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lifting barriers for nature-based forest management

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SUMMARY

Conversion from plantation forestry into nature-based forest management is a leading current issue in Europe. It is expected that moving in this direction more resilient forests and a more sustainable forestry sector can be achieved. In the temperate nemoral zone of NW Europe, in which Denmark is situated, these changes manifest in replacement of plantation forestry in favour of more nature-based forest management building natural forest dynamics and the related irregular and diverse stand structures. Correspondingly, natural forests have become increasingly important references for forest management. This thesis is concerned with the understanding and development of tools to describe the long-term goals for such stand structures in nature-based forest management.

Observation and quantification of 10 years of dynamics in Suserup Skov, a temperate, beech dominated, deciduous, near-natural forest in Denmark, revealed a multitude of different developmental processes. To a large extent these processes were not included in the understanding of the forest's structure and dynamics. Especially, understorey layers played a surprisingly large role in both the spatial and temporal structure. Release of understorey layers following the canopy breakdown enables most patches in the forest to bypass the innovation phase. Analysis of the spatial structure of a one hectare plot in Suserup Skov in three dimensions by means of profile and crown projection showed that beneath the canopy 1-3 understorey layers are common. The main reasons for this well-developed stratification was found to be irregularity of the canopy across small neighbouring structural units in combination with the presence of four co-occurring tree species with different strategies and life-cycles. Relating the profile diagrams to measurement of relative light intensity one meter above the forest floor showed that understorey light intensity in Suserup Skov has no simple correlation with the developmental phase of the canopy. In fact, "dense" growing understorey across neighbouring structural units was found to be the main determinant for understorey light.

The profile- and crown projection diagrams from Suserup Skov illustrated the potential of profile diagrams to communicate an overview of the irregular and diverse stand structures in nature-based forest management. This was confirmed in explorative, in-depth interviews with professionals with different academic background as well as years of experience. Profile diagrams communicate detailed information about stand structures in a way the professionals can easily comprehend, by guiding their mental imaging of the specific stand as well as other forest stands. This helps them to display an intuitive understanding of irregular stand structures. Being a support for the mind, the profile diagrams also augment professionals' discussions of stand potentials and long-term goals for stand structures in nature-based forest management which supported both the development and the understanding of the goals.

An adaptive management process where scientists and professionals from all levels of the Danish Forest and Nature Agency constitutes a successful example of social learning among scientists and professionals in the development of long-term goals for stand structures and dynamics in nature-based forest management and tools to describe these goals. In collaboration 19 Forest Development Types in combination with their illustration by means of profile diagrams were developed as a way to communicate the long-term goals for stand structures and dynamics on a given locality. The goal is described with respect to stand structure, species composition and regeneration dynamics and this is also illustrated in a profile diagram showing the stand structure and composition at »maturity«. Furthermore the goals for production, conservation and recreation are specified.

A follow-up questionnaire survey proved that such illustrated FDTs have taken hold amongst the professionals in the Danish Forest and Nature Agency. Professionals at all levels of the classical forestry hierarchy assess the tool favourably as a way to describe long-term goals for stand structures and dynamics in nature-based forest management as well as an aid for their work in order to realise these goals. Additionally, all staff groups have already used, respectively have clear ideas of future uses of the FDTs, ranging from management planning and silvicultural decisions to communication with various stakeholder groups. The professionals' direct acceptance and implementation of the FDTs in various aspects of their work indicate the potentials of the tool to initiate and support the desired changes towards nature-based forest management.

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SAMMENDRAG

I disse år omlægges skovdriften i mange europæiske lande fra aldersklassevis drift til mere naturnære principper. Forventningen er, at der med naturnære skovdrift kan udvikles skove, der er mere stabile, og som lever op til samfundets ønsker om et bæredygtigt skovbrug, hvor økologiske, sociale og økonomiske hensyn og interesser varetages. I den tempererede, nemorale klimazone, hvor Danmark ligger, medfører denne udvikling et skift fra plantage skovbrug til en mere naturnær drift, der udnytter skovens egen strukturvariation, dynamik og selvregulering. Som følge af denne udvikling er naturskove blevet stadig vigtigere referencer for skovdrift. Denne afhandling beskæftiger sig med forståelse af naturskoves bevoksningsstruktur og dynamik og med udviklingen af redskaber til at beskrive denne, og langsigtede mål for bevoksningsstrukturer dynamik i den naturnære skovdrift.

Observation af 10 års dynamik i Suserup Skov, en bøgedomineret urørt skov på Sjælland, afslørede overraskende mange udviklingsmønstre, hvoraf mange ikke var inkluderet i den hidtidige forståelse af skovens struktur og dynamik. Den vertikale struktur er vel udviklet, og underetage og mellemlag påvirker skovens struktur og dynamik mere end antaget. Ved sammenbrud i kronetaget springes foryngelsesfasen ofte over, og områder overgår direkte til opvækstfasen som følge af den veludviklede underskov. En fuldstændig kortlægning af den vertikale og horisontale struktur i et 1 ha. plot ved brug af profil- og kroneprojektionsdiagrammer viste en vertikal struktur med helt op til fire kronelag. Den veludviklede vertikale struktur skyldes en finkornet horisontal struktur med overlap mellem grupper af vekslende højde og aldersudvikling samt tilstedeværelsen af både skyggetålende klimaks-arter som bøg og elm og lysåbnings-specialister som ask og eg. Målinger af den relative lysintensitet én meter over skovbunden relateret til profildiagrammerne viser, at lysforhold ikke har en simpel sammenhæng med kronetagets udviklingsfase. Således peger studiet på sammenhængende underetage eller mellemlag over større områder som mere bestemmende for lysforholdene ved skovbunden end kronetagets udviklingsfase eller det samlede antal af kronelag.

Brugen af profildiagrammer i Suserup Skov illustrerede redskabets potentialer til at beskrive og formidle de sammensatte bevoksningsstrukturen, der er målet for den naturnære skovdrift. Et potentiale der blev bekræftet i interview af fagfolk med forskellig akademisk baggrund og erfaring. Dette studie viste, at fagfolkenes forståelsesform er en kreativ aktivitet, hvor evnen til at tænke i billeder er ligeså vigtig som den vidensbetingede analyse. Profil- og kroneprojektionsdiagrammers på en gang visuelle og analytiske sprog, synes at stimulere en sådan respons og desuden at udvide og detaljere fagfolkenes diskussion af potentialer og langsigtede målsætninger for bevoksningsstruktur i den naturnære skovdrift. På denne måde bidrog illustrationerne både til udviklingen og

forståelsen af målene for omlægningen til naturnær skovdrift.

Et »adaptive management« samarbejde mellem forskere og praktikere i Skov og Naturstyrelsen illustrerer fordelene ved, at de to videnskulturer mødes i social læring i udviklingen af langsigtede mål for naturnære bevoksningsstruktur og udviklingen af redskaber til at beskrive og formidle disse mål. Samarbejdet resulterede i 19 skovudviklingstyper (SUT), der beskriver målene med angivelse af forventet skovstruktur, træartsfordeling og bevoksningsdynamik, der også illustreres i et profildiagram. Desuden angives den forventede forekomst og skovudviklingsmål opdelt efter vedproduktion, biologiske værdier og rekreative værdier.

En opfølgende spørgeskemaundersøgelse viser, at Skov- og Naturstyrelsens medarbejdere tager godt imod de illustrerede skovudviklingstyper. Alle personalegrupper fra skovrider til skovarbejder anser skovudviklingstyperne som en god måde at beskrive de langsigtede mål for naturnær bevoksningsudvikling og som et brugbart redskab i deres arbejde med at realisere disse mål. Resultaterne viser, at ansatte på alle niveauer fra skovrider til skovarbejder allerede har anvendt eller har klare forventninger til anvendelse af skovudviklingstyperne i mange aspekter af deres arbejde, gående fra drift og driftsplanlægning til dialog med andre myndigheder og forskellige brugergrupper. Praktikernes direkte accept og implementering af skovudviklingstyperne i stort set alle dele af deres arbejde antyder redskabets potentialer for at igangsætte og støtte de ønskede ændringer i retningen af naturnær skovdrift.

PREFACE

This Ph.D. thesis is submitted as partial fulfilment of the requirements for the degree of Philosphiae Doctore (PhD.) at the Royal Veterinary and Agricultural University (KVL), Copenhagen, Denmark.

Experienced researchers have described the ultimate aim for a PhD thesis work to me as »reach the scientific frontline and get one inch further«. This ambition also counts for the current thesis. However, relevance for the Danish forestry profession has been given equally weight. Correspondingly, the research presented in this thesis have an applied nature with a close link to the decision to convert from plantation forestry into more nature-based forest management in the Danish state forests and the challenges related to this decision (Danish Forest and Nature Agency, 2002).

During the course of the project, I have considered learning about the discipline's academic methods equally important as the final project. I have therefore allowed myself to approach the project from natural scientific, the humanities as well as social scientific perspectives. The different scientific approaches are reflected in the five papers on which the thesis is based. One of these papers has been published; one accepted for publication; two submitted for publication while the fifth paper is still in the »pipe-line«.

I have had my base at the Danish Centre for Forest, Landscape and Planning, Department for Parks and Urban Landscapes. However, from the very beginning my ambition was to 'run the stairs' between the 2nd floor - where my department lies - and the 1st floor where the Department of Forestry and Forest Products is situated. My ambition was to learn from both environments and hopefully stimulate cooperation between the two beyond my project. That has been challenging but also great fun. I thank the endless list of people from these departments and many other institutions who have contributed in various ways to my work. Some of you deserve special attention. First and foremost special thanks to my supervisor Associated Professor Jens Balsby Nielsen, who's non-stop flow of »crazy« ideas, full engagement and positive attitude towards my work as well as every other aspect of his job have been a great inspiration. In the same vein I owe a special thanks to Associated Professor Jens Emborg. A knock on his door also opened the door to a whole group of fellow Ph.D. students in the SpyNat Force program with whom I have spent endless hours of study in Suserup Skov. I have hugged every single tree in that forest measuring diameter at breast height. Colleagues at my department still ask whether I have visited »my« forest recently. In the later part of the project I knocked at the door of Professor J. Bo Larsen's office. That was the start of an incredible adventure which among many things resulted in half a year of employment in the Danish Forest and Nature Agency and a whole new master course in Urban Woodland Silviculture. Thanks Bo. And thanks to Bengt Egede

Andersen, Mads Jensen, Mads Jakobsen, Anders Bjorholm Dahl and the many other people with whom I worked during my time in the Danish Forest and Nature Agency. A special thanks to Professor Roland Gustavsson from the Swedish University of Agricultural Sciences, Alnarp for endless discussions about profile diagrams. Thanks to my colleagues Ph.D. Liv Oustrup, Ph.D. Morten Christensen and Ph.D. Katrine Hahn with whom I have had very close cooperation. Katrine also taught me the phrase »the time you enjoy wasting is not wasted«. In that spirit we went to Bosnia to do some great research in the fantastic forest reserve Perucica knowing that in terms of our individual Ph.D. projects it was waste of time.

Last and most importantly a special thanks to Malin for keeping my attention on other aspects and qualities of life than forest.

1. INTRODUCTION

Trends in modern forestry

The profession of forestry developed in the 18th century as foresters' structural interventions in forest ecosystems aimed at optimising timber production (Konijnendijk 2000, Gamborg and Larsen 2003). The higher demands placed by today's society on social and environmental values have, however, widened the scope of forestry to also meet these values, along with wood production. Sustainability and multiple-use are basic postulates of modern forestry (Anko 2005) meaning that protection and use should be balanced and social, ecologic and economical interests integrated. In order to achieve this delicate balance, forest management is worldwide being 'readjusted to nature' (Franklin et al. 2000, Gamborg and Larsen 2003) and parallel adapted to accommodate the demands of urban societies (Konijnendijk 1997, 2000, 2003). In the temperate nemoral zone of NW Europe, in which Denmark is situated, these changes manifests in replacement of plantation forestry based on age-class management of uniform monocultures in favour of more nature-based forest management building on natural forest structures and dynamics. (Schütz 1996, 1999c, Gamborg and Larsen 2003).

NATURE-BASED FOREST MANAGEMENT

The adaptation of forest management to meet the growing and diversifying demands of society has materialised under terms like 'close-to-nature silviculture', 'nature-based silviculture', 'nature-oriented silviculture', 'near-natural silviculture' and 'continuous cover approach' (see e.g. Gamborg and Larsen 2003 for a review) - in the following this concept is simply termed 'nature-based forest management'. For about one century, nature-based forest management has been practised in various forms in Central and Eastern European countries like e.g. Switzerland and Slovenia (Schütz, 1999a, 1999b). However, the paradigm has only recently been officially adapted in NW European countries and regions (e.g. Wales (National Assembly for Wales 1999), Niedersachsen (Niedersächsisches Forst Planungsamt 1995) and Denmark (Danish Forest and Nature Agency 2002)).

In the past there have been different interpretations of nature-based forest management and the concept remains subject to controversy because it uses a wide range of silvicultural tools to create irregular and diverse vegetation structures and habitats; e.g. »plenter« systems, small clusters, co-existing groups and irregular shelterwood systems (Schütz 2002). Besides the silvicultural discussions the controversy also relates to ethical values, mainly expressed in discussions of diversity and to emotional and aesthetic values. The latter, especially where nature-based forest management expands into the context of urban forestry with its strong emphasis on the importance of the forests for the quality of life and well being of the ever growing number of urban dwellers (Helms 1998; Konijnendijk 2000, Konijnendijk 2003, Randrup et al. 2005, Tyrväinen et al. 2005).

CHALLENGES IN CONVERSION TO NATURE-BASED MANAGEMENT

Due to the current interest in nature-based forest management, natural forests have become increasingly important references for forest management (e.g. Emborg et al. 2000, Schütz 2002). Our understanding of the irregular and diverse structures in natural forests is however incomplete, especially in relation to understorey characteristics and their effects on the forest dynamics (McCarthy et al. 2000, Franklin et al. 2002). Additionally, research has in general paid little attention to the tools we use for communicating such complex vegetation structures and dynamics to end-users. From many sides, these two aspects have been pointed out as part of the reason why the processes of natural forest ecosystems are difficult to communicate to forest managers and to achieve in managed forests (Scientific Panel on Ecosystem Based Forest Management 2000, Aber et al. 2000).

A common challenge for management organisations in adapting nature-based forest management, therefore, is to transform the overall targets and policies of sustainable forest management into long-term goals at stand level and to implement these in practice. What stand structures are we aiming at as a mean to fulfil the demands from society and how can the long-term goals for these stand structures be described? These questions are significant challenges, especially for professionals trained and educated within the plantation forestry tradition as is the case for most professionals in Denmark and other NW European countries.

Observations among professionals in the Danish Forest and Nature Agency confirmed this (paper IV). Confronted with the huge task of converting all Danish state owned forests from age-class to nature-based management (Danish Forest and Nature Agency 2002) one could expect that the first question asked by the professionals would be: »how do we get there?« However, this was not the case. The professionals went one step further and asked: “where are we going?” It turned out that their main hesitation in adopting nature-based management principles came from a pronounced uncertainty in terms of long-term goals for stand structures and dynamics. Due to a long tradition of managing regular, even-aged monoculture stands, the professionals were in short of experience with natural forest structures and dynamics. Correspondingly, they were also short of ideas and perspectives on long-term goals for stand structures and dynamics in nature-based forest management

During the last two centuries an inherent understanding of management goals and how to communicate these in the plantation forestry paradigm has emerged, enabling the forest ranks to translate directly between standard parameters and reality. In short, standard parameters such as species, age, height, growing stock and site conditions is enough for the experienced forester to display an intuitive understanding of the stand and envision it in reality, i.e. contextualize or put into context. More irregular and diverse vegetation structures can, however, hardly be described appropriately in terms of such standard parameters (Otto 1995, Tahvanainen et al. 2001, Jensen et al. 2005). And if they could, there would be a mismatch for foresters trained and educated within age-class forestry as they have neither mental nor real models to relate to. Correspondingly, converting from plantation forestry to nature-based forest management demands the development of a common understanding of the nature-based management principles and long-term goals for stand development, necessarily implying the development of tools for organising and communicating these whole new management principles and desirable stand structures to the professionals and other stakeholders.

Objectives

From this perspective, the overall objectives for the investigations presented in this thesis are to:

- Increase the understanding of the irregular and diverse vegetation structures and dynamics in natural forests, and especially to
- Develop and evaluate tools for communication of long-term goals for such irregular stand structures and dynamics in nature-based forest management.

The thesis addresses these objectives by studying the structure and dynamics of Suserup Skov, a temperate, deciduous, near-natural forest in Denmark. Within the limit of ten years of observations, Paper I identifies main development processes as a basis for evaluating and refining a basic forest cycle model developed by Emborg et al. (2000). Going into further detail with the spatial structure, Paper II analyses the spatial structure of a one hectare plot in Suserup Skov in three dimensions by means of profile and crown projection diagrams. Further, the spatial structure is related to understorey light intensity. Departing from the use of profile- and crown projection diagrams in studies of the vegetation structures in Suserup Skov, Paper III changes the perspective and look at profile- and crown projection diagrams from the »readers« point of view. By use of explorative, in-depth interviews with different professionals the paper gives a qualitative looks into the possible gains related to the use of profile and crown projection diagrams as an additional language in the management of irregular forest stand structures. In the same vein, Paper IV applies profile diagrams together with Forest Development Types (FDT) as tools for creating a »discussion room« for new ideas and perspectives on long-term goals for stand structures and dynamics in nature-based forest management in the Danish Forest and Nature Agency. Finally, Paper V reports the results from a questionnaire evaluating the professionals' attitudes to and assessment of FDTs and their illustration by means of profile diagrams as a way to describe long-term goals for stand structures in nature-based forest management and as aid for their work.

In the following chapter the methodological aspects are discussed with emphasis on the thesis' use of profile diagrams as an additional "language" in studies of natural stand structures as well as for describing vegetation structures in nature-based forest management. A synthesis chapter presents the main results of the five papers and presents a discussion in relation to communication theory and epistemological viewpoints. The main results are summarised in the conclusions chapter. Finally, issues of relevance to the profession and future research into the understanding and communication of forest stand structures in nature-based forest management, as I see them, are brought up in the outlook.

2. METHODOLOGICAL ASPECTS

Since the irregular vegetation structures characterising natural forests and stands subjected to nature-based forest management are difficult to describe in numbers and words, it would seem logical to study the potentials of visual tools as an additional »language«. According to Mamali (2001) visualisations of forests may be characterised at three different projection scales each representing a specific level of detail; Stand, Forest and Landscape scale. The focus of illustrations at the landscape scale (areas over 200 ha) is to show the spatial arrangement of forests and the surrounding landscape, and similarly the focus of illustrations at the forest scale (areas up to 200 ha) is to project area layout such as harvesting parcels and relations between different types of stands. Finally, the focus of illustrations at the stand level (plot level) is to illustrate the horizontal and vertical structures with respect to canopy layers, understorey conditions, habitat qualities, silvicultural prescriptions and crown/folia characteristics on a single tree level (Mamali 2001).

