations have pioneered much of the work in this direction in the US because of their focus on the needs of diverse species. One of the top forest concerns for local governments is the impact of development patterns, where the focus of modelling is development and not forest management per se.

Finally, forest (or natural resource) planners in all sectors have come under increasing pressure to broaden the participation in planning. This need is especially acute when considering multi-ownership landscapes. Many national and state forests have been using the internet to share planning documents and solicit public comments, and national forests are developing the capacity to share online interactive maps. The integrative and participatory nature of the new state forest assessments and strategies should position them to serve as web portals for forest issues. The next logical step (and challenge) appears to be linking these capabilities with dynamic DSS, which allow users to test assumptions and learn about ecosystems (and perhaps human systems) instead of being limited to analyses of only a few predetermined options, as is currently the case. Simpler, faster and more visual tools have shown promise in this area (MarineMap 2010). For larger, more complex landscape problems, tiered public involvement strategies have been effective at bridging the science-policy divide (Hulse et al. 2004).

References

Barker, K. and Crist, P. 2002. Market research for the development of a DSS to support local-level land use planning. NatureServe, Washington DC.

Bettinger, P. 2009. Forest management and planning. Academic, Amsterdam ; London. 331 p.

Brown, G.G. and Reed, P. 2009. Public participation GIS: a new method for use in national forest planning. Forest Science 55:166-182.

Butler, B.J. 2008. Family Forest Owners of the United States, 2006. Gen. Tech. Rep. NRS-27. U.S. Department of Agriculture, Forest Service, Northern Research Station, Newtown Square, PA. 72 p. http://treesearch.fs.fed.us/pubs/15758

Cubbage, F.W. and Newman, D.H. 2006. Forest policy reformed: A United States perspective. Forest Policy and Economics 9:261-273.

Davis, L.S., Johnson, K.N., Bettinger, P.S. and Howard, T.E. 2001. Forest management: to sustain economic, ecological, and social values. McGraw-Hill, New York. 804 p.

FMRC. 2011. TAUYIELD 1.1 for Windows. Virginia Tech University, Forest Modelling Research Cooperative, http://frec.vt.edu/ForestModellingResearchCooperative/tauyield.htm (April 30)

Food, Conservation, and Energy Act of 2008. United States Federal Law 110-234, 122 Stat. 923.

Funk, T., Rauscher, M., Raffuse, S. and Chinkin, L. 2009. Findings of the current practices and needs assessment for the Interagency Fuels Treatment Decision Support System (IFT-DSS) project. Sonoma Technology Inc. http://frames.nbii.gov/documents/ift-dss/task1_system_eval_memo_20090121.pdf

GAO. 2002. Severe wildland fires: leadership and accountability needed to reduce risks to communities and resources. United States General Accounting Office, Washington, DC.

GAO. 2003. Forest Service: Little Progress on Performance Accountability Likely Unless Management Addresses Key Challenges. United States General Accounting Office, Washington, DC. http://www.gao.gov/products/GAO-03-503

GAO. 2004. Wildland Fires: Forest Service and BLM Need Better Information and a Systematic Approach for Assessing the Risks of Environmental Effects. United States General Accounting Office, Washington, DC. http://www.gao.gov/products/GAO-04-705

GAO. 2007. Wildland Fire Management: Better Information and a Systematic Process Could Improve Agencies' Approach to Allocating Fuel Reduction Funds and Selecting Projects. United States General Accounting Office, Washington, DC. http://www.gao.gov/products/GAO-07-1168

GAO. 2009. Wildland Fire Management: Federal Agencies Have Taken Important Steps Forward, but Additional, Strategic Action is Needed to Capitalize on Those Steps. United States General Accounting Office, Washington, DC. http://www.gao.gov/products/GAO-09-877

Gordon, S.N. 2006. Decision support systems for forest biodiversity management: A review of tools and an analytical-deliberative framework for understanding their successful application. Oregon State University, Corvallis, OR.

Gustafson, E., Nestler, J., Gross, L., Reynolds, K., Yaussy, D., Maxwell, T. and Dale, V. 2002. Evolving approaches and technologies to enhance the role of ecological modelling in decision-making. In: Dale, V. (ed.). Ecological modelling for resource management. Springer-Verlag, New York. Pp. 135-164.

Gustafson, E.J., Roberts, L.J. and Leefers, L.A. 2006. Linking linear programming and spatial simulation models to predict landscape effects of forest management alternatives. Journal of Environmental Management 81:339-350.

Gustafson, E.J., Lytle, D.E., Swaty, R. and Loehle, C. 2007. Simulating the cumulative effects of multiple forest management strategies on landscape measures of forest sustainability. Landscape Ecology 22:141-156.

Hemstrom, M.A., Korol, J.J. and Hann, W.J. 2001. Trends in terrestrial plant communities and landscape health indicate the effects of alternative management strategies in the interior Columbia River basin. Forest Ecology and Management 153:105-125.

Hulse, D.W., Branscomb, A. and Payne, S.G. 2004. Envisioning alternatives: using citizen guidance to map spatially explicit assumptions about future land and water use. Ecological Applications 14:325-341.

IGDSNRE. 1998. A strategy for the development and application of decision support systems for natural resources and the environment. Interagency Group on Decision Support for Natural Resources and the Environment, http://www.i4sd.org/article-11.html

Johnson, K.N. 1987. Reflections on the development of FORPLAN. In: Hoekstra, T.W., Dyer, A.A. and LeMaster, D.C. (eds.). FORPLAN: An evaluation of a forest planning tool. USDA Forest Service Rocky Mountain Research Station, Denver, CO. Pp. 45-51.

Johnson, K.N., Swanson, F., Herring, M. and Greene, S. (eds.). 1999. Bioregional assessments: science at the crossroads of management and policy. Island Press, Washington, D.C.

Johnson, K.N., Gordon, S.N., Duncan, S., Lach, D., McComb, B. and Reynolds, K. 2007. Conserving creatures of the forest: A guide to decision-making and decision models for forest biodiversity. College of Forestry, Oregon State University, Corvallis, OR. 88 p.
http://ncseonline.org/sites/default/files/A10%20%28II%29%20Final%20Report%20ConservingCreatures%208.21.07.pdf

Kilgore, M., Salk, R., Carpenter, C. and Prichard, T. 2005. State forest resource planning programs in the northeast United States. Northern Journal of Applied Forestry 22:221-228.

Kilgore, M.A., Hibbard, C.M. and Ellefson, P.V. 2006. Comprehensive strategic planning for the use and management of forest resources: The experiences of state governments in the United States. Forest Policy and Economics 9:42-49.

Kirilenko, A., Chivoiu, B., Crick, J., Ross-Davis, A., Schaaf, K., Shao, G., Singhania, V. and Swihart, R. 2007. An Internet-based decision support tool for non-industrial private forest landowners. Environmental Modelling & Software 22:1498-1508.

Liang, J., Buongiorno, J. and Monserud, R.A. 2004. CalPro: a spreadsheet program for the management of California mixed-conifer stands. Gen. Tech. Rep. PNW-GTR-619. 32 p.
http://www.treesearch.fs.fed.us/pubs/viewpub.jsp?index=7506

MacCleery, D. 2008. Re-inventing the United States Forest Service. In: Durst, P., Brown, C., Broadhead, J. [and others]. (eds.). Re-inventing forestry agencies: experiences of institutional restructuring in Asia and the Pacific. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. Pp. 45-78.

MarineMap. 2010. MarineMap consortium wins award for innovation in technology from the U.S. Institute for Environmental Conflict Resolution. MarineMap Consortium, http://marinemap.org/news/marinemap-wins-innovation-in-technology-award (April 30)

McLarin, M. 2006. Forest estate modelling of multiple-use forest management. http://www.gottsteintrust.org/media/mmclarin.pdf

Mendoza, G.A. and Vanclay, J. 2008. Trends in forestry modelling. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 3:1-9.