When addressing the current thesis, the different techniques for visual analysis at the stand scale was compared in a study of a 10x120 m transect in Suserup Skov. The objective was to identify techniques that are suitable for both the scientific analyses of natural forest stand structures and for the communication of such stands structures to fellow researchers, students and professionals. The following three techniques were compared: 1) photos taken with a 20 mm lens, 2) computer line graphic made in Silva (Pretzsch et al. 2002), and 3) hand drawn profile- and crown projection diagram (Fig.1). This comparison showed that photos taken with a 20 mm lens are well suited for communicating details, but hardly allow analysis of structural attributes as also argued by Seddon (1990). The Silva visualisation communicated an overview of the stand structures. However, tree shapes are standardized limiting analysis of growth and shape of individual trees in relation to their position in the overall structure. In comparison, hand drawn profile diagrams proved to communicate an overview of the structure and at the same time depict the shapes of the individual trees in detail. This combination of stand structures and individual tree shapes enables analysis and communication of the spatial structure at both stand and single tree level. This pilot study was presented as a poster at the international NatMan/Pro-Silva Conference 'Beech Forests in Europe – bridging research and practice' (Nielsen 2004), and following the experiences, profile- and crown projection diagrams were applied in the thesis' investigations of natural forest stand structures (Paper II).

Profile diagrams in understanding and communicating stand structures

I define the profile diagram as a development of a cross section of the forest stand, showing the vertical nature of the trees while a crown projection diagram is the corresponding plan showing the horizontal nature of trees. Together the two images create a right angled projection which summarises and presents a range of information about the stand structures. By abstracting from the position of the viewer and their comprehension of space the information is presented in a form that the viewer could not achieve in reality. As such information is described in a way in which we have not perceived it before. In this way, profile- and crown projection diagrams disclose spatial and social patterns which previously were 'not visible', as exemplified in Paper II and III. It is for this reason that Bruno Latour (1999) declares that if an image which depicts things as the eye sees them is worth a thousand words then an image which depicts reality in a way the eye never could see is worth a whole forest!

Profile- and crown projection diagrams have gained interest during the last century, especially where mixed-forest management has been practiced, indicating that the more irregular and diverse (i.e. complex) the structures are, the greater the needs for integrative visual tools. The earliest use of crown projection diagrams date back to the late 1870s where Blomqvist (1879) made drawings of boreal forests (Sarvas 1958). This was followed by profile diagrams of English forests by Watt (1925) and soon after by many other forest ecologists in the tropics and the Central and Eastern Europe. Since then, researchers and teachers in forestry (e.g. Mayer 1980, Oldeman and Schmidt 1986, Oldeman 1990, Oliver and Larson 1990, Otto 1994, Röhrig et al. 2006), forest ecology (e.g. Leibundgut 1959, Koop 1989) and landscape architecture (e.g. Gustavsson 1986, Gustavsson and Ingelöv 1994) have used profile diagrams (sometimes including crown projections). However, the use has mostly been limited to illustration and documentation of forest structures and management concepts (Baker and Wilson 2000).

Roland Gustavsson's work with profile diagrams is a rare example of the use of profile- and crown projection diagrams as a research methodology - not simply as nice illustrations. Here, drawing of profile and crown projection diagrams are central means of investigating how a forest environment functions and the significance of different visual qualities in that environment. Gustavsson uses profile- and crown projection diagrams as thinking aids where words and numbers set limits on the ability to understand and to express the design or management ideas. (e.g. Gustavsson 1986, Gustavsson and Fransson 1991, Gustavsson and Ingelög 1994). It is also in his way that drawing of profile and crown projection diagrams is used in education and practice. When landscape architects draw them, it is as a means to better understand the landscape under consideration in terms of space, form, relationships, scale, materials, light, shadow, colour and components – and this whether it is an existing forest or a proposed »design«.

During the field work in Suserup Skov (spring and summer 2002) the communicative aspects of profile- and crown projection diagrams gradually caught my attention. Could they support the communication and understanding

Figure 1: Profile diagram, photo documentation (2o mm lens) and Silva visualisation from a 10x120 m transect in Suserup Skov, a near-natural, temperate, deciduous forest in Denmark. Trees with dbh < 5 cm are not shown in the profile diagram and Silva diagram. Dashed lines link the photo documentation to the hand-drawn profile diagram and the Silva diagrams by pointing out individual trees. The figure is modified from Nielsen (2004), where the hand drawn crown projection diagram and the crown projections generated by use of Silva are also shown.

of long-term goals for stand structures in nature-based forest management? Following this idea, the perspective on profile- and crown projection diagrams in the current thesis changed from being a tool to study forest structures and dynamics, to studies of profile diagrams as a tool to describe and communicate long-term goals for irregular and diverse forest stand structures in the conversion to nature-based forest management.

This change in focus from the forest 'out there' to the forest 'created in the mind of professionals' when interpreting profile diagrams necessarily caused a change in the academic methods away from the natural sciences. Using case study design in combination with in-depth interviews, Paper III investigates how professionals contextualise from profile- and crown projection diagrams when planning the management of irregular stand structures. Additionally, as the epistemological aspects of profile diagrams and image-based management tools in general remain unstudied, I had to turn to other disciplines and related theories such as theory on professionals' learning (e.g. Schön, 1983; Dreyfus and Dreyfus, 1986; Persson, 1997), participatory planning (e.g. Innes, 1998; Taket and White, 2000), and communication theory (e.g. Nørretranders, 1993; Persson, 1997) for theoretical guidance. These methodologies and related theories from the humanities enabled a qualitative »look« into the professionals' utility of profile diagrams as an additional language in understanding and communicating irregular forest stand structures.

The improved understanding of ways in which professionals contextualise from profile diagrams was achieved simultaneous to the Danish Forest and Nature Agency after - 250 years with management of plantation forestry - initiated a process of developing long-term goals for more natural-based stand development in the Danish state forests (Danish Forest and Nature Agency, 2005). Facing this challenge paper IV takes a social scientific approach and constitutes an example of social learning among professionals and scientists in an adaptive management context, which also contained elements of action research. In this collaborative process Forest Development Types and profile diagrams were applied as tools to organise and ease development of long-term goals as well as tools to communicate such novel goals.

Paper V continues the social scientific approach taken in paper IV. The paper uses a questionnaire surveys among employees in the Danish Forest and Nature Agency to evaluate the FDTs in combination with their illustration by means of profile diagrams as a way to describe long-term goals for stand structures and dynamics in nature-based forest management and as an aid for their work in order to realise these goals.

In summary. I have allowed myself to revise the original project outline and objectives during the project time in order to reflect the parallel development in Danish forestry. Furthermore, I have allowed myself to build on the mutual supportiveness of academic methodologies belonging to the natural sciences, the humanities as well as the social sciences in the thesis' investigations into the understanding and communication of forest stand structures in nature-based forest management. For a thoroughly description of how the different academic methodologies and theories have been applied, the reader is referred to the individual papers.

3. SYNTHESIS

In this chapter the results of the investigations addressed in the five papers are summarised and discussed in relation to the objectives put forward in the introduction.

Understanding forest stand structures and dynamics

Given the leading current trends in European forest management it is not surprising that natural forests have become important references for development of more nature-based forest management. This is exemplified in e.g. the pan-European project "Nature-based Management of Beech in Europe", supported by EU fifth framework program (http://www.flec.kvl.dk/natman).

The 'forest-cycle' concept, developed in Europe by Jones (1945) and Watt (1925, 1947) have proven to be one of the most useful tools for improving our understanding of the basic dynamics in natural forests (Emborg et al. 2000, Standovár and Kenderes 2003). Since the introduction of their concept, scientists have developed a considerable number of specific forest cycles, all describing a number of continuous sequential shifts between a series of upgrading and degrading developmental phases (e.g. Leibundgut 1959, Zukrigl et al. 1963, Meyer and Neumann 1981, Mueller-Dombois 1987, Jenssen and Hofmann 1996, Emborg et al. 2000, Grassi et al. 2002). Besides improving our understanding, forest-cycle models have supported communication of the overall spatial and temporal structure and dynamic in natural forests between researchers, students and professionals and thereby been supportive for the implementation of nature-based forest management in practice. However, several authors have argued that the simplification can lead to misinterpretation because of the exclusion of complexity of developmental processes (Franklin et al. 2002, Standovár and Kenderes 2003). Muth and Bazzaz (2002) describe the importance of crown expansion for the forest dynamics and Pontailler et al. (1997) and McCarthy et al. (2001) describe the complexity of regeneration and graduatly take over of understorey. These are processes which are not incorporated in most forest cycle descriptions.

MAIN DEVELOPMENT PROCESSES IN SUSERUP SKOV

To address this, Paper I quantifies different development processes in Suserup Skov. From a inventory in 1992 a basic forest cycle for Suserup Skov was developed (Fig. 2a) (Emborg et al. 2000). A re-inventory in 2002 enabled us to quantify different development processes within the limit of ten years of dynamics, thereby critically evaluate and revise the basic forest cycle. The observations revealed a surprisingly large turn over in phases. In total 47 % of the forest changed phase during the ten year period which was nearly three fold the expected (i.e. paper I: table 3). To a large extent these dynamics followed the basic model of the forest cycle. The most important can be summarised as follows (Fig. 2b):

1. A major part (0.12 ha of 0.24 ha) of the innovation phase in 1992 changed into the aggradation phase in 2002.
2. A major part (0.97 ha of 2.29 ha) of the aggradation phase in 1992 changed into the early biostatic phase in 2002.
3. A major part (0.16 ha of 0.28 ha) of the degradation phase in 2002 originated from areas of the late biostatic phase in 1992.

However, deviations from the basic forest cycle were surprisingly many. The most important can be summarised as follows (Fig. 2b):

1. The majority of the area that changed into the innovation phase originated from phases (0.74 ha) other than the degradation phase (0.05 ha).
2. Nearly half of the area (0.84 ha) that changed into the early biostatic phase originated from phases other than the aggradation phase (0.97 ha).
3. The majority of the area that changed into the aggradation phase originated from phases (1.35 ha) other than the innovation phase (0.12 ha).

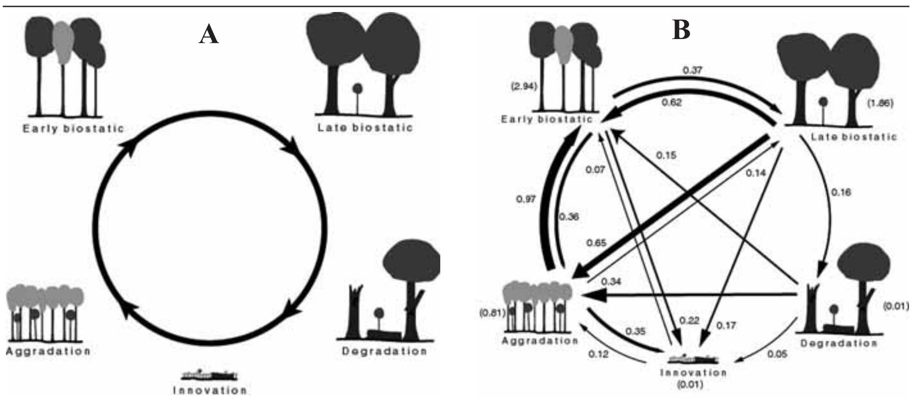


Figure 1: A) Basic forest cycle developed by Emborg et al (2000). B) Refined forest cycle illustrating observed development processes. Reprint of fig. 1 and 4, paper I.

The effects of a severe storm in 1999 and the arrival of Dutch elm disease in 1995 explain some of the observed deviations. However, the majority of the observed deviations seem to occur because the basic forest cycle model does not incorporate the process of lateral crown expansion of trees surrounding gaps and patches of up growth or the processes related to well-developed understorey layers. The latter is in many cases overlooked in studies of unmanaged forests (McCarthy et al. 2001, Franklin et al. 2002) resulting in understorey light intensity often being described as having a simple correlation with the developmental phase of the canopy (Emborg 1998, Grassi et al. 2003).

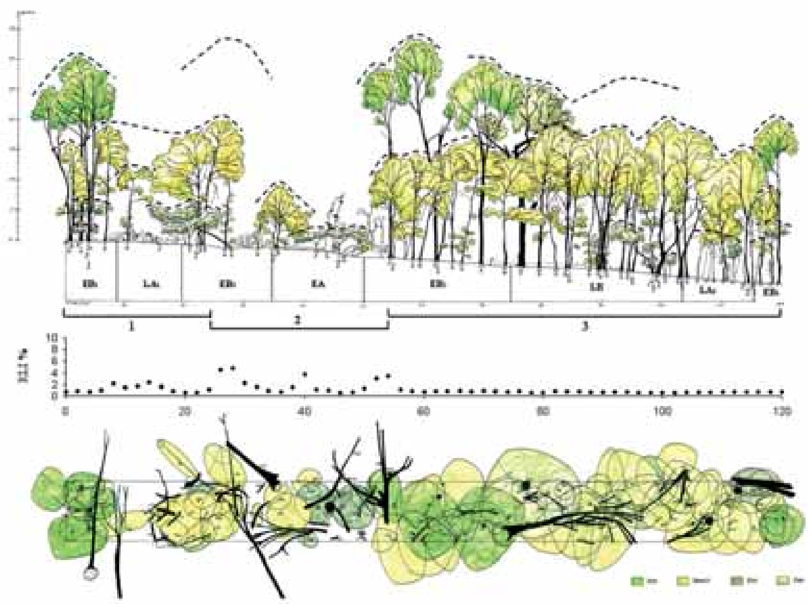


Figure 3. Profile diagram, RLI and crown projection diagram for a 120x10 m transect in Suserup Skov. Based on the developmental phases of the canopy trees, the transect was divided into eight sub-zones, whereas a more spatial approach reflecting both canopy and understorey characteristics led to a division into only three larger zones (1-3). The different zones and sub-zones are described below:

<u>Description of the zones reflecting both canopy and understorey characteristics</u>

1: This zone is characterised by very irregular canopy and understorey structures.

2: The gap in the canopy and the dense innovation of ash (and beech) at the forest floor characterise this zone

3: A regular and closed canopy layer of beech in the late aggradation phase, overlapping, or overlapped by, a varied number of canopy-layers, characterise this large zone.

<u>Description of sub-zones along the transect according to the developmental phase of the canopy trees:</u>

EB_1: Slim ash trees in the early biostatic phase form the canopy, clearly separated from the understorey of beech in late/early aggradation, beneath which umbrella shaped elms up to 7 m height form a scattered understorey.

LA_1: The canopy consists of beeches in the late aggradation phase of which one is located east

of, but overlapping, the transect. Below this, a scattered understorey of umbrella shaped elm up to 7 m's height.
EB_2: The canopy is made up by a beech in the early biostatic phase located east of, but overlapping, the transect, clearly divided from a scattered understorey of beech in the early aggradation phase. The forest floor is covered by dense ash regeneration, 20-100 cm height, which is not shown in the profile diagram.
EA: The breakdown of a large beech in the 1999-storm created this gap. To day dense innovation of ash (not depicted in the profile diagram) and scattered umbrella-shaped elm in the early aggradation phase make up the canopy. The umbrella shaped elm and the beech was established as advance regeneration prior to gap formation.
EB_3: A group of slim ash trees in the early biostatic phase form the canopy, below which dense growing beeches in late aggradation form a well-developed understorey. The forest floor is almost free of vegetation, resulting in a relatively high room (ca. 8 m) beneath the canopy.
LB: An Oak and a beech (overlapping the transect) in late biostatic form the canopy below which dense growing beeches in late aggradation, as in zone E, form a well-developed understorey. Below this is scattered elm.
LA_2: Dense growing beeches in late aggradation form the canopy, below which there is a scattered understorey of beech and elm in early aggradation. Standing beech snags (107m and 112m) refer to the previous tree generation.
EB_4: Slim ash in early biostatic forms the canopy. Below this is an understorey of beech and elm with a well-developed stratification.
Drawing by Anders Busse Nielsen. Modified reprint of figure 3, paper II.

STRUCTURE AND UNDERSTOREY LIGHT IN SUSERUP SKOV

To detail the understanding of »what is beneath the canopy« and how understorey characteristics affect understorey light intensity, the spatial structure of a 1-ha plot in Suserup Skov was analysed in three dimensions by use of profile- and crown projection diagrams. These analyses showed that beneath the canopy 1-3 understorey layers were common (Paper II: fig. 3 and 4). The main reasons for this well-developed stratification seemed to be irregularity of the canopy across small neighbouring structural units (Paper II: fig. 2) in combination with the attendance of four co-occurring tree species with different strategies and life-cycles: *Fagus sylvatica, Quercus robur, Ulmus glabra, Fraxinus excelsior*. Relating the spatial structure to understorey light intensity (RLI) measurements, as shown in figure 3, indicated that understorey light intensity is a pro-duct of the continuous cover of dense growing understorey across neighbouring structural units more than the developmental phase of the canopy trees or the number of canopy layers.

Communicating long-term goals for stand structures and dynamics

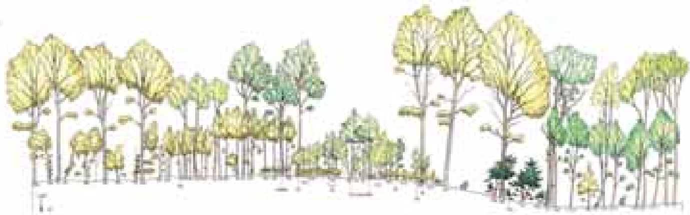
Refining the scientific understanding of structures and dynamics in natural forests in the above mentioned aspects and relating it to nature-based forest management, however, only provide part of the solution to the challenges faced by professionals when urged to move toward nature-based forest management. As described in the introduction, a major barrier for nature-based forest management in countries with a long tradition of plantation forestry is that the professionals feel a pronounced uncertainty about the long-term goals for stand structures and dynamics.

FOREST DEVELOPMENT TYPES AND PROFILE DIAGRAMS

To address this, paper IV describes how scientist and professionals from all levels of the Danish Forest and Nature Agency were united in an adaptive management process to develop long-term goals for stand structures and dynamics in nature-based forest management and simultaneously to develop tools to communicate such novel goals. The idea was to facilitate the encounter between the professionals' experience-based, contextual knowledge and skills and the scientific contextual-free knowledge. The outcome of this social learning process was 19 Forest Development Types (FDT) scenarios in combination with their illustration by means of profile diagrams, as published in Larsen and Danish Forest and Nature Agency (2005) as well as Larsen et al. (2005).

A FDT scenario describes the long-term goals for stand structures and dynamics on a given locality (climate and soil conditions) in order to accomplish specific long-term aims of functionality (ecological-protective, economical-productive, and social/cultural functions). The goal is described with respect to stand structure, species composition and regeneration dynamics and this is also illustrated in a profile diagram showing the stand structure and composition at »maturity«. Furthermore, the goals for production, conservation and recreation are specified (Fig. 4).

Name — **Forest Development Type 12: Beech with ash and sycamore**



Structure

Species rich well structured forest with beech as dominating element mixed with ash, sycamore and cherry and in the south-eastern parts of Denmark additionally with hornbeam and lime. The in-mixed species occur mainly in groups but also as single trees. The horizontal structures arise between groups of varying size and age. Where the light demanding species such as ash, sycamore and cherry dominate horizontal structures occur with shade trees (beech, hornbeam, elm and others) in sub-canopy strata.

Species distribution

Beech: 40-60 %
Ash and maple: 30-50 %
Cherry, hornbeam, oak, lime and others up to 20 %

Dynamics

Beech regenerates mainly in groups or smaller stands. Ash and sycamore are gap specialists and regenerate mainly in smaller openings later followed by beech. Hornbeam belongs to the sub-canopy stratum and regenerates under shade, whereas the pioneer species (cherry and oak) occur after larger openings and /or in relation to edges.

Functionality

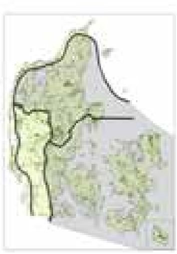
Productive: The forest development type has a high potential for production of hardwood in big dimensions and in good quality.

Protective: The beech dominated forest is in most parts of the country the potential natural vegetation; consequently many indigenous species are connected to this forest type. It has a great potential in conserving the biodiversity connected to the NATURA 2000 habitat types 9139 and 9150.

Recreational: It gives through its mixture of (indigenous) species in combination with pronounced variation in size a multitude of recreational experiences and intimacy.

Occurrence

The forest development type belongs on protected sites in the eastern and northern parts of Denmark on rich, well drained soils with good water supply as illustrated below.



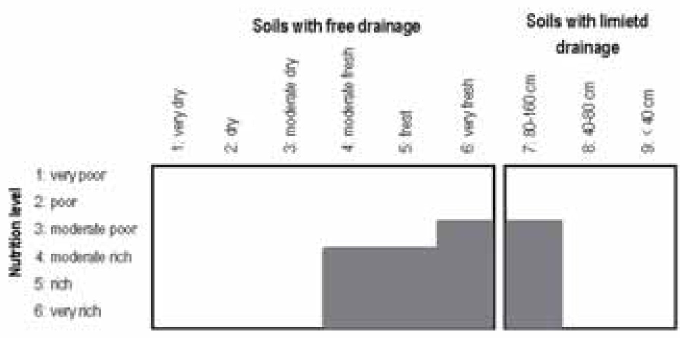


Figure 4: Example on a FDT which is inspired by the stand structures and dynamics in Suserup Skov. The DK-map in the lower left corner shows the four eco-regions, and which eco-zones the FDT will occurred in (grey raster). Reprint of fig. 3, paper IV and figure 1 paper V.

The questionnaire survey described in paper V show that such illustrated FDTs have taken hold amongst the employees in the Danish Forest and Nature Agency. The results show that professionals at all levels of the classical forestry hierarchy assess the tool favourably as a way to describe long-term goals for stand structures and dynamics in nature-based forest management as well as an aid for their work in order to realise these goals (paper V; table 1). Furthermore, both forest managers and forest workers have already used and have clear ideas of future uses of the FDTs. The areas of uses rang from management planning and silvicultural decisions to communication with various stakeholder groups (paper V; table 3 and 4). The professionals' direct acceptance of the illustrated FDTs indicates the tool's potential to support and catalyse the changes toward nature-based forest management.

THE IMPORTANCE OF PERSONAL KNOWLEDGE AND EXPERIENCES

FDT scenarios provided an adequate framework for organising and analysing alternative long-term goals for stand structures in dialogue between scientists and professionals. As such they helped to stimulate and organise new ways of thinking about the uncertain and complex future stand structures and dynamics. In addition, illustrating the FDT scenarios by means of profile diagrams forced the professionals to consider the principles of nature-based forest management and its impact on stand structures and dynamics in a way they were unable to by means of only the verbal FDT scenarios. As such the illustrations augmented the discussion of the FDTs and were instrumental for information to be transformed into personal as well as shared knowledge. The profile diagrams evoked mental images because they are visually iconic rather than symbolic in the way that words necessarily are. In this way Hare (2002) highlights the representative aspect of drawing as one which presents visual material in a visual form and the unsayable in an unsayable form. As illustrated in paper III, IV and V, it is through these two ways of working that profile- and crown projection diagrams support understanding and communication of the implications on forest stand structures and dynamics related to the ongoing conversion to nature-based forest management. The case study reported in paper III confirms the later observations. Here explorative, in-depth interviews with five professionals with different academic backgrounds as well as years of experience revealed that the detailed, graphic illustrations of actual or proposed stand structures augmented their analysis and discussions. Paraphrasing Taket and White (2000) the graphical information in profile diagrams »gave voice« to those interviewed as it seems to activate another important type of information; namely their own experiences. The professionals recognised this mechanism themselves, as they often and with great passion described other stands, which they wanted us to visualise. This use of references was expressed in three distinctive ways:

1. Specific references. Comparisons between specific stands
2. Generic references. Referring to general knowledge or forest types without mentioning specific localities
3. Metaphoric references. For instance the comparison of a dense growing hazel with a bamboo planting, because of the multi-stem character and the low canopy they have in common.

The importance of personal knowledge and experiences for the understanding of long-term goals for stand structures and dynamics in nature-based forest management was also confirmed in the questionnaire survey (paper V). Here, respondents stated that »visits to nature-based managed forests« and »general knowledge and experience« are the specific elements that have greatest importance for their understanding of the goals, as communicated in the FDTs (paper V: table 2). This shows that creation of meaning goes beyond simple decoding of information. It is also »reading knowledge and experiences into« the FDT scenarios and their illustration. These observations are in line with hermeneutic and semiotic philosophy where interaction between reality, its representation and the reader's mind is the precondition for creation of meaning (Fiske 1982, Stanford Encyclopedia of Philosophy 2006). Gombrich (1980) terms this »the beholder share«.

THE SOCIAL DIMENSION OF UNDERSTANDING AND COMMUNICATION

Due to the beholders share, developing a shared understanding of the FDTs and their implementation in the Danish state forests, is not simply a question of each individual to grasp what they personally consider to be the idea expressed in the FDTs, but also to reach an agreement of this and its implications; i.e. develop a 'interpretive community' (Fish 1980). In this context, the process of FDT-development confirmed the importance of dialogue for the development of both personal and inter-personal understanding. Through dialogue the professionals' knowledge and experiences were activated which empowered their understanding and simultaneously shaped perceptions that became part of shared base-line interpretations (i.e. paper IV). The professionals themselves recognised this importance of dialogue. Thus, respondents to the questionnaire (paper V) regarded »discussions with colleagues« as the single element that has the greatest importance for their understanding of the long-term goals for nature-based stand structures and dynamics as communicated in the FDTs and their illustration.

Recognising this 'social dimension' (to employ J.B. Harley's phrase, 1992) of understanding, the basic model of successful communication of the long-term goals for nature-based stand development therefore comes down to that of dialogue (Persson 1997, Innes 1998).In other words, the potentials of FDTs in creating a shared understanding of long-term goals for stand structures and dynamics in nature-based forest management is partly dependent on the way in which the tool is used; i.e. whether it is used as a tool for communicating these goals »to« the professionals (one-way communication) or as a platform for discussions »about« those goals with and among those very professionals. The latter was the case in the adaptive management process of developing long-term goals for stand structures and dynamics in the Danish state forests (paper IV).

It is therefore important to stress, that the professionals' positive assessment and general acceptance of the FDTs is not only attributed to the "tool" itself but also to the engagement of the professionals themselves in its development. The collaborative process provided room for plenty of discussions of the meaning, accuracy and implications of the FDTs. Further, the eagerness of developing and testing the »new« tool was for sure boosted by the fact, that the conversion to nature-based forest management already was decided politically beforehand (Danish Forest and Nature Agency 2002). Hence, the professionals' direct acceptance of the FDTs may to a large extent reflect the political-administrative preparations. However, all in all the professionals' direct acceptance of the FDTs and implementation of it in various aspects of their work indicates the tools potential to initiate and catalyse the desired changes toward nature-based forest management across all levels of the classical forestry hierarchy. After all, the observed positive attitude and assessment of FDTs (paper V) is the precondition for the tool to become a powerful agent in the future development of a shared understanding of the principles and long-term goals for nature-based stand development.

4. CONCLUSIONS

In summary, the present work has lead to a number of conclusions of which the most important will be summarised in the following:

- Quantification of 10 years of dynamics in Suserup Skov with respect to the forest cycle revealed many different and complex developmental processes. To a large extend these processes were not included in the understanding of the forest's structure and dynamics. Especially the process of lateral crown expansion and processes related to well-developed understorey layers deviated from the forest cycle.

- Lateral crown expansion of canopy trees surrounding gaps and patches with up growth does not only have major implications for the individual trees in Suserup Skov. The process also plays a large role in the spatial and temporal structure of the whole forest, because crown expansion relocates the borders between patches in a very dynamic way. The results indicate that especially trees in the early biostatic phase actively displace their crowns towards high-light patches such as canopy gaps (paper I).

- Understorey layers are well developed in Suserup Skov and play a surprisingly large role in both the spatial and temporal vegetation structure. Beneath the canopy 1-3 understorey layers are common (paper II). Release of understorey layers following the canopy breakdown enables most patches in the forest to bypass the innovation phase (paper I). The results indicate that the main reasons for the well developed stratification is irregularity of the canopy across small neighbouring structural units in combination with the presence of four co-occurring tree species with different strategies and life-cycles (paper II).

- Understorey light intensity in Suserup Skov has no simple correlation with the developmental phase of the canopy. The results illustrate that understorey light intensity is determined as much by understorey characteristics as by the developmental phase of the canopy trees or the total number of canopy layers. In fact a dense growing understorey across neighbouring structural units was found to be the main determinant for understorey light intensity (paper II).

- The adaptive management process of FDT-development illustrates the gains related to the joining of the knowledge cultures of scientists and professionals in the development of long-term goals for stand structures and dynamics in nature-based forest management and development of tools to describe such novel goals (paper IV). The process of FDT-development also revealed the social learning demands comprehensible tools (platforms) to organise and ease discussions of the issues faced (paper IV). Here FDT and profile diagrams turned out to be decisive »new« tools in each their way.

- FDTs provide an adequate framework for organising discussions and stimulating the development of long-term goals for stand structures and dynamics in nature-based forest management (paper IV).

- Profile diagrams communicate detailed information about stand structures in a way the professionals can easily comprehend, by guiding their mental imaging of the specific stand as well as other forest stands. This helps them to display an intuitive understanding of irregular stand structures (paper III).

- Being a support for the mind, the profile diagrams also augment professionals' discussions of stand potentials and long-term goals for stand structures (paper III and IV). The results indicate that this extended dialogue supported both the development and the understanding of the goals (paper III and IV).

- FDTs in combination with their illustration by means of profile diagrams have taken hold amongst the professionals in the Danish Forest and Nature Agency. The results show that professionals at all levels of the classical forestry hierarchy assess the tool favourable as a way to describe long-term goals for stand structures and dynamics in nature-based forest management as well as an aid for their work in order to realise these goals (paper V). Both forest managers and forest workers have already used and have clear ideas of future uses of the FDTs ranging from management planning and silvicultural decisions to communication with various stakeholder groups (paper V).

- The professionals' direct acceptance and implementation of illustrated FDTs in various aspects of their work indicate the potentials of the tool to initiate and catalyse the conversion to nature-based forest management.

5. OUTLOOK

The dominant research agenda has concentrated on providing generalised and objective facts as guidance for professionals' management (Jönsson and Gustavsson 2002), and most research does not legitimate the scientists to reflect on how their findings can become powerful agents in creating the desired understanding and changes in practice (Marcin 1995, Innes 1998). However, addressing the challenges and uncertainties experienced by professionals when urged to move from plantation forestry towards the emerging paradigm of nature-based forest management, the findings of this thesis indicate that the research approach taken also needs to accept and adapt to this new agenda. As I see it, greater emphasis on the advancement of knowledge through communication and collaboration between scientists and the professionals is central to overcome the uncertainty experienced by professionals trained and educated within age-class forestry. A good example of this is the described process of developing long-term goals for stand structures and dynamics in nature-based forest management in the Danish state owned forests and communication of these goals by means of FDT scenarios in combination with their illustrations by means of profile diagrams (paper IV). This project owns its success to the active participation and commitment of both scientists and professionals from all levels of the classical forestry hierarchy.

Participatory practices in natural resource management and research has so far focused on the public and stakeholder groups. Since the 1980's collaborative approaches like e.g. »community forestry« and »adaptive management« have been developed and widely applied when it comes to involving the *public* in forest research and management in especially developing countries (Wollenberg et al. 2000a, 2000b, de Boo and Wiersum 2002) but to an increasing extent also in European urban forestry (Van Herzele et al. 2005). Such approaches can also serve as inspiration for collaboration between researchers and professionals when moving from one forest management paradigm to another. Here, the research approach is changed from serving the research consumers "out there" to actively involve those commissioning and using the research findings in a collaborative approach that tap into their energy and commitment. Correspondingly, it is suggested that further research should focus on the opportunities and constraints related to scientists and professionals joining forces in the development and implementation of nature-based forest management and how to organise such collaborative approaches in order to support professionals in overcoming the uncertainties they experience.

In this context, the process of developing long-term goals for stand structures and dynamics in nature-based forest management (paper IV) showed that comprehensible communication tools (platforms) for organising (FDTs) and facilitating discussions (profile diagrams) of the issues faced is a precondition for the exchange of experiences and advancement of knowledge. This first study of the tools we use to describe and communicate about forest stand structures in nature-based forest management indicate that further research into the functionality and the 'communicative effectiveness' of the tools currently used for communication of the nature-based management principles and long-term goals for stand development is needed. This would be a valuable basis for identification of needs and further development of tools.

The professionals' massive use of references when trying to get a hold on the principles and long-term goals for nature-based stand development, point to »reference landscapes« as an important type of »instrument«. Correspondingly, it is suggested that future work should focus on the establishment of a network of reference landscapes or maybe even »landscape laboratories« inspired by those that lately have been established to support the development of urban forestry (Gustavsson 2002). During the last decades a number of landscape laboratories have been established in Sweden and Denmark as settings for "full scale" studies of new approaches to design, establishment and silviculture in urban woodlands. At the same time – and maybe more importantly - these landscape laboratories are settings for interaction between different disciplines and knowledge exchange between scientists, students and professionals (Gustavsson 2002, Nielsen et al. 2005a, b, c, d, e, Tyrväinen et al. 2005). Inspiration could be taken from this approach in the establishment of reference landscapes for nature-based forest management. On the one hand, such references can serve as scientific studies of stand development and test of silvicultural approaches, e.g. inspired from studies of natural forests as Suserup Skov, while on the other hand they serve as demonstration plots where professionals can observe irregular stand structures and the effects of different silvicultural actions on these. In this context, the professionals use of both specific, generic and even metaphoric references (paper III) illustrate that not only forest stands having reached the desired »equilibrium state« have their place. Also - and maybe even preferably - stands representing structures at all developmental stages between the desired mixtures of species in irregular and divers structures and the well known even-aged monoculture stands we are about to leave behind. Furthermore, the investigations presented in this thesis indicate the additional gains related to scientists and professionals collaborating on the studies and experiments taking place in such reference landscapes. If so, they can become active settings for social learning and exchange of knowledge between researches, the profession, students, and even the public – a real learning laboratory.

Based on the studies of Suserup Skov it is suggested that research activities in such laboratories could focus on the processes related to understorey characteristics and lateral crown expansion of canopy trees at gap-edges or surrounding patches with up growth. Since the processes related to a well-developed understorey and manifested in patches, by-passing the degrading part of the forest cycle and also the innovation phase, further research into these dynamics would be a valuable supplement to the current focus on regeneration processes related to gap-dynamics in e.g. the project »Nature-based Management of Beech in Europe«. Also lateral crown expansion of canopy trees surrounding gaps or patches with up growth played a larger role in the spatial and temporal structure and dynamics than expected. Correspondingly it is suggested to do further research and even experiments into this mechanism in both natural and managed forests in combination with studies of different tree species' response to »edge effects«. Such studies in combination with the aspiration of social and environmental functionalities would be beneficial as a basis for formulating management guidelines regarding harvest and gap sizes and shape in nature-based forest management.

Finally, research should also pay attention to the challenges of communicating the principles and long-term goals for stand structures and dynamics in nature-based forest management beyond the forest ranks. When working with lay persons and stakeholder groups it is a well-known fact that special attention must be given to the approaches taken and to the tools used for communication. Concerning the latter, being able to visualise the issues discussed is generally regarded as a precondition for successful participation (Sheppard 2001, Bell 2001, Stoltman et al. 2004, Tyrväinen et al. 2005, Nielsen et al. 2006). In line with this, a poster depicting all 19 FDTs in profile diagrams was made in order to support communication of the FDTs to a broader circle including interest groups and the public in general (Fig. 5). This poster was presented as a way to reach the public at the 8th European Forum on Urban Forestry, held in Slovenia (Nielsen et al. 2005). Furthermore, the survey addressed in paper V demonstrates that the FDTs and their illustration by means of profile diagrams are already being used in communication with the public and that the professionals in the Danish Forest and Nature Agency expect to use the FDTs in this way in the future. The question then is to what extend FDTs and their illustrations in profile diagrams are appropriate in communication with laypersons? The findings of Nielsen et al. (2006) indicate that lay persons are able to imagine the forest stand in nature from looking at profile diagrams. However, further research is needed to evaluate lay person's perception of FDT scenarios and their illustration by means of profile diagrams and especially the tool's effectiveness in facilitating understanding among lay persons who participate in nature-based forest management planning processes. Developing knowledge of this topic is of outmost relevance in highly urbanised Europe.

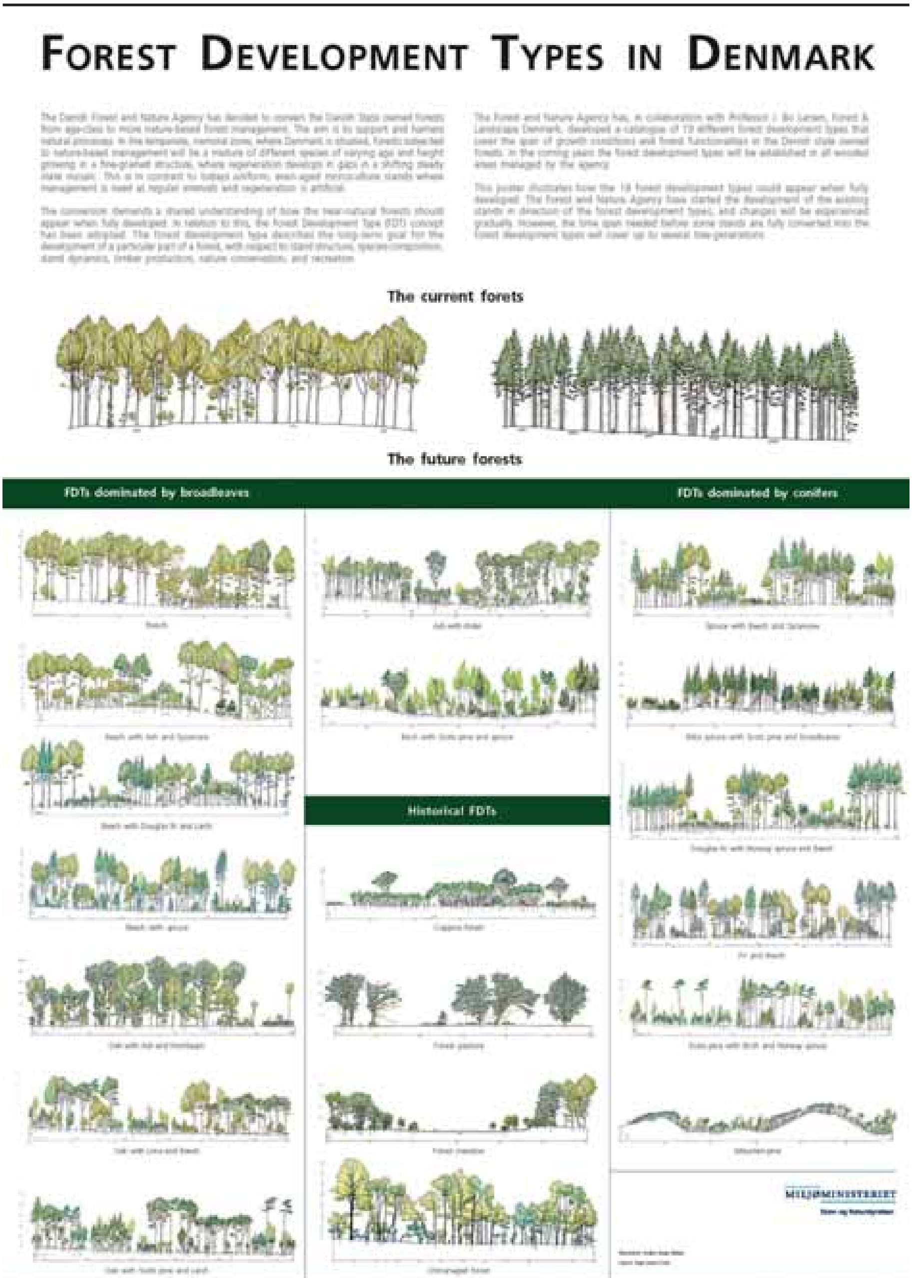


Figure 5. Poster depicting the present forest types and the future 19 FDTs in Denmark. The two upper profile diagrams show typical forest stands at present (even-aged monocultures of beech, respectively Norway spruce). Below the 19 FDTs are grouped in broadleaved dominated (9), conifer dominated (6), and "historic" (4). Original size is A1.