Mowrer, H.T. 1997. Decision support systems for ecosystem management: an evaluation of existing systems. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

NASF. 2011a. Forest action plans. National Association of State Foresters, http://www.forestactionplans.org (June 11)

NASF. 2011b. National Association of State Foresters. National Association of State Foresters, St. Paul, MN. http://www.stateforesters.org (Feb 29)

Oliver, C.D. and Twery, M.J. 2000. Decision support systems: models and analyses. In: Johnson, N.C., Malk, A.J., Sexton, W.T. [and others]. (eds.). Ecological Stewardship: A Common Reference for Ecosystem Management. Elsevier Science Ltd. Pp. 661-685.

Overhulser, P., Sessions, J., Holloway, R., Rasmussen, M. and Johnson, D.L. 2006. Oregon state forests - an approach to policy analysis under complex demands. In: (ed.)^(eds.) CAES--FLP --CATPRN Joint Workshop: Crisis in Agriculture and Resource Sectors: Analysis of Policy Responses. Calgary, Alberta. October 17. http://www.farmlevel.re.ualberta.ca/Meetings/Overhulser.pdf

Peterson, D.L., Evers, L., Gravenmier, R.A. and Eberhardt, E. 2007. A consumer guide: tools to manage vegetation and fuels. GTR-PNW-690. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. http://www.treesearch.fs.fed.us/pubs/25953

Ralston, R., Buongiorno, J., Schulte, B. and Fried, J. 2003. WestPro: a computer program for simulating uneven-aged Douglas-fir stand growth and yield in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-574. USDA Forest Service, Pacific Northwest Research Station, Portland OR. http://www.treesearch.fs.fed.us/pubs/viewpub.jsp?index=5344

Rauscher, H.M. 1999. Ecosystem management decision support for federal forests in the United States: a review. Forest Ecology and Management 114:173-197.

Rauscher, H.M. 2005. Decision-support systems for forest management. Computers and Electronics in Agriculture 49:1-5.

Rauscher, H.M. and Potter, W.D. 2001. Decision support for ecosystem management and ecological assessments. In: Jensen, M.E. and Bourgeron, P.S. (eds.). A Guidebook for Integrated Ecological Assessments. Pp. 162-183.

Rauscher, H.M., Schmoldt, D.L. and Vacik, H. 2006. Information and knowledge management in support of sustainable forestry: a review. In: Shao, G. and Reynolds, K.M. (eds.). Computer Applications in Sustainable Forest Management Including Perspectives on Collaboration and Integration. Springer-Verlag, New York.

Reynolds, K., Bjork, J., Hershey, R.R., Schmoldt, D., Payne, J., King, S., DeCola, L., Twery, M. and Cunningham, P. 2000. Decision Support for Ecosystem Management. In: Johnson, N.C., Malk, A.J., Sexton, W.T. [and others].

(eds.). Ecological Stewardship: A Common Reference for Ecosystem Management. Elsevier Science Ltd. Pp. 687-721.

Reynolds, K.M. 2005. Integrated decision support for sustainable forest management in the US: fact or fiction? Computers and Electronics in Agriculture 49:6-23.

Reynolds, K.M., Hessburg, P.F., Keane, R.E. and Menakis, J.P. 2009. National fuel-treatment budgeting in US federal agencies: capturing opportunities for transparent decision-making. Forest Ecology and Management 258:2373-2381.

Rollins, M.G.; Frame, C.K., tech. eds., 2006. The LANDFIRE Prototype Project: nationally consistent and locally relevant geospatial data for wildland fire management. Gen. Tech. Rep. RMRS-GTR-175. Fort Collins: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 416 p.

RTI. 2003. Fact Sheet #20: Impacts of the Forest and Fish Rules on non-industrial private forest landowners in north eastern Washington: some key consequences from riparian zone case study evaluation. University of Washington, Rural Technology Initiative, Seattle, WA. http://www.ruraltech.org/pubs/fact_sheets/fs020/index.asp

RTI. 2005. Fact Sheet #36: Technology transfer from research to forestry applications: using the Landscape Management System (LMS). University of Washington, Rural Technology Initiative, Seattle, WA. http://www.ruraltech.org/pubs/fact_sheets/fs036/index.asp

Scheller, R.M., Mladenoff, D.J., Crow, T.R. and Sickley, T.A. 2005. Simulating the effects of fire reintroduction versus continued fire absence on forest composition and landscape structure in the Boundary Waters Canoe Area, northern Minnesota, USA. Ecosystems 8:396.

Scheller, R.M., Domingo, J.B., Sturtevant, B.R., Williams, J.S., Rudy, A., Gustafson, E.J. and Mladenoff, D.J. 2007. Design, development, and application of LANDIS-II, a spatial landscape simulation model with flexible temporal and spatial resolution. Ecological Modelling 201:409-419.

Scheller, R.M., Hua, D., Bolstad, P.V., Birdsey, R.A. and Mladenoff, D.J. 2011. The effects of forest harvest intensity in combination with wind disturbance on carbon dynamics in lake states mesic forests. Ecological Modelling 222:144-153.

Schuster, E.G., Leefers, L.A. and Thompson, J.E. 1993. A guide to computer-based analytical tools for implementing national forest plans. USDA Forest Service, Intermountain Research Station,

Sessions, J., Overhulser, P., Bettinger, P. and Johnson, D. 2006. Linking multiple tools: an American case. In: Shao, G. and Reynolds, K.M. (eds.). Computer Applications in Sustainable Forest Management Including Perspectives on Collaboration and Integration. Springer-Verlag, New York. Pp. 223-238.

Shao, G. and Reynolds, K.M. (eds.). 2006. Computer Applications in Sustainable Forest Management Including Perspectives on Collaboration and Integration. Springer-Verlag, New York.

Shields, D.J., Martin, I.M., Martin, W.E. and Haefele, M.A. 2002. Survey results of the American public's values, objectives, beliefs, and attitudes regarding forests and grasslands: A technical document supporting the 2000 USDA Forest Service RPA Assessment. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO. 111 p. http://www.treesearch.fs.fed.us/pubs/4817

Shifley, S.R., Thompson, F.R., III, Dijak, W.D. and Fan, Z. 2008. Forecasting landscape-scale, cumulative effects of forest management on vegetation and wildlife habitat: A case study of issues, limitations, and opportunities. Forest Ecology and Management 254:474-483.

Smith, W.B., Miles, P.D., Perry, C.H. and Pugh, S.A. 2009. Forest resources of the United States, 2007. Gen. Tech. Rep. WO-78. U.S. Department of Agriculture, Forest Service, Washington Office, St. Paul, Minn.

Theobald, D.M. and Hobbs, N.T. 2002. A framework for evaluating land use planning alternatives: protecting biodiversity on private land. Conservation Ecology 6:5.

TNC. 2006. Conservation by Design: A framework for mission success. The Nature Conservancy, Washington DC. http://www.conservationgateway.org/file/conservation-design-framework-mission-success

TNC. 2011. Planning at The Nature Conservancy. The Nature Conservancy, http://www.conservationgateway.org/content/planning-nature-conservancy (March 27)

TPL. 2011. Conservation Vision & GIS. The Trust for Public Land, http://www.tpl.org/what-we-do/services/conservation-vision/ (March 27)

UMCENRP. 2011. University of Minnesota Center for Environment & Natural Resource Policy. University of Minnesota Center for Environment & Natural Resource Policy St. Paul, MN. http://www.forestry.umn.edu/ENRPolicyCenter/Research/natResGovernance.html (Feb 29)

University of Redlands and SDS Consortium. 2011. Resources: tools and models. http://www.institute.redlands.edu/sds/ontology/tools/ (January 10)

USDA and USDI. 2003. National Fire Plan. US Department of Agriculture Forest Service and US Department of Interior Bureau of Land Management, Washington, DC. http://www.fireplan.gov

USDA FS. 2008. Beaverhead-Deerlodge National Forest, Revised Forest Plan, Final Environmental Impact Statement. U.S. Department of Agriculture, Forest Service, Region 1, http://www.fs.fed.us/r1/b-d/forest-plan/index-plan-document-maps.shtml