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7. PAPERS

PAPER I

Christensen M, Emborg J, Nielsen AB. The forest cycle of Suserup Skov – revisited and revised. Submitted to Ecological Bulletin 52.

PAPER II

Nielsen AB and Hahn K 2006. What is beneath the canopy? Structural complexity and understorey light intensity in Suserup Skov, eastern Denmark. Accepted for publication in Ecological Bulletin 52.

PAPER III

Nielsen AB and Nielsen JB 2005. The use of profile diagrams for mixed stands in urban woodlands – the management perspective. Urban Forestry and Urban Greening 3 (3-4): 163-175.

PAPER IV

Larsen JB and Nielsen AB. Nature-based forest management – Where are we going? Elaborating forest development types in and with practice. Submitted to Forest Ecology and Management.

PAPER V

Nielsen AB and Larsen JB. Communication tools for nature-based forest management: Forest development types and profile diagrams. Manuscript for European Journal of Forest Research.

PAPER I

Christensen M, Emborg J, Nielsen AB: The forest cycle of Suserup Skov – revisited and revised.
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THE FOREST CYCLE OF SUSERUP SKOV – REVISITED AND REVISED

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Abstract

We quantified changes in forest structure in Suserup Skov based on two detailed inventories of forest development phases carried out in 1992 and 2002. The inventories were based on a forest cycle model for Suserup Skov, which included five sequential development phases (innovation, aggradation, early biostatic, late biostatic, and degradation). Due to a multitude of different development process nearly half of the total area changed phase during the 10 years, which was more than three times the expected. To a large extent, the observed changes between developmental phases followed the basic forest cycle. However, many deviations from the basic forest cycle did occur, of which the most important can be summarised as: 1) The majority of the area in the innovation phase in 2002 originated from phases other than degradation, due to storm damage resulting in aggregate tree fall and the massive spread of Dutch elm disease resulting in sudden die back of patches dominated by elm trees; 2) The majority of the area in the early biostatic phase in 2002 originated from phases other than the aggradation phase, due to crown expansion of trees in the early biostatic phase surrounding canopy gaps; and 3) the majority of the area in the aggradation phase in 2002 recruited from other phases than the innovation phase, due to a well developed sub-canopy layer that gradually replaced areas with a degraded canopy. These processes are discussed and presented in a revised model of the forest dynamics in Suserup Skov. Finally, the potential of reproducing sub-canopy layers and crown expansions at gap edges in nature-based forest management are discussed.

Introduction

Since the introduction of the forest cycle concept (Watt 1947), researchers have developed a considerable number of specific forest cycles (e.g. Leibundgut 1959, Zukrigl et al. 1963, Meyer and Neumann 1981, Mueller-Dombois 1987, Jenssen and Hofmann 1996, Emborg et al. 2000, Grassi et al. 2002), which have supported our understanding of basic dynamics in natural forests from tree generation to tree generation (Standovár and Kenderes 2003). The forest cycles all describe a number of continuous sequential shifts between a series of upgrading and degrading developmental phases. When related to both time and space the forest cycle is referred to as the mosaic-cycle (Remmert 1991), and is now widely accepted as a basic description of the natural dynamics of temperate, deciduous forests (Oldeman 1990), where patches of trees pass through the forest cycle asynchronous from patch to patch, resulting in a shifting mosaic of developmental phases.

The forest cycle is a major tool in understanding the dynamics of natural forests. However, several authors have argued that the simplification can lead to misinterpretation because the exclusion of complexity of developmental processes (Franklin et al. 2002, Standovár and Kenderes 2003). Muth and Bazzaz (2002) describe the importance of crown expansion for the forest dynamics and Pontailler et al. (1997) and McCarthy et al. (2001) describe the complexity of regeneration and graduate take over of understorey.

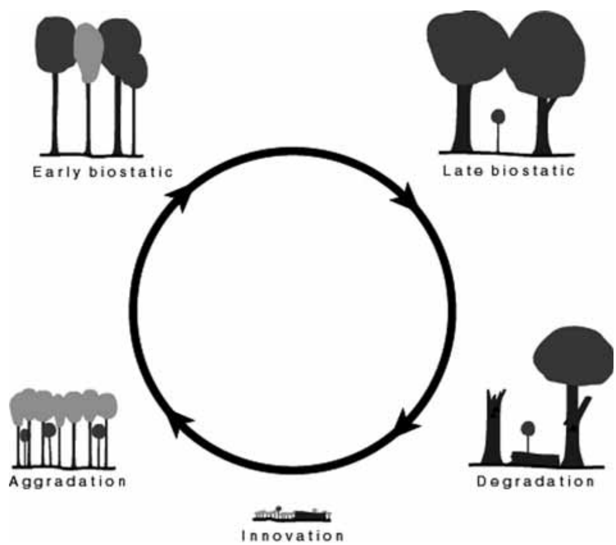

Figure 1: Model of the basic forest cycle, including five developmental phases termed the innovation, the aggradation, the early biostatic, the late biostatic and the degradation phase, in accordance with Oldeman (1990). The definitions of the phases are described in table 1.

A basic forest cycle model for Suserup Skov, Denmark, was developed from an inventory in 1992 (Emborg et al. 2000), as described in Table 1, Fig. 1. A re-inventory in 2002 made it possible to quantify different development processes, thereby allowing a critical evaluation and improvement of the basic forest cycle based on the 10-year observation period. Correspondingly, the objectives of this paper were to 1) quantify changes in development phases from 1992 to 2002 with reference to the basic forest cycle model; 2) evaluate and further develop the basic forest cycle model; and 3) discuss the implications of the results in the context of nature-based forest management.

Table 1: Definition and duration of the five developmental phases in Suserup Skov according to Emborg et al. (2000). The phases are defined explicitly using ecological considerations and arguments and distinguished from each other by easily measurable criteria.

The innovation phase

Definition: The beginning of the innovation phase is defined as the moment when regeneration is well established in a gap, that is more than ca. five vital plants taller than 20 cm per m^2 (less for larger plants).

Comment: Often ash establish first due to its pioneer features, with many wind-dispersed seeds almost every year. Beech establishes within a few years, typically after the first mast year. In addition to the tree vegetation, herbs, grasses, bushes and smaller trees find their place in the open and light conditions.

Average duration: Based on tree-coring and tree height measurements the average duration of the innovation phase is estimated to 14 years.

The aggradation phase

Definition: The beginning of the aggradation phase is defined as the moment when the established regeneration has the competing herbal vegetation under control, which is when the regeneration has reached a height of 3 m.

Comment: The first part of the phase is often dominated by fast growing ash, but often with scattered small trees like elm, wild cherry and elder. Beech often dominates the lower stratum throughout the phase.

Average duration: Based on tree-coring and tree height measurements the average duration of the aggradation phase is estimated to 56 years.

The early biostatic phase

Definition: The early biostatic phase begins when the trees have reached the upper canopy layer, that is has reached a height of 25 m.

Comment: Most often ash dominates from the beginning, but during the early biostatic phase beech completely takes over the canopy stratum.

Average duration: Based on tree-coring and tree height measurements the average duration of the early biostatic is estimated to 96 years.

The late biostatic phase

Definition: The late biostatic phase begins when the trees becomes old, have wounds and scars, and tend to become more vulnerable to biotic and abiotic damages, that is when the trees have reached a dbh of 80 cm.

Comment: Usually beech completely dominates the upper canopy stratum throughout this phase, while scattered undergrowth of elm and beech may occur. Towards the end of the phase the old beeches begin to degenerate, dropping even large branches creating small often short-lasting gaps in the canopy.
Average duration: Based on tree-coring and tree height measurements the average duration of the late biostatic phase is estimated to 108 years.

The degradation phase
Definition: The degradation phase begins when degrading trees causes more permanent gaps in the canopy, large enough to initiate regeneration, that is gaps >100 m^2, which cannot be filled by lateral in-growth of the surrounding trees.
Comment: The phase can be regarded as an interface between the late biostatic and the innovation phase. It may start suddenly as a result of wind-throw, or it may develop gradually as old trees lose vitality and eventually die. Well-established regeneration in a gap defines the end of the degradation phase and the start of a new turn of the forest cycle
Average duration: Based on tree-coring and tree height measurements the average duration of the degradation phase is estimated to 10 years.

One turn of the basic forest cycle in Suserup Skov is, accordingly, estimated to 284 years on average.

Methods and materials

STUDY SITE

Suserup Skov is a 19.2 ha forest reserve located in the central part of Zealand (Sjælland) in the eastern part of Denmark. The forest is a near-natural, temperate, deciduous forest dominated by beech in mixture with ash *Fraxinus excelsior*, elm *Ulmus glabra*, and oak *Quercus robur*. The soil is glacial sediments where both clay, loamy and sandy till occur (Vejre and Emborg 1996). The study was carried out in »Part A« of Suserup Skov (10.60 ha, see Emborg et al. 1996), for which pollen analysis suggests a history of forest cover during the last 6000 years (Hannon et al. 2000). Management has been minimal since 1854 and since 1961 Suserup Skov has been a strict non-intervention reserve (Emborg and Fritzbøger 1996, Heilmann-Clausen et al. 2006).

CLIMATE AND DISTURBANCE FROM 1992 TO 2002

Climatically, the 10-year period from 1992 to 2002 was not substantially different from previous decades. Average annual temperatures were 8.3 °C, which is slightly higher than the average from 1874 to 2003 of 7.6°C, and varied from 6.8°C (1996) to 9.2°C (2002). The average annual precipitations was 741 mm and varied from 505 mm (1996) to 905 mm (1999), compared to an average of 674 mm from 1874-2003 (Cappelen 2004). No exceptional droughts or extremely cold winters occurred in the period. On 3rd December 1999 the southern part of Denmark was hit by a severe storm (mid-latitude cyclone).

The storm followed a long period of heavy precipitation, causing many trees in Suserup Skov to uproot. Scattered single trees were damaged throughout the forest, while some areas experienced heavier damage, resulting in a range of small to intermediate sized gaps (for a detailed description of the storm and analyses of the impact on Suserup Skov, see Bigler and Wolf (2006)). Another important disturbance event in the 10-year period was the arrival and subsequent spread of Dutch elm decease caused by *Ophiostoma ulmi* beginning in 1995. Elm mortality continued until 2002, which created gaps of varying size where patches of elm formed the uppermost canopy layer.

MAPPING OF THE DEVELOPMENTAL PHASES

The development phases were mapped in winter 1992/1993 and autumn 2002. The mapping was done on the basis of »stem-position maps« (1:500) including all trees >29 cm dbh (Emborg et al. 1996, Emborg and Heilmann-Clausen 2006). The uppermost canopy layer defined the phase of a given patch in the forest; i.e. regeneration on the forest floor was only defined as an innovation phase patch when there was a gap above, and trees between 3 and 25 m height were only defined as a patch of aggradation phase if they formed the uppermost canopy layer of that patch (Emborg et al. 2000). This way spatial overlap between neighbouring patches was avoided. The Spatial resolution corresponded to a minimum patch size of 100 m^2. Clinometer, calliper, and measure lines were used to ensure a strict mapping of patches according to the phase definitions (Table 1). Each patch of the mosaic was marked on field charts.

DATA ANALYSIS

All development phases in the 1992 and 2002 inventories were digitized with AutoCad and incorporated into ArcGIS. Spatial Analyst and Geo Processing tools in ArcGIS were used for calculating changes in the areas of development phases between 1992 and 2002. We performed the following two sets of calculations for the observed changes:

1. The expected aggregate area of each of the five phases was calculated presuming that the forest has reached the dynamic phasic equilibrium (Watt 1947), also called the shifting-mosaic steady state (Bormann and Likens 1979) in which the aggregate area of a phase is directly proportional to the duration of that phase, using the formula:

$$E_a = (A/I) \times I \qquad \text{(Formula 1)}$$

Where, E_a is the expected area, *A* is the area of the whole plot (10.60 ha), *I* is the duration of the full forest cycle (284 years), and *i* the duration of the phase.

2. The expected turn over of phases during the 10-year period was calculated using the formula:

$$E_t = (Y / i) \times E \qquad \textit{(Formula 2)}$$

Where E_t is the expected turn over, Y is the studied period (10 yrs), i is the duration of the phase and E_{1992} is the aggregate area of the phase in 1992.

Results

SHIFTING MOSAIC AND AGGRGATE ARE OF THE PHASES

The maps of the shifting mosaics from 1992 and 2002 are shown in fig. 2. Despite the recent disturbances caused by the severe 1999 storm and the attack of Dutch elm disease, the forest is still close to the hypothetical shifting-mosaic steady state (Fig. 3). Moreover, the average patch size of each phase hardly changed (Table 2). The number of patches in the innovation phase, however, increased considerably, leading to an increment in the aggregate area of the innovation phase from 0.24 ha in 1992 to 0.80 ha in 2002, which was a larger increment than »expected« (according to formula 1) (Fig. 3). Also, the aggregate area of the continuing upgrading phases of aggradation and early biostatic was larger than »expected«. In contrast, the area of the degrading phases of late biostatic and degradation was less than expected, which was a direct effect of the 1999 storm (Fig. 3).

TURN OVER IN PHASES 1992 TO 2002

A closer look into the dynamics of the single patches from 1992 to 2002 uncovered additional information about several important processes during the 10-year period. For all phases except degradation, the observed turn over in the 10-year period was larger than expected. In total, 4.96 ha changed phase during the period corresponding to 47 % of the total plot (10.60 ha), which was nearly three fold the expected turn over (Table 3). The observed turn over was considerably larger than expected for the aggradation and late biostatic phases. This was due to the die back of patches of elm in the aggradation phase, as well as storm damage to individual and small groups of trees in the late biostatic phase (Table 3).

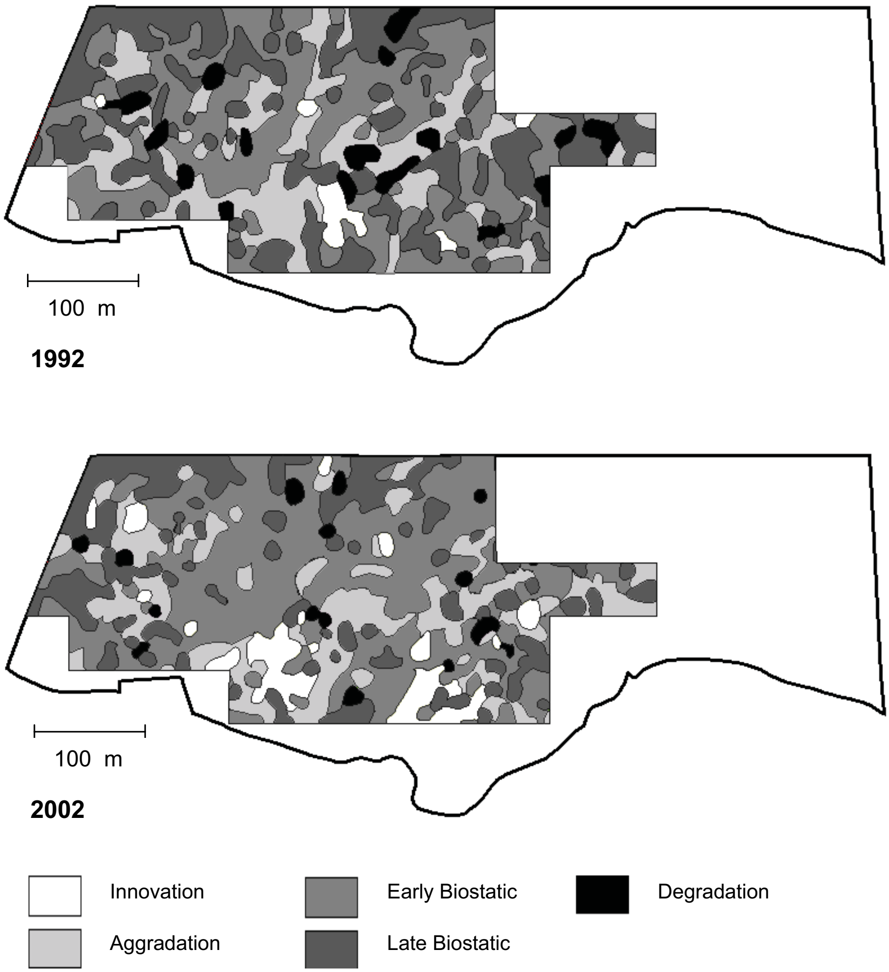

Figure 2: Maps of the developmental phases in 1992 and 2002

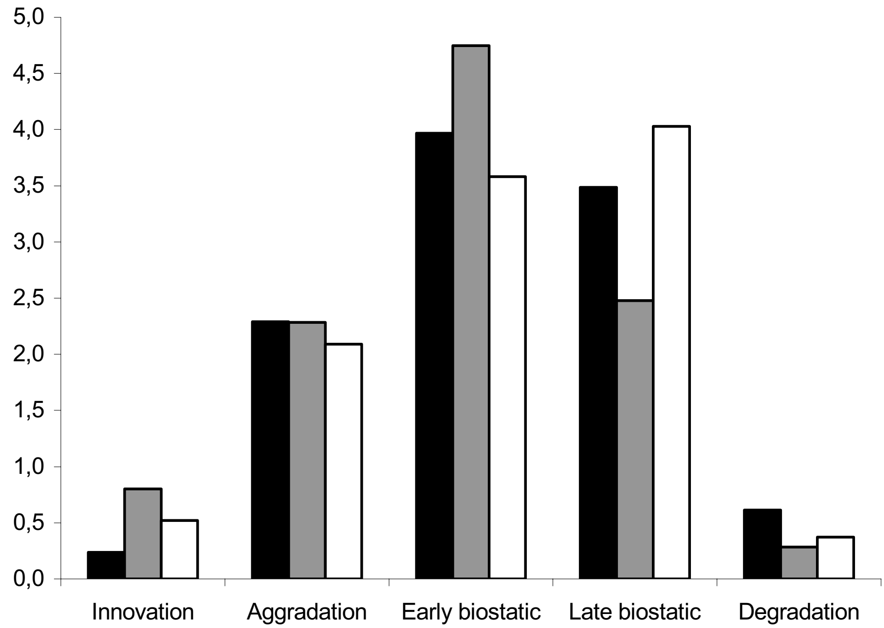

Figure 3: Aggregate area of the different phases observed in 1992 (black) and 2002 (grey) and expected aggregate area of the phases in 2002 (E_a) (white) according to formula one.

Table 2: Aggregate area, number of patches and average patch size observed in 1992 and 2002 according to the five developmental phases.

	1992			2002		
Phase	**Aggregate area (ha)**	**Number of patches**	**Average size (m²)**	**Aggregate area (ha)**	**Number of patches**	**Average size (m²)**
Innovation	0.24	5	476	0.80	15	533
Aggradation	2.29	27	848	2.28	21	1088
Early biostatic	3.97	27	1469	.,75	32	1484
Late biostatic	3.49	52	671	2.48	49	506
Degradation	0.61	16	384	0.28	14	203
	10.60	127	834	10.60	131	809

Table 3: Expected and observed turn-over of phases from 1992 to 2002.

Phase	Duration[1] years	Area (ha) 1992	Expected turnover (E_t)[2] ha	%	Observed turnover[3] ha	%
Innovation	14	0.24	0,17	71	0.23	96
Aggradation	56	2.29	0,41	18	1.48	65
Early biostatic	96	3.97	0,40	10	1.03	26
Late biostatic	108	3.49	0,31	9	1.63	47
Degradation	10	0.61	0,61	100	0.59	97
Total	284	10.60	1,89	17	4.96	47

1) Duration of phases is according to Emborg et al. (2000). See also table 1
2) According to formula two
3) According to fig. 4

OBSERVED DEVELOPMENT SERIES

The high turn over in phases observed over the 10-year period was caused by a multitude of development series which are illustrated in figure 4. To a large extent these mechanisms followed the basic model of the forest cycle (Emborg et al. 2000). The most important can be summarised as follows:

1. A major part (0.12 ha of 0.24 ha) of the innovation phase in 1992 changed into the aggradation phase in 2002.
2. A major part (0.97 ha of 2.29 ha) of the aggradation phase in 1992 changed into the early biostatic phase in 2002.
3. A major part (0.16 ha of 0.28 ha) of the degradation phase in 2002 originated from areas of the late biostatic phase in 1992.

However, deviations from the basic forest cycle (Fig. 1) occurred in all the developmental phases from 1992 to 2002, of which the most important can be summarised as follows:

1. The majority of the area that changed into the innovation phase originated from phases (0.74 ha) other than the degradation phase (0.05 ha).
2. Nearly half of the area (0.84 ha) that changed into the early biostatic phase originated from phases other than the aggradation phase (0.97 ha).
3. The majority of the area that changed into the aggradation phase originated from phases (1.35 ha) other than the innovation phase (0.12 ha).

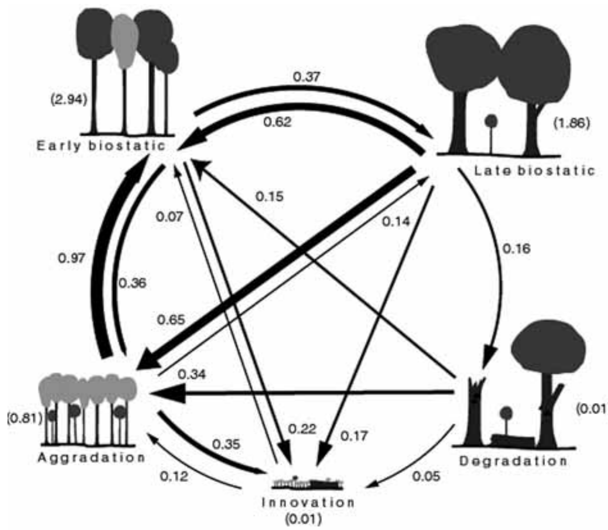

Fig. 4. Refined forest cycle model illustrating area of changes and non-changes (in ha) 1992-2002.

Discussion

Our results indicate that the development of the forest structure from 1992 to 2002 does not follow the basic forest cycle model strictly from patch to patch over time. Furthermore, the pattern of developmental phases differed from a hypothetical steady-state (Fig. 3). Many different processes and short-cuts that deviate from the basic model occurred, which may also serve to counterbalance each other - as illustrated by the arrows pointing back and forth between phases in fig. 4. These deviations from the basic forest cycle model resulted from either 1) the 1999 storm and the arrival of Dutch elm disease in 1995, 2) crown expansion of canopy trees in the early biostatic phase, or 3) a well developed advanced regeneration layer that gradually replaced the canopy. Each of these processes is discussed with reference to the basic forest cycle.

CREATION OF THE INNOVATION PHASE

The aggregate area of the innovation phase increased considerably from 0.24 ha (2%) in 1992 to 0.8 ha in 2002 (8 %), which is directly related to the 1999 storm and the spread of Dutch elm disease. The proportion of gaps in 2002, however, corresponds to reports from other wind disturbed NW European beech dominated forest reserves, e.g. the Fontainebleau reserve (9-11%) in France (Koop and Hilgen 1987).

In the 10-year period the 1999 storm was the most important initiator of gaps > 100m^2. The extremely strong winds during the storm caused direct mortality and damage to both healthy canopy trees as well as senescent ones. These processes explain why approximately half the area in the innovation phase in 2002 originated from patches of the early biostatic and late biostatic in 1992 (Fig. 4).

The spread of Dutch elm disease was the second major factor that initiated patches of the innovation phase in the 10-year period. Dutch elm disease spread rapidly in Suserup Skov after its arrival in 1995, causing mortaliy of nearly all elms larger than 10 cm dbh by 2002. Many of the stems that died where growing in patches in the aggradation and early biostatic phase. Most often, such areas changed into the innovation phase, which explains why nearly half the area (0.34) in the innovation phase in 2002 originated from patches of the aggradation phase in 1992 (Fig. 4). Similar mortality patterns of elm in unmanaged forests have also been observed in Austria (Mayer and Reimoser 1978), UK (Peterken and Mountford 1998) and Germany (Huppe and Röhrig 1996).

CROWN EXPANSION

In forest ecosystems, light is a critical resource (Emborg 1998, Grassi et al. 2002), which is particularly patchy in nature (Nielsen and Hahn 2006), so that trees actively displace their crowns towards high-light patches, such as canopy gaps (Muth and Bazzaz 2002).

In Suserup Skov, the most vulnerable phases to crown expansion processes were small patches of the innovation and degradation phase when surrounded by the early biostatic phase. Frequently, small gaps simply closed and larger patches of innovation or degradation decreased considerably in size due to crown expansion of canopy trees. Such canopy expansions explain why one quarter of the area in the degradation phase (0.15 ha of 0.61 ha) and innovation phase (0.07 ha of 0.24 ha) changed into the early biostatic phase in 2002 (Fig. 4). There was also a 0.62 ha change from the late biostatic phase in 1992 to the early biostatic phase in 2002 (Fig. 4). This is likely the result of trees in the early biostatic phase that expanded their crowns into gaps created by storm related damage and mortality of trees in the late biostatic phase.

Similar processes of beech tree crown expansion into canopy gaps have been reported from unmanaged temperate beech forests in Central Europe

(Koop and Hilgen 1987, Knapp and Jeschke 1991, Tabuka and Meyer 1999) and experimental studies on canopy displacement at forest gap edges in North American mixed hardwoods with *Fagus grandifolia* (Muth and Bazzaz 2002). Consequently, horizontal expansion of crowns does not only have implications for individual trees - it is also an important process for forest structure and dynamics in general, initiating substantial turn-over in terms of phases.

UNDERSTOREY TREES TAKING OVER THE CANOPY

Understorey characteristics are often overlooked in studies of the structural dynamics in unmanaged forests (McCarthy et al. 2001, Franklin et al. 2002). However, our results indicate that the release of understorey trees following canopy breakdown is a main driving process in Suserup Skov, enabling most patches to bypass the innovation phase. Micro-succession from ash to beech (Emborg et al. 2000) only explains a small portion of the observed replacement of the canopy by understorey trees during the 10-year period. Beech is often described as a heavy shading species which not allow the understorey to develop (Knapp and Jeschke 1991, Jenssen and Hofmann 1996). Our results, in contrast, show that the majority of overstorey-understorey transitions were from beech to beech in wind-throw patches with understorey trees (often referred to as advanced regeneration). This explains why more than half of the area (1.35 of 2.28 ha) in the aggradation phase in 2002 was either in the early biostatic phase (0.36 ha), late biostatic phase (0.65 ha), or degradation phase (0.34 ha) in 1992 (Fig. 4).

The change from the early biostatic to the aggradation phase is a direct result of wind-throw in patches with a well-developed understorey. Since beech trees account for more than half of the total number of trees in the early biostatic phase damaged in the 1999-storm (Bigler and Wolf 2006) much of the understorey developed as advanced regeneration beneath a beech canopy. Similarly, the change from the late biostatic to aggradation phase is also a result of wind-throw. Moreover, since few ash grow to a dbh > 80 cm in Suserup Skov (Emborg et al. 2000), and because very few oaks were damaged in the 1999 storm (Bigler and Wolf 2006), trees that developed beneath a beech canopy appears to account for the majority of this change as well. Finally, well developed understorey explain why nearly all the degradation phase areas bypassed the innovation phase and developed directly into the aggradation phase during the 10-year period (Fig. 4). The character of such well-developed understorey in Suserup Skov has been exemplified on profile diagrams by Nielsen and Hahn (2006).

Concluding remarks

The studies of Suserup Skov exemplify the »unpredictable« nature of natural dynamic forests, identifying many and complex developmental processes. During the 10-year observation period, the number of processes deviating from the basic forest cycle model was surprisingly high. The effects of the 1999-storm and the arrival of Dutch elm disease in 1995 explain some of these deviations. However, the majority of deviations seem to occur because the basic forest cycle model does not incorporate the process of crown expansion at gap edges or the process of canopy replacement by understory trees.

Understorey characteristics played a large role in both the spatial and temporal structure. Since the proesses related to well developed understorey manifests in patches by-passing the degrading part of the forest cycle and also the innovation phase, further research into these dynamics would be a valuable supplement to the current focus on regeneration processes related to gap-dynamics in Nature-based Management of Beech in Europe.

Also lateral crown expansion of canopy trees surrounding gaps or patches with up growth played a larger role in the spatial and temporal structure and dynamics than expected. Often trees around gaps closed small gaps and reduced larger gaps dramatically. Further research and maybe even experiments into this mechanism in both natural and managed forests and studies of different tree species' response to "edge effects" would be beneficial as basis for formulation of management guidelines regarding timber harvest and gap sizes and shape in nature-based forest management.

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PAPER II

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What is beneath the canopy? Structural complexity and understorey light intensity in Suserup Skov, eastern Denmark

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Nielsen, A. B. and Hahn, K. 2006. What is beneath the canopy? Structural complexity and understorey light intensity in Suserup Skov, eastern Denmark. – Ecol. Bull. 52: xxx–xxx.

A detailed understanding of the structural complexity and its effects on understorey light intensity in natural forests are important references for the further development of nature-based forest management. Based on a full inventory of a 1-ha plot in Suserup Skov, a near-natural temperate deciduous forest in Denmark, this research describes the structural complexity in three dimensions and identify structural factors, which determine the relative light intensity in the understorey, using profile- and crown-projection diagrams related to relative light intensity (RLI) measured one metre above the ground. The horizontal pattern showed a fine-grained mosaic of trees in different developmental phases resulting in a variable canopy height ranging from 1 to 40 m. Beneath the canopy one to three understorey layers were common. The main reasons for this well developed stratification were irregularity in canopy cover among small neighbouring structural units and the presence of four co-occurring tree species with different reproductive strategies and life cycles. Relating the spatial structure to the understorey light intensity, we found the continuous cover of dense growing understorey layers across neighbouring structural units to be the main determinant for RLI.

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Structure of vegetation and its effects on the understorey light intensity in natural forests are complex and notoriously difficult to explain due to varying canopy height, understorey tree layers, and advance regeneration (Brown and Parker 1994, Franklin et al. 2002, Grassi et al. 2003). In spite of this, understorey data is in many cases overlooked in studies of unmanaged forests (McCarthy et al. 2001, Franklin et al. 2002). Moreover, understorey light intensity is often described as having a simple correlation with the developmental phases of the canopy trees (Emborg 1998, Grassi et al. 2003). Such simplifications can be regarded as one of the reasons why the spatial structure of natural forest ecosystems is neither easy to understand nor to communicate, as indicated by Franklin et al. (2002). From this perspective, a more detailed understanding of the structural complexity and the relationship between structure and understorey light intensity in natural forests is an important reference for further development of nature-based forest management.

One important method applied for detailed studies of vegetation structure is profile and crown-projection diagrams. A profile diagram is a depiction of a vertical section through the forest, while the crown projection diagram is the corresponding map. This method has gained interest during the last century, especially where mixed-forest management has been practiced, indicating that the more complex the structures are, the greater the needs for integrative visual tools (Gustavsson 1986, 1988, Koop 1989, Nielsen and Nielsen 2005). The earliest use of crown projection diagrams date back to the late 1870s where Blomqvist (1879) made drawings of boreal forests (Sarvas 1958). This was followed by profile diagrams of English forests by Watt (1925) and soon after by many other forest ecologists in central and eastern Europe and the tropics (Gustavsson 1986, Koop 1989). Since then, scientist and teachers in forestry, forest ecology and landscape architecture have used profile diagrams (sometimes including crown projections) as descriptive tools illustrating and documenting forest structures (Baker and Wilson 2000).

In contrast to the widespread use of profile- and crown projection diagrams as descriptive tools, their use for analyses have, to our knowledge, mostly been limited to identification of stratification in forest canopies (Baker and Wilson 2000). However, when applied as tools for analysis, such visual tools provide information about many other facets of the structural conditions (Gustavsson 1986). In this research, profile- and crown projection diagrams are combined with quantitative measurements in order to describe the vegetation structure in a 1-ha plot in Suserup Skov, and how the structural complexity affects the understorey light intensity. The research questions were: 1) How does the forest structure influence the relative light intensity in the understorey? 2) Which structural factors determine the understorey light intensity?

Materials and methods

The study was carried out in a 120 × 80 m (0.96 ha) plot in the least disturbed NW part (10.6 ha) of Suserup Skov (19.2 ha) (Fritzbøger and Emborg 1996, Heilmann-Clausen et al. 2006). The tree vegetation is dominated by beech *Fagus sylvatica* in mixture with ash *Fraxinus excelsior*, elm *Ulmus glabra*, and pedunculate oak *Quercus robur*. The ground cover consists predominantly of perennial species adapted to utilise the light in early spring before leafing (*Anemone nemorosa, Mercurialis perennis*, *Corydalis bulbosa)*. Closed canopy characterises most of the plot, with clear signs of an old, now overgrown gap in the SW part of the plot and a young storm-induced, E-W oriented gap (1999) ca 40 m from the N edge of the plot. The plot is situated on an elevated plateau cut through by a shallow NW-SE depression with a 6 m elevation drop. Two small footpaths cross the plot. The plot was selected on the basis of its representative forest structure and the presence of a small bog in the NE quarter (500 m^2) for pollen studies (Hannon et al. 2000). A local grid system with permanent corner posts was laid out, dividing the plot into eight transects of 120 × 10 m (transects no. 1–8). Each transect was again split into six blocks of 20 × 10 m to ease the field mapping of crown projections and drawing of profile diagrams (Fig. 1).

All trees were recorded according to the methodology of Koop (1989). Trees > 3 m height were given a unique number, whereas seedlings < 3 m height were recorded either as number m^{-2} (areas with high densities) or as individuals (areas with scattered seedlings). Horizontal characters (tree positions, crown projections, footpaths, lying dead wood) were positioned and drawn on field charts at scale 1:200 for the whole plot. Crown projections of individual trees were made on transparent sheet-overlay, according to the methodology of Koop (1989).

All vertical characters (top height, height at the greatest width of the crown periphery, height of the crown base, height of the first living fork, standing dead wood, and dead branches) were recorded according to Koop (1989) in tables on site. Hand drawn profile diagrams (viewed from west) were made for transects 2 and 4, each 120 × 10 m (1200 m^2). Tree positions, crown periphery and vertical characters were used to support the profile drawings on site. Mapping crown projection was carried out in early spring 2002 before leafing and profile diagrams were drawn in the leafing period in order to maximize the precision of height-measurements, distinguish dead and living branches and drawing of crown architecture. In order to keep the profile drawings readable the method of nested transects (Koop 1989) was used for delimitation of the trees to be included in the profile. Trees taller than 10 m were drawn for the full 10 m transect width (1200 m^2), trees 2–10 m tall were drawn for a 5 m wide strip (600 m^2) and trees < 2 m height were drawn over a 2 m wide area (240 m^2) around the centre line.

By use of transparent overlay, all crown-projections and profile diagrams made in the field (paper size A4) were transferred to one sheet, which was copied to aquarelle pa-

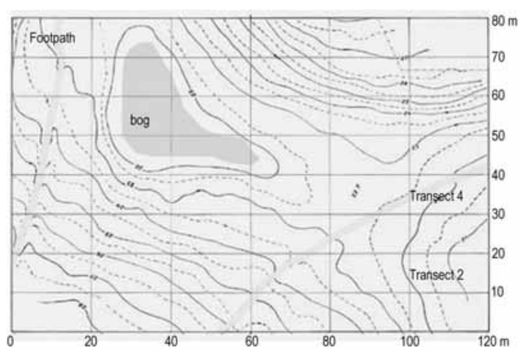

Fig. 1. The studied plot with elevation contours, footpaths, bog and the division of the plot into 8 transects of 120 × 10 m, each subdivided into 6 blocks of 20 × 10 m. Transects 2 and 4 are drawn in the profile diagrams (see Fig. 3 and 4).

per and coloured. Finally the drawings were scanned and adapted into image software (Photoshop 7.0).

Relative light intensity (RLI), calculated as percent of light intensity measured in a nearby open field, was determined along the centre lines of transect 2 and 4 with two m intervals by use of measurements of leaf area index (LAI) with a Li-Cor LAI 2000 instrument. Two simultaneous measurements were taken with cross-calibrated sensors. One sensor was placed in a nearby open field and one sensor was used for measurements under the forest canopy (1 m above ground). The measures of LAI were converted to RLI (photosynthetic photon flux densities, PPFD, µmol $m^{-2} s^{-1}$) in the 400–700 nm wavelength, using an equation based on correlation tests of LAI and PPFD from measurements in similar beech dominated forests in eastern Denmark (Madsen and Larsen 1997). The conversion to RLI was done in order to ease the intuitive understanding of the inverse relationship between canopy cover and light intensity. RLI was first measured in late August 2002 and again in early July 2004. In the analyses, data from 2004 was used, as this dataset was more complete. There were no major differences in the spatial patterns of the RLI values between the two years.