USDA FS. 2010. The forest planning rule. U.S. Department of Agriculture, Forest Service, http://fs.usda.gov/planningrule (December 20)

USDA FS. 2011a. Collaborative Forest Landscape Restoration Program. USDA Forest Service, http://www.fs.fed.us/restoration/CFLR/ (April 22)

USDA FS. 2011b. OptFuels: Optimizing Spatial and Temporal Treatments to Maintain Effective Fire and Non-Fire Fuels Treatments at Landscape Scales. USDA Forest Service, Rocky Mountain Research Station, http://www.fs.fed.us/rm/human-dimensions/optfuels/main.php (April 30)

USDA FS. 2011c. Watershed Condition Framework: a framework for assessing and tracking changes to watershed condition. FS-977. U.S. Department of Agriculture, Forest Service, Washington, DC. 24 p. http://www.fs.fed.us/publications/watershed/Watershed_Condition_Framework.pdf

USDOI BLM. 2005. Proposed Dillon resource management plan and final environmental impact statement. United States Department of Interior, Bureau of Land Management, http://www.blm.gov/mt/st/en/fo/dillon_field_office/rmp/Final.html

USDOI BLM. 2011. Rapid ecoregional assessments. US Department of Interior, Bureau of Land Management, http://www.blm.gov/wo/st/en/prog/more/climatechange/reas.html

USDOI FWS. 2011. Landscape conservation cooperatives. US Fish and Wildlife Service, http://www.fws.gov/science/shc/lcc.html (April 22)

WADNR. 2010. Forest land plan for the South Puget Habitat Conservation Plan planning unit: final environmental impact statement. Washington Department of Natural Resources, Olympia, WA. http://www.dnr.wa.gov/ResearchScience/Topics/SEPANonProject/Pages/amp_sepa_nonpro_flp_southpuget.aspx

28 Addressing forest management planning problems with computerized tools. A synthesis of the experience world-wide

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28.1 Introduction

FORSYS aimed at producing decision support guidelines for forest management planning problems, generally understood as problems that involve the definition of the timing and location of forest management options in order to approximate or optimize management objectives, that are single or multiple and relate to goods and services that are traded or non-traded, subject to resource constraints (Chapter 1). Each FORSYS country report encompassed a listing of problems that are prevalent in the participating country as well as a presentation and a discussion of the tools used to address them. The use of a standard set of dimensions to characterize each problem (Chapter 1) brought together the world-wide experience and provided valuable input to the development of the decision support guidelines. In this chapter we summarize the management planning problems prevalent in the FORSYS participating countries and we discuss the world-wide experience in addressing them with computerized tools.

28.2 The management planning problems

The FORSYS standards contributed to a successful listing of management planning problems prevalent in participating countries (Table 1). In total 250 problem instances were reported, reflecting the diversity of environmental, socioeconomic and institutional contexts in the 26 countries. Some authors were more selective than others and listed fewer problems (e.g. the case of Brazil that eliminated stand-level problems due to their variability). Yet, with the exception of the Netherlands and Turkey that reported 72 and 1 problems, respectively, the number of problems listed by each country ranged from 4 to 16. Further, despite the high level of detail used to describe a forest management planning problem, out of the 168 problem instances reported by all countries (with the exception of the Netherlands) a total of 31 were found to be present in more than one country. Thus the total number of different problems reported from these countries amounted to 137.

According to the reports, the problem most prevalent in the participating countries encompasses a regional scale, a long-term planning horizon, a non-spatial context, more than one decision-maker/stakeholder, multiple objectives and addresses the supply of both wood and non-wood market goods as well as both market and non-market services. This is typically a strategic scenario analysis problem designed to address forest resources sustainability concerns and policy considerations at regional and national levels. Eleven out of the twenty-six participating countries reported this problem as prevalent in their context (Canada, Finland, Germany, Greece, Hungary, Italy, Netherlands, Norway, Portugal, Spain and USA). Second in the list we find both a forest level and a stand level problem. The former encompasses a long-term planning horizon, a spatial context with no neighborhood relations, more than one decision-maker/stakeholder, multiple objectives and addresses the supply of both wood and non-wood market goods as well as both market and non-market services. It is a problem often faced by managers of public forests; it requires the outline of a multi-purpose management plan taking into account various interests and opinions from ordinary citizens and other stakeholders. Six countries reported this problem (Canada, Brazil, Netherlands, Portugal, Spain and USA). The stand-level problem is reported by five countries (Chile, Finland, Germany, Hungary and Russia); it is characterized by a short-term planning horizon, a spatial context with no neighbourhood relations, one decision-maker/stakeholder, a single objective and addresses the supply of market wood products. It is an operational problem often faced by individual forest owners; it may encompass specific harvest decisions e.g. harvesting type, post-operation treatments as well as concerns with timber sales.

The long-term temporal dimension is present in 107 out of the 250 problem instances while the medium and the short term horizon is present in 81 and 62 problem instances, respectively. This is consistent with the long-term biological features of most forest management planning problems. The most common spatial scale is the forest. This is associated with 109 problems while the regional and the stand scales are associated with 61 and 80 problems, respectively. The regional-scale problems are typically associated with multiple objectives and a wide range of products and services within a multiple decision-makers and stakeholders context, while the stand-scale problems typically address a single objective within a single decision-maker context (e.g. a non-industrial (small-scale) forest owner, NIPF). Forest-scale problems tend to me more diverse and numerous as they encompass several types of ownership.

Locational specificity is reported as being important in more than seventy percent of the problem instances while further spatial detail (e.g. addressing neighborhood relations) is needed in less than half of these problem instances (72 out of 179). Nevertheless these figures should be interpreted thoughtfully as some authors reported stand-level problem instances as not being associated with locational specificity thus suggesting a misinterpretation of this dimension. As expected the spatial detail needed tends to increase when we move from the regional to the forest scale.

About fifty four percent of the problem instances reported are associated with a single decision-maker / stakeholder context while almost eighty percent involve multiple objectives. Market wood products are important in about ninety percent of the problem instances while market non-wood products, market services and non-market services are present in 48, 55 and 69 percent of the problem instances. Only 5 percent of the problem instances do not encompass the supply of market products or services.

The number of problem instances that share values of several dimensions is large. This suggested a clustering approach to group problems with similar features. The values of the temporal and the spatial scale dimensions contribute to a substantial differentiation of management planning problems. Often they are correlated with other dimensions such as the spatial context. For example, typically, the level of spatial detail for management planning purposes increases as we move from long to medium and short-term temporal dimensions. Further, they often determine both the data and the management techniques required to address the management planning problem. Thus they were used to define the problem clusters that prevail in the participating countries in order to facilitate the presentation and discussion of computerized tools used world-wide to address them.

The clustering approach started by grouping problem instances according to the spatial scale thus producing regional, forest and stand clusters. Most regional problems reported shared values of other dimensions (e.g. most encompass multiple objectives and are associated with multiple decision-makers / stakeholders contexts) and thus this cluster was no further partitioned. It encompasses 61 problem instances corresponding to 24 problem types (Table 1).

The forest-level problems are evenly split by the temporal dimension (30 long-term problems types and 31 medium and short-term problems types). Thus this cluster was split according to the spatial scale dimension (Table 1) into two sub-clusters. The long-term sub-cluster is also evenly split by the type of products and services supplied. 15 out of the 30 long-term forest-level problem types reported do not involve the supply of non-market goods or services. Thus this sub-cluster was further subdivided according to the values of the goods and services dimension. The number of forest-level problem instances reported was 16, 34 and 59 in the case of, respectively, the long-term associated solely with market products and services sub-cluster, long-term associated with both market and non-market products and services sub-cluster and the medium and short-term sub-cluster.

The stand-level cluster was also partitioned into a long-term and a medium and short-term sub-clusters encompassing 27 and 52 problem instances (Table 1) corresponding to 16 and 25 problem types, respectively. Finally, forest and stand level clusters were also subdivided into 4 additional sub-clusters to group the problem instances that targeted timber as its single product.