Data were described and analysed both quantitatively and qualitatively with the two approaches supporting each other. For the analysis of the small to very small-scale structural patches in the plot, where even single-tree patches were recorded, we assigned individual trees to specific developmental phases (see also Grassi et al. 2003), well aware that that developmental phases are typically assigned to groups (cohorts) of trees. The developmental phases for the individual trees were defined in accordance with Emborg et al. (2000), supplemented with a division of the aggradation phase into an early and a late aggradation phase (Table 1). First, the developmental phases were described quantitatively according to tree species, tree density, and relative share of canopy cover. Weighing paper cuttings of all phase projections and thereafter relating the weight of each phase to the weight of the full plot paper cut, the area of each phase was calculated. Secondly, the spatial complexity was analysed qualitatively by use of the profile- and crown projection diagrams. The profile diagrams from transects 2 and 4 were analysed qualitatively for structural attributes and divided into sub-zones and zones based on two approaches: First, the transects were divided into sub-zones based on the developmental phase of the canopy trees. Second, these sub-zones were grouped into larger zones reflecting both canopy and understorey characteristics. The idea behind these two approaches was to test the effect of densely growing or shady understorey trees on the light intensity. The tests were performed by statistical analyses of how much RLI varied within and between the different zones for the two principles (SAS PROC GLM).

Results

The studied one-hectare plot contained 778 measured individual trees plus an estimated number of 50 000 ash and beech seedlings established in gaps and under the surrounding canopy (Table 2). Beech was the only species well represented in all developmental phases, whereas ash, elm, oak, and shrubs; elder *Sambucus nigra*, rowan *Sorbus aucuparia*, hazel *Corylus avellana*, and spindle *Euonymus europaea*, were limited to one or two developmental phases each. Ash was most common in the innovation phase (and early biostatic phase), elm was most abundant as scattered seedlings (< 3 m height) and small trees in early aggradation phases below canopy, while oak was limited to few individuals in the late biostatic and degradation phases (Table 2).

The horizontal pattern of the structural units, defined by the development phases of the canopy trees, revealed a fine-grained mosaic with spatial overlap of trees in different phases (i.e. height). Every site in the plot was, on average, covered by two canopy-layers assigned to different phases (ca 200% canopy cover) of which trees in early aggradation, late aggradation, and early biostatic phase together accounted for ca 150% canopy cover (Table 2). Seedlings in innovation phase predominately occurred as dense blankets in the larger 1999-gap and four small gaps, but also as scattered regeneration beneath closed canopy (Fig. 2A). Ash seedlings dominated the gap regeneration

Table 1. Definition of the developmental phases as applied to individual trees in this study.

Developmental phase	Definition
Innovation	Seedling > 20 cm, but < 3 m.
Early aggradation	Trees > 3 m, which have competing ground vegetation under control.
Late aggradation	Trees > 15 m, the competition from elm on ash and beech declines due to Dutch elm disease.
Early biostatic	Canopy trees > 25 m but < 80 cm dbh.
Late biostatic	Canopy trees > 80 cm dbh, still vital enough to fill smaller gaps by lateral growth.
Degradation	Degrading and dying trees.

Table 2. The developmental phases described according to number of trees, distribution to species and canopy cover.

Developmental phase	Number of trees in the plot						% canopy cover
	Beech	Ash	Elm	Oak	Shrubs	Total	
Innovation (estimated, in gaps)	1000	49000				51000	21.9
Inonovation (scattered, closed canopy)	16		104		20		
Early aggradation	114	4	200		5	323	40.0
Late aggradation	137	23	18			178	56.0
Early biostatic	48	49				97	52.6
Late biostatic	9	1		3		12	24.6
Degradation	7	5	13	2		28	5.7
Total (minus innovation)	331	82	335	5	25	778	
Total							200.9

with a density of 10–100 trees m^{-2} while the scattered regeneration mainly consisted of elm supplemented by beech, elder, rowan, hazel and spindle (Table 2). Trees in the early aggradation phase were scattered in small, well-dispersed groups of elm and beech, primarily in the northern part of the plot (Fig. 2B), while trees in the late aggradation phase dominated the S part of the plot, being scattered in the N part (Fig. 2C). The trees in the early biostatic phase formed three independent E-W oriented groups (Fig. 2D). Small groups of beech and oak trees characterised the late biostatic phase (Fig. 2E), while few beech, oak and Wych elm trees were classified as being in the degradation phase (Fig. 2F). The spatial overlap of trees in different developmental phases resulted in a complex structure varying from one to four canopy layers (Fig. 2G), where the height of the canopy varied between 1 and 40 m above the forest floor (Fig. 3 and 4).

In general, the understorey light intensity in Suserup Skov was rather low. In transect 2, RLI ranged from 0.5 to 4.8% and in transect 4 from 0.6 to 7.1% (Fig. 3 and 4). The division of each of the transects into sub-zones based on the developmental phase of the canopy trees (approach 1) showed that for transect 2 there were only significant differences ($p< 0.005$) in RLI between early biostatic (RLI mean=1.4) and late biostatic (RLI mean=0.7), while there were no significant differences in RLI between any of the phases in transect 4. In contrast, the division into larger zones, reflecting canopy as well as understorey characteristics (approach 2), showed significant differences ($p< 0.005$) in RLI between zone 1 and 2, and between zone 2 and 3 for both transects. In both transects, zone 2 (around the 1999 gap) had higher mean RLI (transect 2=2.1, transect 4=2.9) than zones 1 north of the gap (transect 2=1.2, transect 4=1.1) and 3 south of the gap (transect 2=0.7, transect 4=1.1). Thus, it appeared that the sub-zones based on the canopy were not reflected in the understorey light intensity whereas the larger zones based on a combined approach including the understorey characteristics much better reflected the understorey light intensity.

Discussion

Well aware that the identification of canopy layers to individual crowns is, to some degree, a subjective interpretation of a spatially restricted zone (Baker and Wilson 2000) the study showed that a mixed deciduous forest dominated by beech in eastern Denmark has the potential to develop a multi-layered structure. Without the presence of other species, naturally beech-dominated stands may grow into a regular uniform, even-aged appearing forest structure, which covers large areas (Jones 1945, Knapp and Jeschke 1991, Jenssen and Hofmann 1996).

When analysing the profile- and crown projection diagrams, we find that the development of a multi-layered structure, besides from the effects of medium-scale disturbances as e.g. of the 1999-storm (Bigler and Wolf 2006), is based a number of specific processes: 1) the presence of four co-occurrence tree species with different regeneration strategies and life cycles, 2) the vertical stratification among beech trees due to competition in the early and late aggradation phases, 3) the process of beech gradually taking over the canopy space from old degenerating ash and oak trees, and 4) the presence of elm as a typical understorey species, adding to the spatial structure as advance regeneration or as a scattered understorey of trees in early aggradation beneath closed canopy.

The four dominant tree species, beech, ash, elm and oak, each contributed to the spatial structure in a specialised way. Beech, as a shade-tolerant and late-successional species, was well-represented in all the developmental phases from the innovation to the late biostatic phase. Typically beech trees dominated the canopy and understorey layers in combination with ash trees in the early biostatic phase. The many small groups of suppressed beech trees in the early aggradation phase indicate that the majority of these have lost the competition to their neighbours. Spatially seen, these suppressed trees make up one or two understorey layers.

Ash, being a gap-specialist, had established intensively in the young (1999) E-W oriented gap, whereas regenera-

Fig. 2A. The spatial pattern of natural regeneration in gaps and scattered advance regeneration (innovation phase, < 3 m height) The large canopy gap initiated dense regeneration of ash and beech in the gap as well as advance regeneration of primarily elm N and NW of the gap. In addition the pattern of seedlings indicates four small gaps in the E part of the plot (see Fig. 2G). Dashed lines indicate the two transects drawn in profile diagrams (Fig. 3 and 4).

Fig. 2B. The spatial pattern of trees in the early aggradation phase (3–15 m) is characterised by a high number of small groups and individual trees. In the S part of the plot, the pattern suggests that the trees have lost the competition to the taller trees in the late aggradation phase (Fig. 2C). In the N part of the plot the early aggradation phase is dominated by elm, which utilizes the radiation from the large canopy gap. Dashed lines indicate the two transects drawn in profile diagrams (Fig. 3 and 4).

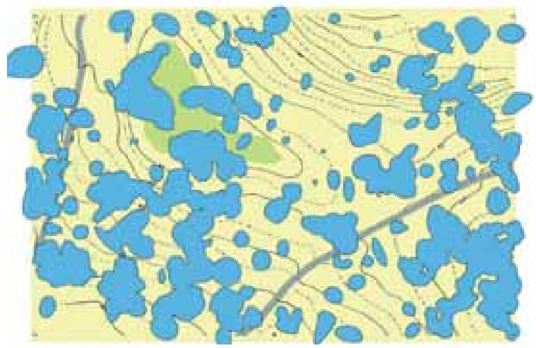

Fig. 2C. The spatial pattern of trees in the late aggradation phase (15–25 m) is characterised by scattered trees in the N part contrasted by dense cover in the SW part of the plot. The dense cover in the SW part relates to the presence of an old, now overgrown gap here. The SW area was registered as canopy gap in 1992. Dashed lines indicate the two transects drawn in profile diagrams (Fig. 3 and 4).

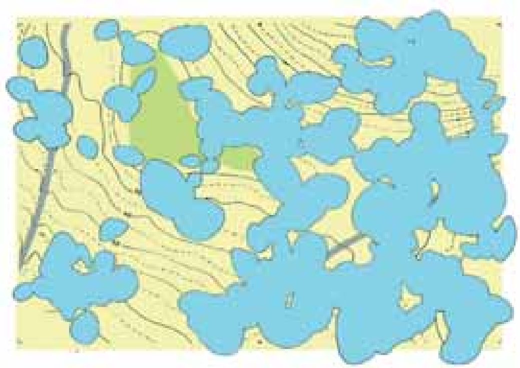

Fig. 2D. The spatial pattern of trees in early biostatic (> 25 m but dbh < 80 cm) is characterised by three more or less parallel strips. Comparing the width and orientation of the strips with the width and orientation of the present canopy gap (Fig. 2G) it is suggested that the trees in the early biostatic phase all were established in former gaps. Dashed lines indicate the two transects drawn in profile diagrams (Fig. 3 and 4).

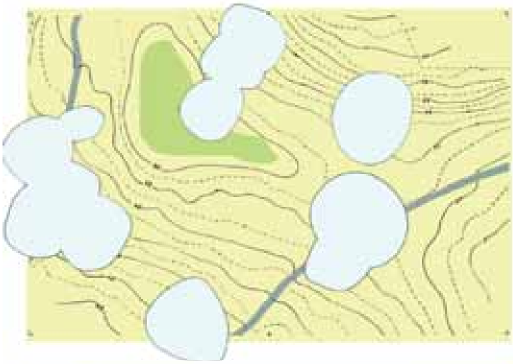

Fig. 2E. The spatial pattern of trees in the late biostatic phase (dbh > 80 cm) shows a scattered pattern of small groups of 1–5 old oak and beech trees. Dashed lines indicate the two transects drawn in profile diagrams (Fig. 3 and 4).

Fig. 2F. The spatial pattern of trees in the degradation phase (incl. young trees damaged by the break down of other trees or Dutch elm disease) is rather fragmented. Dashed lines indicate the two transects drawn in profile diagrams (Fig. 3 and 4).

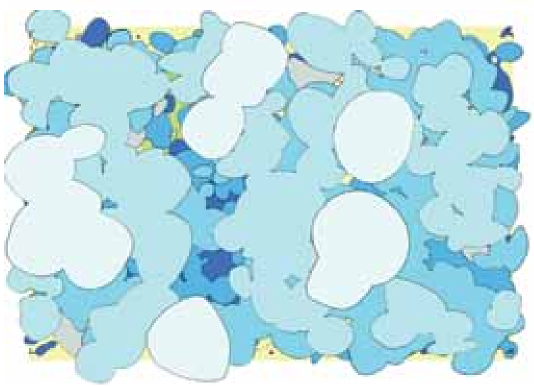

Fig. 2G. The spatial pattern of the canopy according to developmental phases shows a fine-grained mosaic with spatially overlapping trees in different developmental phases (i.e. height). Beside the fine-grained mosaic pattern, the main character is the E-W oriented canopy gap one-third from the N edge of the plot. Dashed lines indicate the two transects drawn in profile diagrams (Fig. 3 and 4).

tion was sparse in all other parts of the plot. Where the early biostatic phase was present, ash formed the canopy, typically with a layer of beech in the late aggradation or even early biostatic phase growing beneath. Here, we expect beech gradually to take over the canopy, either by growing through openings in the ash canopy, or by degradation of the ashes due to their shorter lifecycle. Emborg et al. (2000) has described this mechanism as a micro-succession from ash to beech. Also in places where oak dominates the canopy (late biostatic), it is expected that the vital subcanopy of beech trees in late aggradation and early biostatic phase will gradually take over as the oaks start degrading (lose more major branches or die). Spatially seen, this can be compared to the situation with micro-succession from ash to beech.

Elm is presently a characteristic understorey species according to its dominance as scattered seedlings and trees beneath closed canopy. The main reason for this pattern is a combination of the historic fellings of elm trees (–1940) and the invasion of Dutch elm disease in 1994 (Emborg et al. 2000), which caused high mortality among the large elm trees (> 15 m height). This again led to recruitment of new elm trees by initiation of shoots from the stem base. Advance regeneration of elm seems to be able to establish

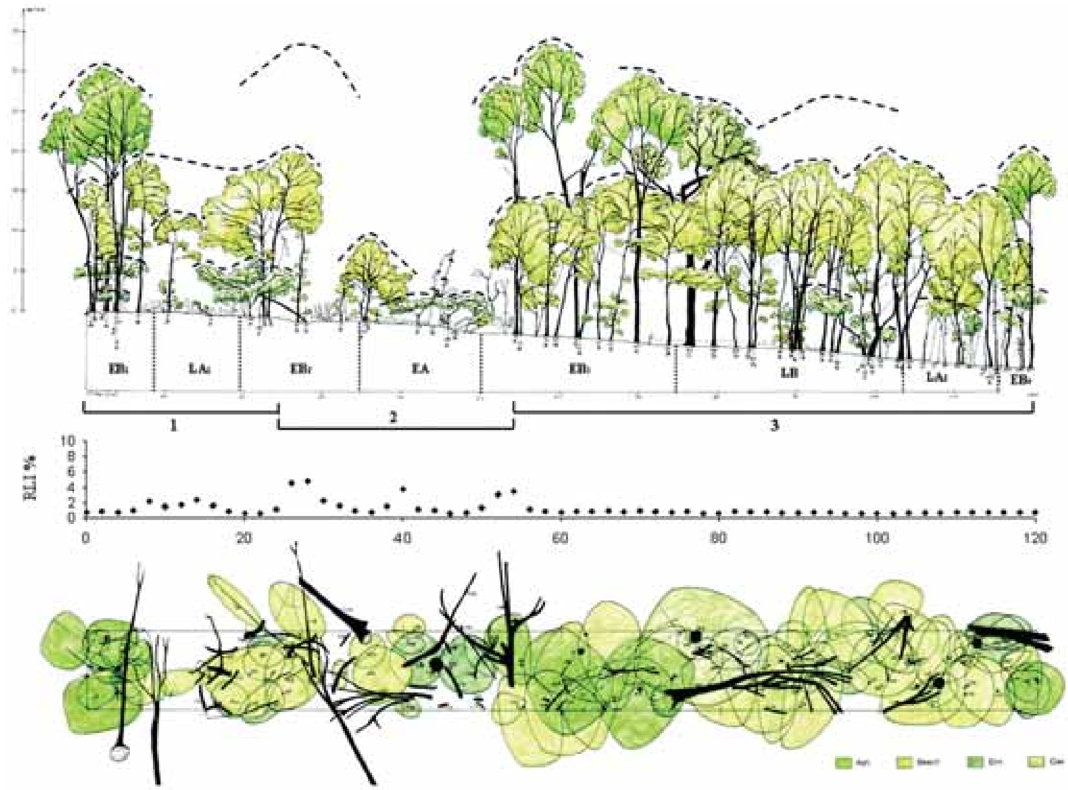

Fig. 3. Profile diagram, RLI and crown projection diagram for transect 2. Based on the developmental phases of the canopy trees, the transect was divided into eight sub-zones, whereas a more spatial approach reflecting both canopy and understorey characteristics led to a division into only three larger zones (1–3). The different sub-zones and zones are described below.

Description of sub-zones along the transect according to the developmental phase of the canopy trees:

EB_1: slim ash trees in the early biostatic phase form the canopy, clearly separated from the understorey of beech in late/early aggradation, beneath which umbrella shaped elms up to 7 m height form a scattered understorey.

LA_1: the canopy consists of beeches in the late aggradation phase of which one is located east of, but overlapping, the transect. Below this, a scattered understorey of umbrella shaped elm up to 7 m height.

EB_2: the canopy is made up by a beech in the early biostatic phase located east of, but overlapping, the transect, clearly divided from a scattered understorey of beech in the early aggradation phase. The forest floor is covered by dense ash regeneration, 20–100 cm height (se Fig. 3B), which is not shown in the profile diagram.

EA: the breakdown of a large beech in the 1999-storm created this gap. To day dense innovation of ash (not depicted in the profile diagram) and scattered umbrella-shaped elm in the early aggradation phase make up the canopy (se Fig. 2A, B, G). The umbrella shaped elm and the beech was established as advance regeneration prior to gap formation.

EB_3: a group of slim ash trees in the early biostatic phase form the canopy, below which dense growing beeches in late aggradation form a well-developed understorey. The forest floor is almost free of vegetation, resulting in a relatively high room (ca 8 m) beneath the canopy.

LB: an oak and a beech (standing in front of but overlapping the transect, see Fig. 2G) in late biostatic form the canopy below which dense growing beeches in late aggradation, as in zone E, form a well-developed understorey. Below this is scattered elm.

LA_2: dense growing beeches in late aggradation form the canopy, below which there is a scattered understorey of beech and elm in early aggradation. Standing beech snags (107 and 112 m) refer to the previous tree generation.

EB_4: slim ash in early biostatic forms the canopy. Below this is an understorey of beech and elm with a well-developed stratification.

Description of the zones reflecting both canopy and understorey characteristics:

1: this zone is characterised by very irregular canopy and understorey structures.

2: the gap in the canopy and the dense innovation of ash (and beech) at the forest floor characterise this zone (se also Fig. 2A, G).

3: a regular and closed canopy layer of beech in the late aggradation phase (se also Fig. 2C), overlapping, or overlapped by, a varied number of canopy-layers, characterise this large zone.

Drawings by Anders Busse Nielsen.