28.3 Computerized tools used to address the management planning problems

The wide range of management planning problems prevalent in the 26 countries is matched by the variability of computerized tools developed and used to address them. Nevertheless, some computing resources and techniques are pervasive e.g. the case of using very creative mechanisms for integrating electronic spreadsheets, geographic information systems and relational database management software. The literature reports several approaches to classify computerized tools used to address forest management planning problems (e.g. Borges et al. 2003, Gordon et al. 2005, Mower 1997, Nabuurs and Päivinen 1996, Rauscher and Reynolds 2005, Reynolds and Schmoldt 2006, Reynolds et al. 2005 and 2008, Schuster et al. 1993). Further, it provides several definitions of automated decision support systems (DSS) (e.g. Zahehi 1993, Mallach 1994, Turban and Aronson 2004).

In this research we have built from previous work to define as DSS any computerized tool with a graphical user interface that includes a data management module and a solution module i.e. a module that provides guidance and support to define the timing and the location of forest management options. We thus classified as DSS any traditional DSS, intelligent systems i.e. expert-based systems, knowledge-based systems, artificial neural networks and hybrid systems combining features of the former. Spatial analysis, temporal projection capabilities, other knowledge management functionalities and availability of explicit support to participatory processes were further used to classify the DSS reported by the participating countries. After presenting a short summary of the most relevant aspects of all country reports we take advantage of this computerized tool classification scheme to check and discuss how each problem type cluster is addressed by all countries.

Austria has four problem types. They are all multiple-use spatial problems with or without neighborhood interrelations, representing either strategic or tactical dimension. Two of them represent stand level problems and one represents regional/national level problems. Austria has multiple visually appealing DSS tools for all three problem types. The DSS tools are mainly developed in R&D projects and they are being used by forest professionals in different organizations, and in some cases also by stakeholders and forest owners. Typically the Austrian DSS tools are built on Web GIS platform offering real-time mobile use. There is a strong focus on knowledge management and prioritization using multi attribute utility functions (MAUT) in the Austrian DSS. The tools address well at least some aspects of the problem types, but because the problems defined are rather wide, the tools appear to provide solutions for “sub-problems”.

Electronic spreadsheets prevail during the initial phases of forest DSS in **Brazil** (intelligence and design). Meetings, workshops and interviews are organized to clarify cost assumptions, objective goals and strategy validation. Data is then typed into commercial matrix generator software. During the design phase, the expert team creates basic models supported by commercial matrix generators like Woodstock, Planflor, Optimber, and *in house* software; data is read from relational databases, transferred to electronic spreadsheets and text files that work as input files to the different brands of matrix generator software. VB macros, C# and SQL procedures are the most common languages used to integrate these different computing and matrix generator environments. The process is considered participatory once the model building phase depends on the previous work of other parties involved (operational, logistics, controllers, GIS team). Regular use of Forest DSS in Brazil is still confined to a very small group of users, most of them working exclusively for the pulp and paper industrial sector. These DSS deal basically with problem types that typically present long term temporal scale, spatial context with no neighborhood interrelations and spatial scale at the forest level, more than one decision maker, are oriented to market wood products and multiple objectives. These multiobjective problems have been solved using goal programming formulations. Other reported cases in Brazil involve basically the same type of problems, but either have only one objective function (six cases) or consider spatial interrelation with neighboring forest stands (one case). Most of the applications still do not incorporate the full potential of mathematical optimization, multi objective techniques, expert system support etc. But, in close cooperation with research activities and graduate programs in the main Brazilian Universities, the use of forest management DSS tools have regularly increased and expanded among forest managers and decision makers.

Most of the forest land in **Canada** is publicly owned and administered by provincial and territorial governments which refer to these areas as Crown land. The policies and procedures that govern the management of Crown land vary from local government to local government based on the form of tenure providing forest companies with access to the forest resources on that land. Forest companies that develop plans for their sustainable forest licensed management units use strategic forest management planning models. The management of public forests also relies on DSS. On Crown land in Ontario, for instance, three systems (SFMM, FSOS and Patchworks) have been approved for forest management planning. Many other forest management planning tools including forest growth and yield models, forest inventory data and spatial planning database systems are also intensively used. A list with the currently most used forest management DSS in Canada would include nineteen different systems.

Mainly oriented to support the management of industrial forest plantations, the development of DSS in **Chile** has evolved based on a strong cooperation between industry and academia. As a result, for the last 30 years, short term planning applications involving the use of linear programming and heuristics have been developed to solve problems like the daily dispatch of trucks, road design, positioning of harvesting machinery in the field and logging. For problem types involving medium and long term planning horizons, at the tactical and strategic levels, the same type of industry-university cooperation has also resulted in MILP and LP applications and formulations to attend the needs of the forest industry in South America and Africa.

State and private forests occupy state-owned or collectively-owned land in **China**. In state forests, governmental agencies are responsible for the management of logging, farming and conservation activities. Local communities or individual households have assumed the management of non-state forests. Computerized forest management tools in China encompass GIS and relational database applications as well as both mathematical programming and knowledge management techniques.

Denmark reports six problem types. Three of the problems are medium or short term forest level problems; two are long term forest level problems. There is only one regional/national level problem and no stand level problems. All problems have a multiple objective character. Denmark has multiple DSS tools for addressing all problem types except the regional/national level planning. The tools are mainly developed for practical use in planning of public and private forestry. Typically, the DSS have GIS facilities to allow for inspection of spatial consequences of stand wise management decisions. Stand level simulators provide large scale forestry with growth and yield models, whereas non-industrial private forest owners use basic information such as stand list information in their planning.

Estonia has seven problem types. They present rather equally short and long term, spatial and non-spatial characters, and single and multiple objectives. It is notable that none of them represents regional/national level. Companies' own information systems and freeware GIS/Web-map tools typically address Estonia's problem types, although they may not be labelled as DSS. Prevalent methods in use are stand simulation models and knowledge-management rules for stand management. Forest register database is used in one problem type, and nature conservation database EELIS is used in another problem type. Both repositories are maintained by state administration. However, the university-based ForMIS tool, capable of conducting model-based forest calculations and model verifications, is not in practical use for solving the prevalent problem types. There are currently no tools for two problem types, because those tools are under development.

Finland has five problem types, which represent all problem dimensions rather equally. Finland has a tradition to address strategic forest management problems by means of facilitated stakeholder group processes in which forest simulation and optimization software as well as GIS and MAUT methods are used. The DSS tools used are typically developed in research-driven processes and they have a long history. Forest professionals use the tools in practice, but the use of computerized tools for operational and tactical planning problems has so far been rather straightforward compared to more adaptive and sophisticated use in addressing the strategic problem types. There is a recognized need to educate practitioners to better use the capabilities of available DSSs in the prevalent planning problems.

Germany reports seven main problem types (which result from cluster analysis of 329 problem types initially reported by the German forest planning experts). Three are stand level operational problems, two are forest level tactical problems, and two are regional strategic problems. In general all goods and services are considered but there are three problems that only focus on wood-market goods. Germany classifies DSS tools in data oriented tools (data modeling, relational databases), model oriented tools (e.g. simulation models to develop management scenarios, risk models) and decision oriented tools (full DSS; based on data and model oriented tools decision processes are modeled and solved). Many of the presented tools integrate/use knowledge management (mind mapping, database management systems, GIS, data mining and ontologisms) and participatory planning (applied for the identification of problems, design and problem modeling, and decision making). The presented tools address the solution of the seven presented problem types. Data and model oriented tools are widely used in practice. Recently, decision oriented tools are being developed (by scientists) in close cooperation with project partners from forestry practice. The systems achieved prototype status and are applied in test applications by forestry operations and forest administrations.

Great Britain reports nine problem types. Five of the forest level problems are medium or short term and only one is long term. Two of the problems are regional/national level problems and four are stand level problems. There are no short term planning problems. Great Britain uses six DSS tools to address their nine problem types. These tools are all developed by Forestry Commission, the governmental forestry organization. They are mainly intended for practical use within the organization; for guiding decisions on forest management and making predictions of risks. The DSS are based on empirical models combined with statistical analysis or database queries but does not contain features for forest simulation or optimization.