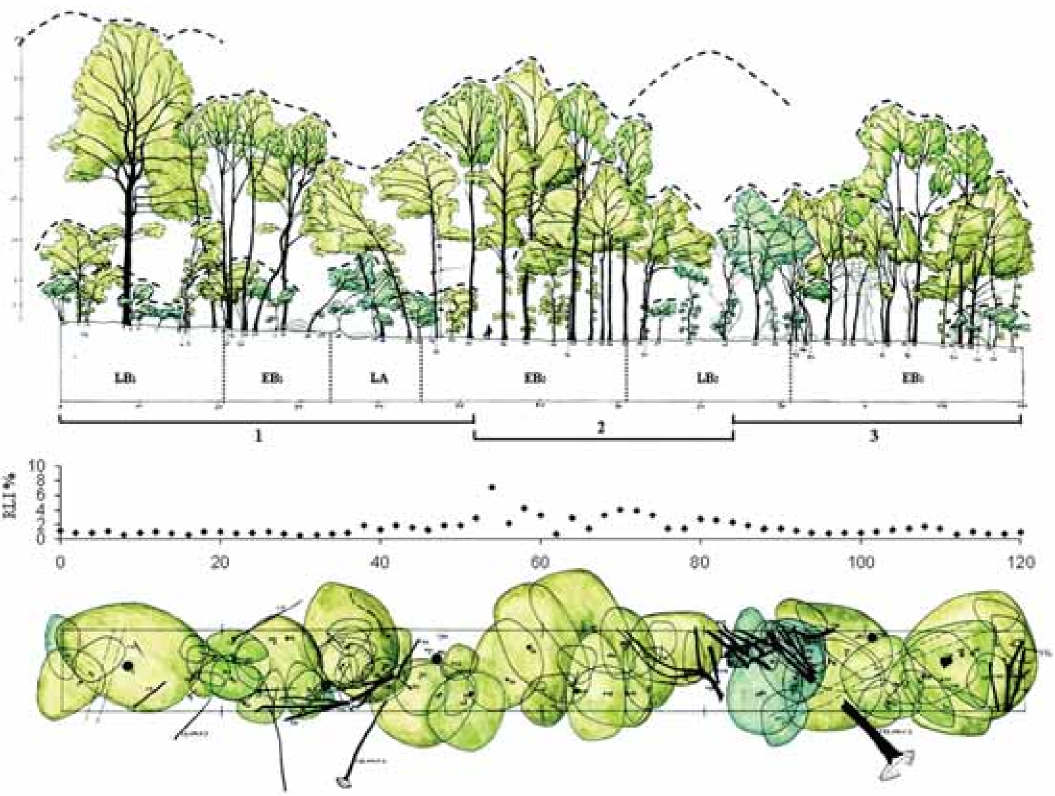

Fig. 4. Profile diagram, RLI and crown projection diagram for transect 4. Based on the developmental phases of the canopy trees, the transect was divided into six sub-zones, whereas a more spatial approach reflecting both canopy and understorey characteristics led to a division into only three larger zones (1–3). The different sub-zones and zones are described below.

Description of sub-zones along the transect according to the developmental phase of the canopy trees:

LB_1: the canopy is made up by three beeches in late biostatic, two of them standing east of, but overlapping, the transect (se also Fig. 2G). Beech and elm in the early aggradation phase form a scattered understorey from 1 to 13 m height, clearly divided from the canopy.

EB_1: four slim ash and two beeches in the early biostatic phase form the canopy, which is clearly divided from the understorey of beech and elm in early aggradation.

LA: the break down of a large beech in the 1999-storm (tall snag at m 47) created a gap in the canopy layer, which in 2002 has been closed by lateral crown expansion of three beeches in the late aggradation phase and elm in the early aggradation phase. The forest floor is covered with innovation of ash, 20–100 cm height, which is not shown in the profile diagram (se Fig. 2A). The beech and elms were established as advance regeneration prior to gap formation.

EB_2: the canopy consists of three ash trees and two beech trees in the early biostatic phase. An understorey of beech in the late aggradation phase is growing to the ash-crowns from beneath, resulting in dense folia from 10 to 30 m height. Shoots along the stems of the beech trees indicate the suppression.

LB_2: the canopy is defined by a beech tree in the late biostatic phase standing east of but overlapping the transect (se Fig. 2G). Beech and elm on the turn from early to late aggradation form a well-developed understorey at 6–18 m height. Dutch elm disease has caused stem and basal shoots on many of the elm trees, and these secondary "clowns" together with a few suppressed elms form a third, scattered canopy layer at 1–4 m height.

EB_3: slim ash trees in the early biostatic phase form the canopy, which is clearly separated from the dense understorey of beech in the late aggradation phase. Umbrella shaped elm in the early aggradation phase form a second, scattered understorey layer. An old beech-snag (m 102) refers to the former tree generation.

Description of the zones reflecting both canopy and understorey characteristics:

1: a more or less dense understorey of umbrella shaped elm and suppressed beech in early aggradation characterise this zone (se Fig. 2B).

2: a dense folia from 10 to 30 m height below which there is a nearly naked forest floor, characterise this zone.

3: like in transect two, the southern part of the transect is characterised by a dense growing understorey of beech (and elm, 84–90 m) in the late aggradation phase, overlapping or overlapped by a varied number of canopy-layers.

Drawings by Anders Busse Nielsen.

as soon as the regularity of the upper canopy layer(s) decreases. An example of this is the broad establishment of elm trees in the S part of the plot, which in 1992 contained a gap, and in a similar process elm is establishing north of the present (1999) gap.

The relatively low levels of light reaching the forest floor (ranging from 0.5% under closed canopy to 7.1% under light canopy cover) in our study were similar to the findings of Emborg (1998), also from Suserup Skov. However, the variation in RLI was related not only to the developmental phase of the canopy, as suggested by Emborg (1998) and Grassi et al. (2003), but also to understorey characteristics. We found that in areas with regular closed understorey layers of beech in late aggradation (50–120 m in Fig. 3 and 4) RLI was consistently low, even where the total number of canopy layers and the developmental phase of the canopy trees varied. This can be explained by an intense inter-tree competition (high number of individuals and the ongoing stratification) in the aggradation phases, which makes the crowns "melt together" as if they where part of the same multi-stemmed tree. The findings by Brown and Parker (1994) suggesting that leaf area density is highest among trees in the early developmental phases support this interpretation. A relatively low canopy height may also decrease the amount of light in the understorey (Brown and Parker 1994).

Based on these findings, we suggest that the understorey light intensity is a product of the density and height of the sub-canopy layers more than the developmental phase of the canopy trees or the number of canopy layers. From a silvicultural point of view this finding highlights the importance of paying as much attention to the density of sub-canopy layers as to the species and developmental phase of the canopy when deciding management actions aiming at initiating natural regeneration.

Conclusion

We demonstrated the spatial complexity of the forest structure in a 1-ha plot in Suserup Skov visually by use of profile- and crown projection diagrams. By linking the diagrams to quantitative measurements of understorey RLI and data on individual trees it was possible to refine the understanding of the spatial complexity of vegetation structure and identify structural factors which determine the understorey light intensity. The horizontal pattern showed a fine-grained mosaic of trees in different developmental phases resulting in a variable canopy height ranging from 1 to 40 m height. Beneath the canopy one to three well-developed understorey layers were the most frequent spatial structures across developmental phases and dominant species in the canopy. The canopy cover was, on average, double-layered, calculated as the sum of the layers of trees in different developmental phases. The main reasons for this well-developed stratification seemed to be irregularity of the canopy layers across small neighbouring structural units in combination with the presence of four co-occurring tree species with different regeneration strategies and life cycles. A comparison of the spatial structure to understorey light intensity indicate that RLI in the understorey, varying from 0.5 to 7.1%, is as much a product of the density of the sub-canopy layers as the developmental phases of the canopy or the numbers of canopy layers. In fact, we found the continuous cover of dense growing understorey trees across neighbouring structural units to be the main determinant for RLI one m above the ground.

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PAPER III

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The use of profile diagrams for mixed stands in urban woodlands—the management perspective

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Abstract

In the emerging paradigm of urban forestry objectives are often to develop mixed stands with complex structures. Such stands cannot easily be described in words and numbers. A logical alternative would seem to describe the structure of such mixed stands by use of image-based management tools. However implementing new management goals and using image-based tools challenges professionals, educated and trained within the age-class forestry tradition, to use their knowledge in a creative way. This paper describes how professionals contextualise from hand drawn profile diagrams when planning the management of mixed stands. The appropriateness of profile diagrams in this context is further discussed. The study was carried out as a case study focusing on the planning and development of long-term management goals for two young mixed stands for recreational use. We used explorative, in-depth interviews to identify the perspective on profile diagrams, as experienced by five individuals with different academic backgrounds as well as years of experience. The interviewees revealed that personal experiences and mental images played a key role in order to display an intuitive understanding of the subject stands through the profile diagrams. Further, they recognised this approach themselves often referring to other stands to make comparisons. The types of references used could be divided into three distinct categories: specific, generic and metaphoric. With regard to the ongoing move from age-class forestry to multifunctional management of mixed stands, this aid to dialogue might be the most relevant way in which profile diagrams can contribute to the implementation of new management paradigms.

Keywords: Image-based management planning; Communication; Urban forestry; Visualisations

Introduction

In urban recreational woodlands the management goals are often to develop mixed stands and structures of vegetation (forest interior), which are very different from the regular uniform structure of vegetation in the even-aged monocultures characterising most commercial forestry in Northern Europe. Whereas the tree population in age-class forestry has easily been described by simple numeric and verbal standard parameters, the structure of vegetation in mixed stands can hardly be described in numbers or words (Tahvanainen et al., 2001). It would therefore seem logical to describe the structure of vegetation in mixed stands with image-based management tools.

In urban woodlands the species and structures of vegetation are in focus for the visitor (e.g. Jensen and Koch, 1997; Tyrväinen et al., 2003). In the last decades mixed stands have been the predominant choice of stand type for the afforestation of periurban Denmark (e.g. Skov- og Naturstyrelsen, 2003). One of the main

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arguments for choosing mixed stands has been the flexibility with which they can be developed to different forest types over time. For this reason long-term management goals have not been determined in most cases. In relation to active involvement during the first two decades, the most common approach has been to observe the stand development. Today many of these mixed stands are in late aggradation, characterised by a high tree density and high grow rates leading to canopy closure and competitive exclusion. In this stage of development mixed stands can fulfil multiple management objectives, with variation in species distribution and structure. However, future possibilities of developing different structure of vegetation might be lost due to the ongoing canopy closure and competitive exclusion; this makes the formulation of management goals relevant. In this context, image-based management tools seem to be a way of raising awareness amongst professional of the multiple potentials in specific mixed stands.

Management tools and contextual information

Ideally the complexity of a specific forest stand can be reduced to contextual information with the use of management tools each carrying specific meaning which the professionals, due to inherent understandings, easily unpack and interpret (Fig. 1) (Nørretranders, 1993). In age-class forestry such inherent understanding has emerged over the last two centuries, enabling professionals to translate direct between standard parameters and reality. In short, written or verbal standard parameters such as species, age, height, growing stock and growth conditions is enough for the experienced forester to display an intuitive understanding of stand conditions and envision the stand in reality, i.e. contextualise or put into context. Today this set of standard parameters make up a framework of references among all professionals who are educated and trained within this tradition.

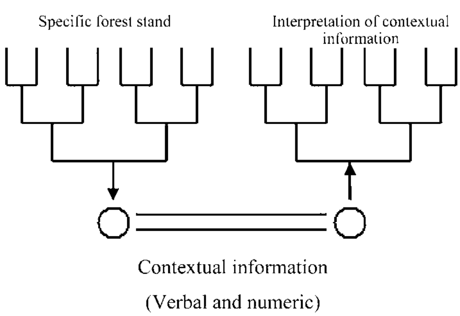

Fig. 1. The function of management tools is to reduce a complex reality to contextual information that can communicate a comprehensive view, which enable the manager to interpret the problems and potentials of a specific stand. The movement is from the left upper corner to the right. On the left side a lot of information is condensed by the exclusion of information (production of exformation), i.e. the condition or management objectives for a specific forest stand are expressed in management tools (symbolised by the circle). On the right side the information expressed by the tools is read and interpreted by the manager. Using his experience and knowledge he is able to unfold the exformation: i.e. envision the stand in reality. Modified from Nørretranders (1993).

More complex structures of vegetation, which are often the management goals in recreational woodlands, are, in contrast, hardly to be described appropriately in terms of species, age, height, growing stock and growth conditions, etc. (Tahvanainen et al., 2001). Additionally, there is a mismatch for professionals coming from age-class forestry, as there is no direct translation from the well-known standard parameters to reality and vice versa. Referring to Dreyfus and Dreyfus (1986) the capacity to make management decisions can be divided into five stages from ''novice'', ''advanced beginner'', ''competent'', ''proficient'' and ''expert'' (Table 1). Going from management of even-aged monocultures to management of mixed stands the direct and spontaneous translation between forest-condition and management tool fails, and even experts in organised forestry will have some experience of being ''beginners''. This study is founded on the assumption that the formulation of management goals for a young mixed forest stand can reveal how different professionals think in action when facing such challenges. Mature stands are easy to assess and the potentials for future development is limited. In contrast, young mixed stands represent a range of possibilities that challenge the knowledge and creativity of the professionals in the context of performing management planning.

Moreover actions are not simply a question of information, experiences and knowledge, but also intuition and values. Managing new forest types (mix of species and tree size/age) by use of new tools (image-based) challenges professionals to use their knowledge in a creative or even experimental way. This presumes a change in attitudes (Jönsson and Gustavsson, 2002; Konijnendjik, 2003). One must assume that competent professionals are highly engaged in their work. They care about their actions and it may take a lot for them to actually change their standpoints. However, standpoints are mobile (Palm, 1994), and incompatible standpoints can lead to discrepancy between what is said and what is done: espoused theory and theory-in-use (Argyris and Schön, 1978). From that point of view professionals' abilities and attitudes are the condition for development and implementation of new management concepts and –practices (Argyris, 1993; Persson, 1997). Consequently,

Table 1. Five stages in a professional's capacity to make contextual management decisions. Modified from Dreyfus and Dreyfus (1986)

Stage	Characteristic
Novice	Context independent elements and rules as basis for action
Advanced beginner	Experience and context depending elements supplement the context independent elements and rules as basis for action
Competent	Goals and strategy are chosen consciously and carefully considered in order to reduce the complexity. The professional is personally involved in his action
Proficient	Intuitive identification of the problem, goals and strategy based on experiences, which are analysed before action
Expert	Intuitive, holistic and synchronised identification of problem, goals, strategy, decision and action, not divided by analytical considerations

to successfully develop and implement tomorrow's management concepts and –tools, it is essential to understand how the professionals themselves experience the process of management planning, and specifically in this case study, how the professionals themselves experience the use of image-based management tools.

Image-based management tools

Image-based management tools can be characterised at three different projection scales each representing a specific level of detail; Stand, Forest and Landscape scale. The goal for illustrations at the landscape scale (areas over 200 ha) is to show the spatial arrangement of forests and the surrounding landscape, and similarly the goal for illustrations at the forest scale is to project area layout such as harvesting parcels and relations between different types of stands. Finally, the goal for illustrations at the stand level is to illustrate the horizontal and vertical structure of vegetation with respect to canopy layers, understorey conditions, habitat qualities, silvicultural prescriptions and crown/folia characteristics on a single tree level (Mamali, 2001).

From the different techniques designed to generate illustrations at the stand scale hand drawn profile diagrams (Figs. 2 and 3) can be described as primarily addressing the structure of vegetation, photo-realistic images primarily addressing the forest sceneries/aesthetics (e.g. Jensen and Koch, 1997; Tahvanainen et al., 2001; Tyrväinen et al., 2003), while the focus of computer-based systems for modelling stand development like SILVA (Pretzsch et al., 2002) and BWINPRO (Nagel et al., 2002) predominately is on modelling yield and growth in relation to different silvicultural treatments. Consequently, hand drawn profile diagrams would appear to offer good opportunities for professionals to achieve additional insight into the technical conditions and potentials of the structures of vegetation in mixed stands in recreational forests.

Profile diagrams

As the name indicates, hand drawn profile diagrams are a depiction of a section through the forest (normally 3–10 m wide) and the corresponding map. The diagrams try to highlight the essential elements of the structure of vegetation. Such diagrams have been important tools for visual analyses of the structure of vegetation in different forest types throughout the last century, especially where mixed-forest silviculture has been practised, indicating that the more complex the structures are, the greater the need for the overview that sections and plans can provide. The earliest use of crown projection diagrams dates back to the late 1870s when Blomqvist (1879) made drawings of boreal forests. This was followed by profile diagrams of English beech forests by Watt (1925) and soon after came many other forest ecologists in Central and Eastern Europe and the tropics. Since then, scientist and teachers in silviculture (Oldeman, 1990; Oldeman and Schmidt, 1986), forest ecology (Koop, 1989) and landscape architecture (Gustavsson, 1986, 1988; Gustavsson and Fransson, 1991) have used profile- and crown projection diagrams as tools for illustrating and analysing structures of vegetation at the stand scale. The current study uses the term profile diagrams as synonymous with crown projection diagrams for existing stands. The term principle profile diagram is used to denote such diagrams used to project a future condition. The history of the use of profile diagrams has been carefully described by ex. Gustavsson (1986) and Koop (1989).

Looking at profile diagrams from the users point of view

Profile diagrams have to our knowledge never been tested as a way to provide professionals with additional insight into stand conditions and potentials in the context of management planning. One could ask

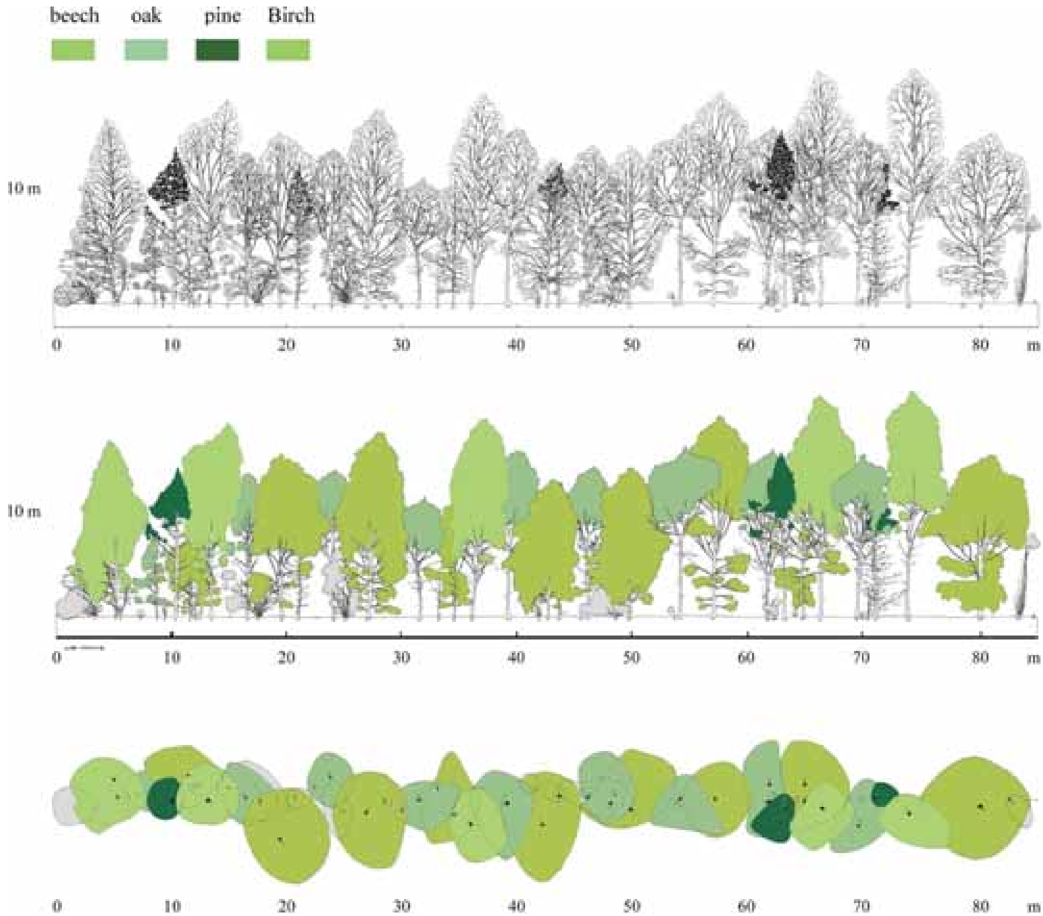

Fig. 2. Profile diagrams documenting stand conditions (autumn 2002) for stand one (see Table 1). Top: profile diagram where crown architecture and branches are depicted. Middle: The same profile but coloured, omitting branch structure. Below: The corresponding crown projection diagram. As a pioneer species birch has made a head start and is clearly in advance of the other species. Scots pine and most of the oaks have developed badly and will soon be eliminated from the system due to ongoing canopy closure and competitive exclusion. The shade-tolerant beech has developed solitary-like branching, folia clothing to the ground (Nielsen, 2003).

whether further improvements in technology are as needed as further improvement of our knowledge of how professionals interpret and use profile diagrams and similar image-based tools (Sheppard, 2001). Thus, the objective of this paper is to:

1. Describe and understand ways in which different professionals contextualise from hand drawn profile diagrams when planning the management of mixed stands.
2. Discuss the appropriateness of profile diagrams for management of mixed stands.