Greece reports six problem types, four are strategic (i.e. long term) planning problems, one is tactical and one is operational planning problems. Most of the problems are forest level problems and regional/national levels are also represented. Stand level problems are not presented. Most of the problems are described as multi-objective problems. In Greece, most of the reviewed forest management DSSs were concerned with forest fire risk assessment (including forest fire simulators), analyzing and optimizing forest fire fighting strategies on operational spatial and forest level scale and their relationship to the socio-economic and environmental impact. Other six are concerned with sustainability assessment of investment projects in mountainous Mediterranean areas. The methods used for the DSS development were: forest fire simulators, goal programming, fuzzy logic, multi-criteria analysis and heuristics. The tools are all developed in research projects and used either for research or in practice for large-scale forest planning, or both.

Hungary reports sixteen problem types: four stand-level problems (2 operational, 2 strategic); one forest-level strategic problem (on market-wood products); five forest-level tactical and operational problems; and six regional/national problems (3 strategic, 3 tactical). In general all goods and services are considered but some problem types concentrate only on market-wood products. Hungary reports twenty DSS tools which address all prevalent problem types. The presented tools range from the National Forestry database (relational database linked to GIS/mapping) to forest fire simulators or tools for harvest optimization. The National Forestry Database is the main tool for forest management planning and is clearly addressed to practical use. The other presented tools are applied to some extent but mainly used by researchers. Many of the tools use knowledge management (relational databases; GIS/mapping). Some tools are used in participatory processes (although they do not integrate a specific module for it).

Ireland reports thirteen problem types. Eight of them are stand level problems. There are three forest level problems, all of them either medium or short term. Two of the problems are on regional/national level. Ireland reports eleven DSS tools, which address nine of the prevalent problem types. The tools are mainly developed in R&D projects and they are being used by forest professionals in different organizations, industry and in some cases also by private forest owners. The tools typically include forest simulation models, optimization and GIS features. Four problem types are not addressed by any tool for various reasons; there is no need for tools, the problem types are partly handled by existing tools, or the area is under investigation.

In the case of **Italy** four problem types are predominant which present 10 different instances of the problems. These are mainly differentiated by the spatial scale (e.g. region, district, single property and stand). The regional and district-level problems are strategic while the problem addressing a single property is tactical and problems at stand level are operational. All of them address multiple objectives. Four problem types are identified, which include 10 problem instances in Italy. For each of the four problem types at least one DSS/computerized tool is reported, but not all the ten forest instances that are described have a DSS which addresses them.

Morocco reports five problem types. Two of them are strategic problem types, two are tactical and one is operational. Regarding the spatial scale, three of them are stand level, one is forest level and the last one is regional. Moroccan forest department has designed and implemented computerized systems to support decision and to manage information related to forest resources. These systems may be classified as a classical Information systems and do not rise up to a full DSS. Four main computerized tools related to forest management have been identified. One mainly stores management plans, support for auction and harvest. Another is a web mapping solution to monitor hunting leases on forest. The third is a web-GIS solution to help monitoring and preventing forest fires, and another application to monitor forest health.

The interpretation of the existing management planning problems in the **Netherlands** requires previous consideration of the process of de-institutionalization of the forestry sector that has taken place over the last three decades, in which forestry has been substituted by nature management. In the current nature management frame more than 70 problems have been reported covering (with similar proportion) all spatial, temporal, and goods and services levels. In the Netherlands a geo-information system and a knowledge management system are developed in coordination and shared by all major nature management organizations. Both place forestry in a landscape management context. These are more information systems and knowledge organization systems than decision support systems. They are like repositories. Knowledge management is the basis of these tools, but they do not facilitate participation. The main nature of management problem types can be addressed using these tools.

Norway reports six problem types. Eight of them are stand level problems. There are two forest level problems, one concerning market wood products only and the other multiple products and services. There is one regional/national level problem. It is notable that all problems are long term. Norway has five DSS tools for handling the prevalent problem types. Only one problem type is not addressed by any tool. The tools are all developed in research projects and used either for research or in practice for large-scale forest planning, or both. Typically, the tools use area based models for growth, price and costs and include methods for simulation and/or optimization.

Forest decision support systems in **Portugal** have been used mostly by researchers, consultants from both the academia and private firms and managers in the public administration and the forest industry. The SADfLOR concept and architecture (Borges et al. 2003) as well as simulation approaches (Barreiro and Tomé 2011) have been extended to develop most DSS currently available. Recent efforts aimed at extending the use of DSS to non-industrial private forestry, namely through outreach projects targeting forest owners' associations. Information technology, efficient algorithms, knowledge management techniques and sophisticated heuristics have been intensively used to integrate and enhance decision support functionalities e.g. growth and yield projection and solution optimization to formulate and solve stand, and forest and regional level planning problems at various temporal scales (e.g. from long to short term temporal dimensions). All relevant contributions have been developed and supported by a close cooperation between the academia and managers of public and industrial forests in Portugal. The use of participatory architecture techniques to develop some DSS has been highlighted as critical success factor.

Russia has six problem types. Four of them are tactical and one is operational and one strategic. None of the problem types is non-spatial. Only one of the problem types has only one decision-maker. The two regional and two stand level problem types have a single objective while the two forest level problem types have multiple objectives. Russia has multiple DSS tools as well as other scientific simulation models available for addressing the prevalent problem types. Only one problem type out of six has currently no associated computerized tools. Typically, the DSS in Russia are developed and used by research institutes and academia; practitioner's use seems to be scarce, but the DSS experts have made multiple large-scale calculations. The available DSS tools typically include advanced simulation models, matrix models, process-based models, dynamic programming, data mining, heuristics, non-linear optimization and/or MCDA methods.

Slovenia reports ten problem types: five stand level problems (4 tactical and 1 strategic); one forest-level strategic focusing only on market wood products; one forest-level strategic focusing on market and non-market services; one forest-level operational problem (all goods and services); and two regional problems (one tactical and another strategic, focusing on all goods and services). Most of the ten problems described in the results are spatial problems, where neighborhood interrelations are considered and more than one decision maker is involved. Slovenia presents ten DSS which address the presented problem types. The country shows remarkable forest management planning activity which is reflected by the range of the presented tools (relational database for supporting regional, forest and stand management; tool for preventing bark beetle damage; tools tool for estimating optimal habitat conditions for brown bear, etc.). Knowledge management is used in various tools (GIS, relational databases). Some specific application for participatory planning is also presented. Traditionally there was a huge gap between knowledge on DSS tools (developed in R&D projects) and practical applications. Recently the development (interaction with users in the development phase) of DSSs and their use in applied research tasks has gained substantial importance.

South Africa reports twelve problem types. Regarding spatial scale, five are forest level, two are regional level, and four are stand level problems. Regarding the temporal scale, two are strategic, three are tactical and six are operational problems. Most of them are characterized by multiple decision makers except one. Seven of them have multiple objectives while three are mainly devoted to market wood products as a single objective. South Africa reports nine DSS tools which address all the prevalent problem types in the country. The tools have been developed both by R&D projects and by private companies. They are being used by forest professionals in different organizations, industry and in some cases also by private forest owners. The tools typically include forest simulation models, optimization and GIS features. Four problem types are not addressed by any tool for various reasons; there is no need for tools, the problem types are partly handled by existing tools, or the area is under investigation. South African decision support tools are still focused on the singular goals of optimum wood and fibre production, conducted by large sized companies and do not support current complex multi-criteria decision making yet. There is a need for DSS at the regional and national planning levels and for systems dealing with supporting small scale and community based forestry. In this sense strategic and tactical stand level problems are poorly or even not addressed by any DSS.

In **Spain**, the regular use of computerized tools and DSS in forest management planning is still limited to a small group of users, most of them working in universities and research institutions. There is a wide range of tools to support stand-level planning, among which three are more relevant: RODAL-ARBOREX by the Forest Planning Center for private properties in Catalonia, GesMO© by the public administration and industries in Galicia, or the use of PINEA2 by the administration. Among the tools available for modern landscape-level strategic and tactical planning, it is worth mentioning MONTE, a DSS that has been used in various pilot projects, and SILVANET a more specific tool for group decision-making processes. There is a lack of tools for operational management planning (optimizing time/space relationships for harvesting and transportation of products). Recently promoted strategic regional plans have demanded the combination of regional simulations (e.g. ESCEN or SIMANFOR) with analyses at a more detailed spatial resolution (landscape or even representative stands possible with SAD_DRIADE).

Sweden reports five problem types. Three of the problems are forest level problems, two medium or short term and one is long term. There is only one regional/national level problem and one stand level problem. All problems have a spatial character. Sweden has multiple DSS tools for addressing all problem types. The tools are mainly developed in R&D projects and some of them have a long history, while others are "second generation tools" recently developed. They are being used by forest companies and other forest organizations, in research and education. Typically, the tools are based on individual tree models for growth and yield and include methods for simulation and/or optimization.

Switzerland reports ten problem types. Two are stand level problems (strategic and operational temporal levels), four are landscape strategic problems, two are forest tactical problems, and two are regional problems. Market wood and non-market goods and services (often simultaneously) characterize all problems. Switzerland reports eighteen tools that support sustainable forest management. Eight are classified as DSS in the sense that they give advice to decision-makers (e.g. forest-level management planning tool, natural hazards management tool). Ten are management support tools (MST) that support scenario analysis and the assessment of management alternatives. Various tools are sensitive to spatial dependencies (GIS, optimization techniques, etc.). Many of the tools resulted out of PhD projects and research projects and are not used in practice (but there is some exception). The presented problem types are addressed by at least one tool but none of the tools can cope with participatory planning (multiple decision makers). The used knowledge management techniques are database management systems and GIS.

A DSS (ETÇAP) was developed for the development of sustainable management plans for the **Turkish** forests accommodating multiple forest values and long term forest management objectives. The DSS integrates database and GIS tools to deal with input and output information and offers linear programming and heuristic methods (simulated annealing) to solve the spatially constrained optimization problem.

In the **USA**, DSS have been widely used to guide timber-oriented planning in the case of industrial forests. Planning systems supporting the management of public forests in USA have a long history, pioneered by the USDA Forest Service. Since the 70´s, when the USFS pioneered the use matrix generator for input to linear programming solvers, DSS have been extensively used to produce forest-wide planning in USA. By the end of the nineties, though, there has been a trend away from optimization approaches and towards the use of simulation tools. Different types of knowledge management are embedded in these DSS. With fire and fuels management receiving major planning emphasis, DSS have required the inclusion of both factual knowledge (in the fire and effects simulation) as well as procedural knowledge in the form of an analysis methodology. Although required, most used DSS do not have any specific capabilities to facilitate public participation. This interaction occurs indirectly through USFS analysts. For the management of state-owned lands and local governments, the most important technologies are geographic information systems, followed by remote sensing, ecological, economic and resource simulation models, and decision support models. Although limited to a few examples in these cases, planning has relied on the common strategy of using growth and yield software to model alternative pathways, which then fed into a harvest scheduling heuristic to help identify efficient strategies. At the local level, two issues related to forests govern forest planning efforts: protection of water supplies and the control of land use development patterns to preserve natural amenities.

28.4 Discussion and conclusions

The use of computerized tools to support forest management planning is pervasive (Table 2). They may consist of electronic spreadsheets, geographic information systems and relational database management software or else take the form of a DSS. Nevertheless, twelve countries report that no computerized tool whatsoever is available to address some of the problem clusters prevalent there. According to the reports, some stand-level problem clusters are not addressed by computerized tools in 7 countries, while 7 and 3 countries report the unavailability of any computerized tool to address some forest and regional-level problem clusters prevalent there, respectively. This may reflect both earlier tendencies to invest in technology to address the latter spatial scales and the context and the low profitability of stand-level management planning in those countries. In fact out of those 7 countries only 2 do report the need to develop computerized tools for stand-level problems prevalent there (Estonia and Italy). Nevertheless, apparently, out of the 7 countries that report not having any computerized tool to address some of its forest-level problem clusters, none points to the need of developing any such tool. This suggests caution on the interpretation of these results. More discussion on this can be found at the end of this section.

The use of sophisticated computerized tools i.e. of DSS is also widespread. There are only two clusters where the number of countries that report the use of simple computerized tools is greater than the number of countries that report the use of DSS (Table 2). This is the case of tactical/operational stand-level as well as of long-term forest-level problems that target the supply of both market and non-market goods and services (Table 2). Nevertheless the predominance of DSS appears to be related to the importance of the country’s forest industry as well as to the problem cluster characteristics.
DSS are used to address the forest-level cluster characterized by long term planning horizons and the supply of wood products in 6 out of 8 countries where this cluster is reported as prevalent (Table 2). Nevertheless 2 of these countries do report the parallel use of simpler tools to address this same cluster in some institutional contexts. The forest and stand-level problem clusters characterized by long term planning horizons and the supply of wood products are addressed by DSS in over 75 percent of the reporting countries. Tactical and operational forest level problems targeting the supply of wood products are also typically addressed by DSS in most countries (over 76 percent of reporting countries too).
These results highlight the importance of a traditional forest product (timber). They may reflect as well concerns with the efficiency and the effectiveness of forest management

practices that target timber supply by the forest industry and by society at large. Apparently these concerns and favorable institutional contexts have prompted the development of advanced tools such as DSS to support the development of forest management plans targeting the supply of timber products. This is in concordance with the fact that most countries where the timber forest industry is relatively important (e.g. Finland, Sweden, Portugal, USA, Canada, Chile and Brazil) report the use of DSS to address these problems.

The country data suggests that the stand-level cluster characterized by medium or short term planning horizons and the supply of wood products is the least addressed by DSS. 46 percent of the no. of countries where this cluster is prevalent do not report the use of DSS to address it. Yet all countries where the timber forest industry is relatively important and that report this cluster as prevalent do use DSS to address it (e.g. Portugal, Chile and Finland). This may reflect the impact of industrial timber demand on small scale forest owners behavior e.g. incentives and rental agreements that may prompt the use of more advanced tools to manage the stands. It may reflect too the investment in research and development of advanced tools to support tactical and operational management as well as transportation problems to address logistic and competitiveness concerns of the industry and the country's economy.

The forest-level cluster characterized by a long term planning horizon and involving the supply of market products and services an non-market services is the second least addressed by DSS. 53 percent of the no. of countries where this cluster is prevalent do not report the use of DSS to address it. This is the second most reported cluster (by 17 countries). Apparently it has been easier to update or develop DSS to address concerns with environmental services in countries where there was already some experience of using advanced models and tools to address industrial forest products supply concerns. Most countries where the forest industry is relatively important and that report the use of DSS to address clusters that target wood products report also the use of DSS to address the supply of non-market services. Conversely, the other countries report the unavailability of DSS to address this problem. Timber supply efficiency and effectiveness concerns appear to have played a leading role in the adoption of advanced technologies in forest management planning. Nevertheless the new demands have prompted further development and application of information and communication technologies to the forest sector (Reynolds et al. 2005).

Regional problems are reported to be addressed generally by DSS. The regional-level cluster involving the supply of market products and services and non-market services is the most reported cluster (by 19 countries). 15 countries where this cluster is prevalent do report the use of DSS to address it. This group includes countries where the forest industry is relatively important.

The country reports list a total of 265 DSS applications (Table 3). Yet this list is not exhaustive. Several countries (e.g. Canada and USA) chose to report only the most important or the most frequently used DSS. Others chose to focus on DSS for addressing only some clusters prevalent in the country (e.g. Chile) or else on categories of DSS (e.g. China and Brazil).

Despite a huge variability between individual features of DSS reported, in general, they share the modular structure described in the forestry literature (e.g. Borges et al. 2003, Reynolds et al. 2005 and 2008, Schuster et al. 1993). DSS typically include a data management module, a module to project vegetation growth according to management options, a module to help interpret the output of projections and/or to help define the management plan and a graphical user interface.

In general the use of geographic information system (GIS) is not as widespread as the use of databases within a DSS. As expected the percentage of DSS that includes a database or a GIS is generally lower in the case of stand-level problems. Inventory data may be easily stored in a flat file or a spreadsheet and topological data is perceived as not important. The percentage of DSS that includes a database ranges from 6o percent, in the case of the cluster of long-term stand-level problems that do not target only wood products, to 92 percent in the case of the cluster of forest-level problems with medium and short-term planning horizons that target only the supply of timber products (Table 3). Long-term scenario analysis targeting only timber supply at regional or forest levels often take as input strata or analysis areas that group stands together. In this case, according to the reports, the aggregated inventory data is often stored in spreadsheets rather than in databases. Further, the use of forest and regional simulators often does not require the organization of the inventory data in a database. This is consistent with the relative low percentage of DSS integrating GIS to target these problems.

Nevertheless, the fact that some countries report early DSS and these systems were in most cases used to address forest long term problems targeting only timber products my contribute further to explain the relatively low usage of GIS in this case. In fact, some countries (e.g. Denmark, Norway and Sweden) report that some planning problems are in reality spatial problems, but have been handled as non-spatial with the tools available, and that there is a need for development of the modeling of spatial aspects. This further explains the low percentage of DSS that include GIS and it suggests the need to overcome what sometimes is perceived as a shortcoming.

In general, the use of knowledge management techniques (KMT) is reported to be more frequent when DSS address clusters involving regional or forest-level problems and long-term time horizons that target both timber and non-timber products and services. For example, the percentage of DSS that includes knowledge management techniques increases from 17 to 55 percent when non-timber products and services are included in long-term forest-level problems (Table 3). This seems consistent with the need of capturing expert knowledge or of using knowledge base systems to assess the supply of environmental services as a consequence of the unavailability of forest models. In any case, the low number of instances of KMT reported may be a consequence of the fact that KMT currently being used are not recognized as such. This highlights the importance of developing an ontology and a standard terminology to recognize and foster the use of KMT to enhance the functionality of forest management DSS. The contribution of KMT to enhancing forest management DSS is prone to increase as transferable DSS components, metadata and cloud computing becomes more topical. KMT may contribute further to decrease costs of developing contextually adaptable DSS.

As expected the use of vegetation simulators and prescription writers is widespread in the case of long-term management planning problems (Table 3). Yet, the number of DSS reported to have no vegetation simulation capabilities when addressing long-term problems is unexpectedly high. These temporal projection capabilities are often not needed when addressing short term problems (e.g. operational management planning, transportation and logistics problems).

The use of quantitative techniques (e.g. mathematical programming, heuristic approaches) to model and solve management planning problems is very frequent. The percentage of DSS that encompass operations research approaches ranges from 30 to 100 percent in the case of the clusters characterized by long-term stand-level problems and by medium and short-term forest-level that target only timber supply, respectively (Table 3). The former is typically addressed by DSS that enumerate a few silviculture strategies and conduct simple financial analysis. In the case of all other clusters that percentage is higher than 60 percent highlighting the potential of quantitative approaches to address forest management planning problems.

The use of qualitative approaches and explicit support to participatory processes is reported as less frequent. Some DSS may indeed be used for supporting multi-stakeholders decision making but there is no specific tool or specific features for explicitly supporting participatory processes, thus pointing to a shortcoming of current DSS to address collaborative and participatory planning processes. Nevertheless, there is also very little information available as to whether the DSSs have been used in participatory planning. Thus, we cannot really draw any conclusions concerning the usefulness of DSS in participatory planning. Recent research (Menzel et al. 2012) highlights the potential of DSS within participatory planning contexts.

Overall the information regarding the development of the DSS is scarce. Moreover, it is often limited to who developed the DSS and for what purpose. The percentage of DSS for which no development information was provided ranged from 26 to 81 in the case of clusters characterized by short and medium term forest and stand level problems and long-term forest-level problems that target only timber supply, respectively (Table 3). Many DSS have been developed to answer demands from forest planning practice and the development process has probably often been informed to, at least to some extent, by forest managers. However, in other cases, it seems that stakeholders have not been involved in the development of the DSS. In fact, with the exception of the clusters characterized by long and medium and short-term forest-level problems that target only timber supply, stakeholders are reported to have not been involved in the development of many DSS for which this information was provided.

This points to a shortcoming to be addressed when providing guidelines to support the development of DSS for forest management planning. To improve the performance of future DSSs, especially in contexts characterized by multiple objectives and multiple stakeholders, it may be necessary to change from a product-oriented to a process-oriented view on the development process and to include users and even other stakeholders. This conclusion from the British chapter may have a general relevance: "*there is a need for an increased focus on the process of development, over and above a focus on the product, and for developers to work collaboratively with potential end-users to identify and understand their needs and to build trust and credibility for the DSS produced*". The dissemination of architecture approaches (e.g. Marques et al. 2011 and 2012) referenced in the Portuguese report assumes particular relevance.

The lack of involvement of stakeholders in development processes may explain in part the fact that a relatively large percentage of DSS is not used by forest managers, particularly in the case of stand and regional level problems (Table 3). Many countries seem to share the challenge of better transferring the available DSS and their functionalities from academia and research institutes to forestry practice. Apparently, many DSS have remained mostly as researchers or consultants' tools. DSS are also to a lesser extent used for educational purpose.

The success of the application of DSS in practice based on assessments from managers or consultants is reported only in a few cases (Table 3). However, there is probably a lot of undocumented or informally documented experience out there which could be useful for improving existing and developing new systems. This observation points out one relevant avenue for further research: learning about smaller and greater successes in using DSS in practice, and synthesizing the hands-on experiences as reasoned guidelines for both DSS developers and users world-wide.

The rationale for this book was that DSS developers in different countries might mutually benefit from benchmarking and knowledge sharing. Often, problems have similar features and each country may have its own solutions and yet the lack of a standard terminology is an obstacle in many cases to the effectiveness of communication efforts. This research thus targeted the need to develop an ontology and a standard terminology to enhance and foster the development and use of forest management DSS. The template for developing each country report addressed this need and helped the communication between authors with very diverse experience and expertise. Nevertheless results must be interpreted with caution as there are still differences between interpretations of important concepts and dimensions of forest management planning problems. Hopefully this research may have contributed to overcome these shortcomings, to facilitate the communication between DSS researchers, developers and users. This will be influential to develop guidelines to support the development of DSS that may better address forest management planning. A concluding wish is that the forest DSS community, evolved during the preparation of this book, will continue its joint international activities as a community of practice in a regular and fruitful basis.

Literature cited

Borges, J. G., A. Falcão, C. Miragaia, P. Marques and M. Marques. 2003. A decision support system for forest resources management in Portugal. In: G. J. Arthaud and T. M. Barrett (Eds.) *System Analysis in Forest Resources*. Kluwer Academic Publishers, Managing Forest Ecosystems Vol. 7: 155-164.

Gordon, S. N., K. N. Johnson, K. M. Reynolds, P. Crist and N. Brown. 2005. *Decision support systems for forest biodiversity: evaluation of current systems and future needs*. Final report, project A10. Washington, DC: National Commission on Science and Sustainable Forestry

URL: http://ncseonline.org/NCSSF/DSS/Documents/docs/NCSSF_A10_final_report_040128sg.doc

Marques, A. F., Borges, J. G., Garcia-Gonzalo, J. and Lucas, B. 2012. A participatory approach to design a toolbox to support forest management planning at regional level. *Forest Systems* (accepted for publication)

Barreiro, S. and Tomé, M. 2011. SIMPLOT: Simulating the impacts of fire severity on sustainability of eucalyptus forests in Portugal. *Ecological Indicators* 11: 36–45

Marques, A., J. G. Borges, P. Sousa and A. M. Pinho 2011. An entreprise architecture approach to forest management decision support design. An application to pulpwood supply management in Portugal. *European Journal of Forest Research* 30: 935-948

Mallach, E. 1994. *Understanding decision support systems and expert systems*. Irwin Inc., 695 p.

Menzel, S., E-M. Nordström, M. Buchecker, A. Marques, H. Saarikoski, and A. Kangas. 2012. Decision support systems in forest management: requirements from a participatory planning perspective. *European Journal of Forest Research* **131**(5): 1367–1379.

Mower, H. T. 1997. *Decision support systems for ecosystem management: an evaluation of existing systems*. USDA Forest Service Gen. Tech. Rep. RM-GTR-296, 154 p.

Nabuurs, G. and R. Paivinen. 1996. *Large scale forestry scenario models - a compilation and review*. EFI Working Paper 10, 174 p.

Rauscher, H. M., K. M. Reynolds, et al. 2005. "Decision-support systems for forest management." *Computers and Electronics in Agriculture* **49**(1): 1-5.

Reynolds, K.M., J.G. Borges, H. Vacik and M.J. Lexer. 2005. Information and communication technology in forest management and conservation. In: L. Hetemaki and S. Nilsson (Eds.) *Information Technology and the Forest Sector*. IUFRO World Series Volume 18. Vienna, Austria: International Union of Forest Research Organizations: 150-171.

Reynolds, K.M., M. Twery, M. J. Lexer, H. Vacik, D. Ray, G. Shao and J. G. Borges. 2008. Decision support systems in natural resource management. In: F. Burstein and C. Holsapple (Ed.) *Handbook on Decision Support Systems*. Springer, International Handbooks on Information Systems Series, Handbook on Decision Support System 2: 499-534

Schuster, E., L. Leefers, and J. Thompson. 1993. *A guide to computer-based analytical tools for implementing National Forest plans*. USDA Forest Service Gen. Tech. Rep. INT-296, 269 p.

Turban, E. and J. Aronson. 2004. *Decision support systems and intelligent systems* (7th Ed.). Prentice-Hall, Inc. 890 p.

Zahedi, F. 1993. *Intelligent systems for business. Expert systems with neural networks*. Wadsworth Publishing Company, California, 658 p.

Table 1. Distribution of forest management planning problem instances per problem type cluster and country

CLUSTER/COUNTRY	Stand LT	Stand M/ST	Forest LT /only Mk	Forest LT /others	Forest M/ST	Regional	Total
Austria	1	2	0	0	0	1	4
Brazil	0	0	3	1	0	0	4
Canada	0	0	0	2	1	1	4
Chile	0	2	1	0	4	0	7
China	1	1	0	2	1	0	5
Denmark	0	0	2	0	3	1	6
Estonia	1	2	1	1	2	0	7
Finland	0	1	0	0	1	3	5
Germany	0	3	0	0	2	2	7
Great Britain	1	3	0	1	2	2	9
Greece	0	0	0	1	2	3	6
Hungary	2	2	1	0	5	6	16
Ireland	1	3	0	2	4	1	11
Italy	0	1	0	1	1	1	4
Morocco	1	2	0	1	0	1	5
Netherlands	6	18	0	6	18	24	72
Norway	3	0	1	1	0	1	6
Portugal	3	2	6	1	2	2	16
Russia	0	2	0	0	2	2	6
Slovenia	1	4	1	1	1	2	10
South Africa	0	1	0	0	4	2	7
Spain	3	1	0	4	5	1	14
Sweden	1	0	0	1	2	1	5
Switzerland	1	1	0	2	2	2	8
Turkey	0	0	0	0	1	0	1
USA	0	0	0	2	1	2	5
TOTAL	**26**	**51**	**16**	**30**	**66**	**61**	**250**

Legend	
Stand LT	Stand, Long term
Stand M/ST	Stand Medium or Short term
Forest LT /only Mk	Forest Long term supplying only market goods and services
Forest LT /others	Forest long term all others
Forest M/ST	Forest Medium or Short term
Regional	All Regional types

Table 2. Number of countries that report the use of each class of computerized tools to address each problem type cluster (*)

TOOL CLASS	Comp tool other than DSS (**)	DSS	Reported need to move to a DSS approach when a DSS is not available
Stand LT, only wood	3	6	1
Stand LT, all others	5	7	
Stand M/ST, only wood	6	6	
Stand M/ST, all others	12	8	3
Forest LT /only wood	3	6	
Forest LT /all others	11	9	5
Forest M/ST, only wood	6	10	1
Forest M/ST, all others	10	13	1
Regional	10	16	3

(*) Some countries report the use of both computerized tools other than DSS and DSS for the same problem type cluster

(**) Including spreadsheets, databases, GIS, g&y models,… not used within a DSS

Legend

Stand LT, only wood	Stand, long term, supplying only wood products
Stand LT, all others	Stand, long term, not supplying only wood products
Stand M/ST, only wood	Stand, medium or short term, supplying only wood products
Stand M/ST, all others	Stand, medium or short term, not supplying only wood products
Forest LT /only wood	Forest, long term supplying only wood products
Forest LT /all others	Forest, long term not supplying only wood products
Forest M/ST, only wood	Forest, medium or short term, supplying only wood products
Forest M/ST, all others	Forest, medium or short term, not supplying only wood products
Regional	All Regional types

Table 3. Number of DSS and respective modules reported as being used to address each problem type cluster (*)

	Stand LT, only wood	Stand LT, all others	Stand M/ST, only wood	Stand M/ST, all others	Forest LT, only wood	Forest LT, all others	Forest M/ST, only wood	Forest M/ST, all others	Regional	TOTAL
DSS (total)	**23**	**15**	**20**	**15**	**29**	**58**	**26**	**31**	**48**	265
with Database	14	9	13	12	20	53	24	28	43	216
with GIS	4	6	3	12	12	49	19	24	39	168
with other KM	3	8	3	5	5	32	13	12	30	111
with vegetation simulator	18	15	16	7	23	54	17	9	26	185
with automated solution quantitative support	7	10	12	10	21	53	26	26	30	195
with automated solution qualitative support	2	4	2	7		5	3	7	5	35
with expl support for part process				2		10	3	7	13	35
DSS Development										
reported?	9	7	8	4	21	25	10	8	15	107
if yes with stk invol?	4	2	3		17	11	7	7	9	60
DSS Users										
research	15	9	9	7	21	39	8	11	23	142
consultant	7	5	6	1	23	27	13	2	7	91
managers	11	6	9	5	12	34	19	15	13	124
public				3		4	3	5	7	22
other (e.g. students)	8	4	6	2	6	12	4	1	8	51
DSS application success among managers or consultants										
reported?	4	3	4	5	14	27	13	10	10	90
if so, the assessment is positive?	3	1	4	1	13	23	13	6	9	73
if so, the assessment is negative?	1	2		4	1	1		4	1	14

(*) some countries reported only a subset of DSS available to address the problem type cluster; further some DSS were reported to be able to address more than one problem type cluster

Legend

GIS	Geographical information system
KM	Knowledge management techniques
Vegetation simulator	Any computerized tool that may project vegetation growth (g&y models,…)
Database	Relational or object-oriented database
Stk	Stakeholder
part process	Participatory processes
Automated solution quantitative support	use of operations reserach techniques, simulation,...
Automated solution qualitative support	logic modeling and other qualitative approaches

Stand LT, only wood	Stand, long term, supplying only wood products
Stand LT, all others	Stand, long term, not supplying only wood products
Stand M/ST, only wood	Stand, medium or short term, supplying only wood products
Stand M/ST, all others	Stand, medium or short term, not supplying only wood products
Forest LT /only wood	Forest, long term supplying only wood products
Forest LT /all others	Forest, long term not supplying only wood products
Forest M/ST, only wood	Forest, medium or short term, supplying only wood products
Forest M/ST, all others	Forest, medium or short term, not supplying only wood products
Regional	All Regional types