Materials and methods

The study was designed as a case study focusing on the planning and development of long-term management goals for two younger mixed stands, expected to represent many of the possibilities and challenges related to management of planted mixed stands for recreational use (Table 2), Explorative, in-depth interviews (Denzin and Lincoln, 2000) were used to identify the perspective on the management of mixed stands and profile diagrams, as experienced by professionals of different background (Kvale, 1997; Denzin and Lincoln, 2000).

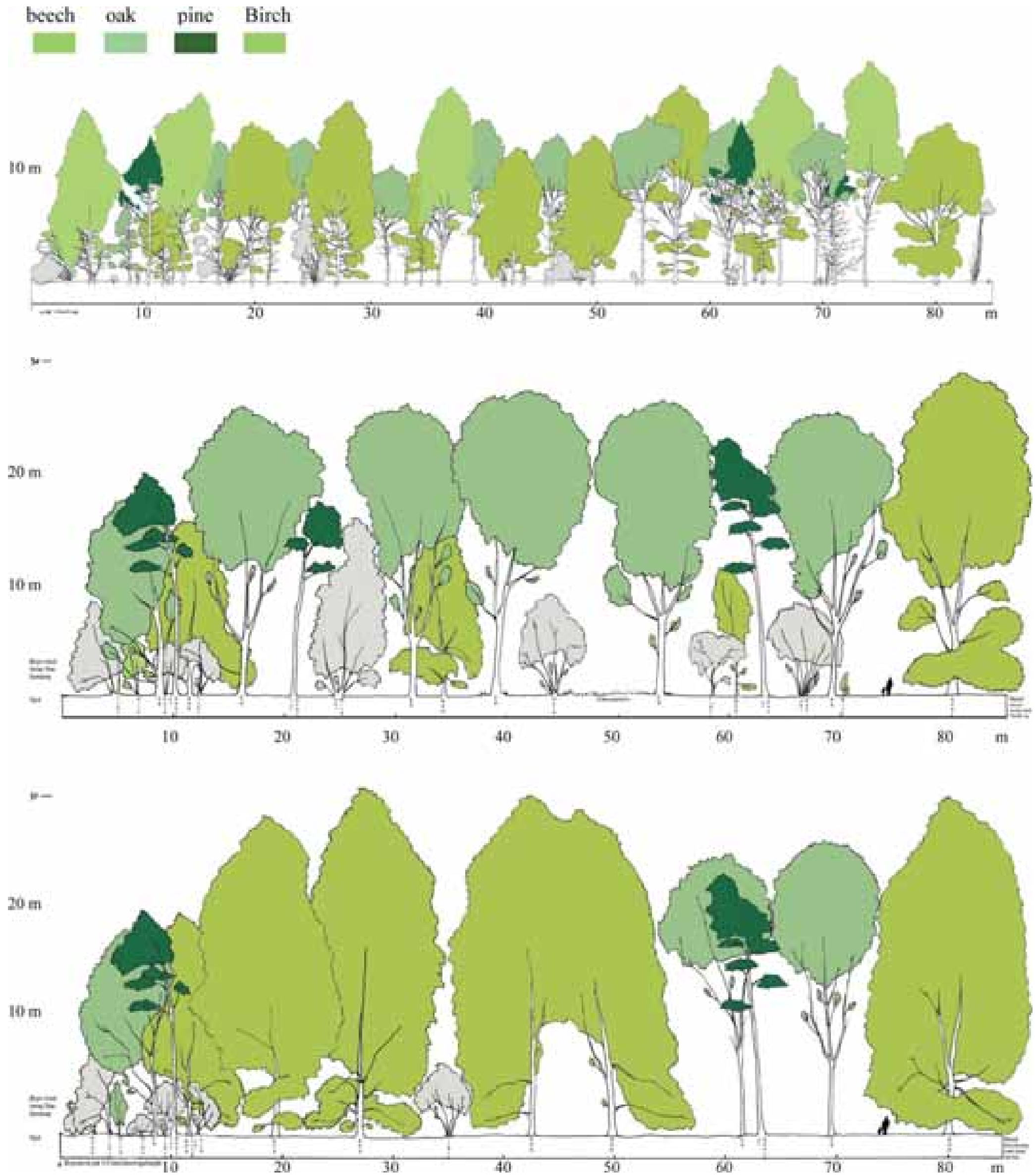

Fig. 3. Principle profile diagrams visualising the two alternative management goals formulated by the interviewees. Top: Line profile diagram documenting stand conditions (autumn 2002) used as a basis for analysis of stand conditions. Middle: Visualisation of management strategy one; from the actual conditions there is potential to develop a multi-layered stand with oak and small numbers of scots pine and beech in the uppermost canopy and a scattered understorey of well-developed individual beech and the present understorey species. (Table 1). Below: Management strategy two; the actual stand conditions also represent the potential to develop a forest type with solitary-shaped beeches standing ''shoulder to shoulder''. This dark and dense forest character is contrasted by small groups of oak, scots pine and birch with management of the understorey. In both management strategies the goal for the fringe of the stand is a dense, multi-layered character (Nielsen, 2003).

Table 2. The two stands around which the case study was conducted

	Stand 1				Stand 2			
Ownership	Municipality of Ishøj, Denmark				Swedish university of agricultural science, Alnarp			
Functionality	Part of a peri-urban forest belt near recreational landscapes and acting as a screen against two motorways				Part of a peri-urban forest belt (landscape laboratory) near recreational landscapes used for teaching and research; planting acting as a screen against a railway			
Main arguments for management	Development of the recreational and biological values.				Development of the recreational and biological values and settings for research and education.			
Soil	Loamy glacial till				Loamy glacial till			
Climate	Cool-temperate, sub-oceanic				Cool-temperate, sub-oceanic			
Year of plantation	1977				1986			
Species distribution according to the plan of plantation	*Pinus sylvestris* 30%	30%			*Alnus glutinosa*	50%		
	Laric leptolepis 20%	20%			*Corylus avellana*	20%		
	Betula verrucosa	26%			*Viburnum opulus*	5%		
	Fagus sylvatica	12%			*Cornus sanguinea*	5%		
	Quercus robur	12%			*Ribes alpinum*	5%		
					Acer pseudoplatanus	5%		
					Quercus robur	3%		
					Pyrus communis	3%		
					Sorbus aucuparia	2%		
					Fraxinus excelsior	2%		
			Average DBH (cm)	Average height (m)			Average DBH (cm)	Average height (m)
Species distribution as monitored, autumn 2002	*Pinus sylvestris*	22%	15.1	10.3	*Alnus glutinosa*	3%	13.7	9.9
	Laric leptolepis	0%	—	—	*Corylus avellana*	42%	—[a]	5.4
	Betula verrucosa	16%	22.2	17.3	*Viburnum opulus*	6%	—[a]	5.5
	Fagus sylvatica	32%	18.2	12.7	*Cornus sanguinea*	15%	—[a]	5.3
	Quercus robur	30%	18.0	12.1	*Ribes alpinum* 15%	15%	—[a]	2.1
					Acer pseudoplatanus	3%	9.9	9.4
					Quercus robur	9%	12.7	10.0
					Pyrus communis	3%	1.6	2.3
					Sorbus aucuparia	3%	3.8	6.1
					Fraxinus excelsior	0%	—	
Natural seeded shrubs and tree species (Monitored, autumn 2002)	*Sambucus nigra* *Crataegus monogyna* *Ribes spicatum* *Ribes uva-crispa* *Prunus spinosa* *Prunus padus* *Rosa* ssp. *Betula verrucosa* *Quercus robur*				Seedlings eliminated in management actions			
Number of management actions conducted	2			3				

[a]Multi stemmed.

The professionals were deliberately selected in order reflect the extremes of the entire pool of professionals influencing urban woodland management in Denmark.

The professionals responsible for the management of the two stands were selected as interviewees: These were a newly educated forest engineer, an experience landscape architect and a professor in landscape planning (Table 3). Two additional interviewees were selected from an operational enumeration of the entire pool of professionals responsible of urban woodland management in Denmark (Yin, 1994). Here forestry, ecology and landscape architecture were identified as the dominant disciplines in design, planning and management of urban woodlands (Jönsson and Gustavsson, 2002). The knowledge bound to professionals as well as academics and researchers was identified as important in the evaluation of profile diagrams in mixed forestry management, as mixed stands hardly exist in Danish forestry and only few local authority parks departments have experience of management of mixed stands. Based on these two criterions the professor in forestry and the forest ecologist were identified as representing the missing extremes of the pool, see Table 3.

Interviewing was carried out until little new information or insight was forthcoming (Kvale, 1997; Yin, 1994; Denzin and Lincoln, 2000). In total the five professionals were interviewed each 2 or 3 times within a time span of 3 months, with a total of 13 interviews (Table 4). This number of interviews is similar to the average of studies based on in-depth interviews (Kvale, 1997).

Table 3. Interviewees

Title used in this paper	Discipline	Position	Experience of forestry	Knowledge to the stands	Experience of the use of profile diagrams
Forest engineer	Bachelor of forest and landscape engineering	Management planner, Park & Vej, municipality of Ishøj	Graduated 2002	Recently employed in the department responsible of the management of stand 1. One visit to the stand	No experience of profile diagrams
Landscape architect	Master in landscape architecture	Head of the Park & Vej department in the municipality of Ishøj	Nearly two decades of experience as manager in the municipality of Ishøj	Responsible of the management of stand 1 for more than a decade	Used sections during the education, but not sections of forest stands
Professor in forestry	Master and PhD degree in forestry	Professor at forest and landscape, Denmark, KVL	Experience as researcher and teacher from two universities, focusing on nature-based forestry	No prior knowledge of the stands	Familiar with profile diagrams, but never used in this context.
Forest ecologist	Master in forestry and PhD degree in forest ecology	Associated professor at forest and landscape Denmark, KVL	Few years of experience as forest ranger followed by more than one decade as researcher and teacher focusing on natural forests	No prior knowledge of the stands	Tested profile diagrams as part of PhD-study, but never used in practice
Professor in landscape planning	Master and doctor degree in landscape planning.	Professor at department of landscape planning. SLU, Alnarp	Several decades of research as teaching experience, focusing on forest design	Initiator for the planting of stand 2 and responsible for the management	Doctoral thesis based on analysis of different forest types by use of profile diagrams.

Table 4. List of interviews

Interviewees	Round 1		Round 2
	Stand 1: conditions and potentials	Stand 2: conditions and potential	Long-term management goals
Forest engineer	X	X	X
Landscape architect	X	X	X
Prof. in forestry	X		X
Forest ecologist		X	X
Prof. in landscape plan.	X	X	X

In the first round of interviews, the professionals responsible for the management of the subject stands were interviewed about both stands whereas the two additional interviewees each were interviewed for one of the stands. Thus the responsible managers were interviewed three times and the additional interviewees twice.

Preparing and completion of interviews

We successfully made contact to the selected professionals by phone; followed up by personal contact where we described the research objectives and the role they were assigned as interviewees.

To provide a knowledge base for the interviews, a representative plot was selected for a full inventory in each of the two stands. In each plot, horizontal characters (tree positions, including stumps, and crown projections) were positioned and drawn on field charts at scale 1:100 for the whole plot. All vertical characters (tree height, height at the greatest width of the crown periphery, height of the crown base, height of major branching and dead branches) and breast height diameter were recorded in tables on site. These measurements were used to support the depiction of the vertical structure in profile diagrams, drawn on site, as described by Gustavsson (1986). All fieldwork was carried out during the late fall 2002 in order to maximise the precision of height-measurements, crown projections and depiction of crown architecture. By use of transparent overlays, all profile diagrams made in the field (A4) were transferred to one sheet (Fig. 2, profile diagram at the top), which was scanned and coloured according to species by use of Adobe Photoshop (Fig. 2, middle and button). Finally, the diagrams were presented as posters at a scale of 1:100, for use in the interviews.

One senior and one junior researcher carried out all interviews, as described by Jönsson and Gustavsson (2002), each of 2–3 h duration. Interview guides were used to ensure, that the questions and topics addressed were the same for all interviewees. However the order and direction of the discussions took different turns depending on the interviewee's actions and personal interests. The interviews were conducted in two rounds. In the first round of interviews the discussions were focused on stand condition and potentials while the focus of the second round of interviews was on the long-term management goals. Prior to the first round of interviews the profile diagrams, tables with standard parameters (number of trees per hectare, species composition, etc.) and verbal descriptions of the management history of the two stands were provided to the interviewees as a 'briefing' (summarised in Table 2). Moreover, this briefing information was presented orally as an introduction to the interviews. In the first round, each interview was conducted in two parts. The first part, conducted indoors, centred on how the interviewees' experienced the stand condition and potentials by interpreting the verbal and numeric information and profile diagrams. The interviewees were presented with the profile diagrams and given time to study them. As interviewers, we stimulated the interviewees to analyse and discuss stand conditions and potentials, and the interviewees were asked to propose long-term management goals and strategies. After a short break (ca. 15 min) and while the interviewee still had a clear memory of "how he experienced the stand" from the profile diagrams, the second part was conducted on site. In the stand, along the transect of the profile diagrams, the interviewees were encouraged to reflect on their analysis of stand condition and potentials. Prior to the second round of interviews the management objectives formulated by each of the interviewees in the first interviews, were condensed through preliminary analysis and expressed in words and drawn up as principle profile diagrams (at a scale of 1:100) (Fig. 3). In the subsequent interviews these principle profile diagrams were used to generate discussion of long-term management goals. At the same time the interviewees were invited to discuss ways in which the development of a mixed forest stand could be planned and communicated amongst foresters and different groups of professionals.

In all the interviews questions were asked in such a way as to allow the interviewees to focus on the stand and management planning. Thus, no explicit questions were asked about how they experienced the planning process nor their use or appreciation of profile diagrams as a management tool. However, the questions were levelled in such a way as to allow us to indirectly study (during the interviews as well as in later analysis) the interviewees' experience of the planning situation and their use of profile diagrams in support of their actions.

Analysis of interviews

All interviews were taped and transcribed verbatim and analysed manually according to the seven steps of the hermeneutic methodology for reaching a valid and general understanding (Kvale, 1997). Condensing and categorisation of the meanings was followed by narrative reconstruction in order to structure the scattered statements and actions into condensed stories for each interviewee's. In this way each interviewees statements and actions was presented according to the following four categories: Analyses of stand conditions and potentials, Use of references, Use of profile diagrams, Assessment of profile diagrams as a management tool. These analyses were discussed with the interviewees before final in depth interpretations were carried out. Using the theoretical framework presented in the introduction to this paper as template for comparison we went beyond explicit statements and actions in order to develop structures of meaning and meaning relations, inspired by hermeneutic and post modernistic reconstruction (Kvale, 1997; Yin, 1994). Only this final stage of analysis is presented and discussed in this paper.

Results

In the following we present three aspects of the results: a) How the interviewees used the profile diagrams to interpret stand conditions and potentials, b) how long-term management goals were formulated, and c) how the interviewees' attitudes towards profile diagrams as a management tool in mixed forestry was characterised. Based on this, the appropriateness of profile diagrams in management of mixed stands is discussed.

Profile diagrams as additional information

All interviewees triangulated between the profile diagrams, the tables with numerical standard parameters and the verbal descriptions when analysing stand conditions. However, they emphasised that most important for their understanding of stand condition and potentials was the additional and detailed information they gained from interrogating the details of the profile diagrams. By allowing them to interrogate detailed crown- and folia characteristics in different species and at the same time providing them with an overview of the structure of vegetation, the detailed, graphic visualisation of actual and desirable structures augmented their analyses of stand conditions and potentials as well as their understanding of the suggested management goals.

Even the interviewees with prior knowledge of the stands found that analysis of the diagrams added to their understanding of the stands. Moreover, the interviewees in general agreed about stand condition as well as the potentials and most significant future management issues. On site all the interviewees found the ideas and mental images they had generated from analysing the profile diagrams indoor were confirmed. Only small adjustments were made. The accuracy, with which the interviewees analysed stand condition from the profile diagrams, and the similarities between the interviewees' responses, therefore seems to confirm the common assumption that profile diagrams communicate the structure of vegetation effectively and in an easily understandable fashion.

Importance of personal experience

When interpreting the contextual information, personal experience and references proved to be of crucial importance for all the interviewees. Thus, we noticed that all the interviewees often had mental images of another forest stand that they used to compare and judge the depicted stand. The interviewees themselves recognised this approach, as they often and with great passion described other stands, which they wanted us to visualise. The use of references was expressed in three distinctly different ways:

1. *Specific references*: The interviewees coming from the municipal management department mostly used specific comparisons between two stands.
2. *Generic references*: The interviewees coming from universities predominately used generic references and only mentioned specific localities when asked to.
3. *Metaphoric references*: We noticed the use of metaphoric comparisons. For instance, the forest ecologist compared the dense sub canopy layer of hazed in stand two (Table 2) with a bamboo planting, his children used to play in. Why? Because the multi-stem character and low canopy cover made up by the hazel is reminiscent of bamboo.

The use of generic and even metaphoric references may indicate of lack of specific references, as both types of forest stands discussed are rare in the southern Scandinavia. This, however, expresses the interviewees' capacity to abstract from the specific level in favour of more generic experiences and theoretical knowledge. The noted difference in use of reference types between the interviewees employed in a municipal department and the interviewees working in universities supports this interpretation. The predominant use of generic references reflects the theoretical and principle biased everyday experience of the interviewees working at universities. In comparison, the interviewees from the municipal management department, whose everyday is concerned with the management problems of specific sites, contextualised using specific references to a greater extent.

From information to action – formulating new management goals

As described, all interviewees analysed stand condition and the potentials in very detailed and similar ways despite differences in educational and professional background. However, opinions about the desirable direction for future development of the stands were divergent. This appeared to be related to differences in educational and professional background. This can be exemplified by the way in which the forest engineer, the professor in forestry and the professor in landscape planning argued for their purposed management goals for stand one (Table 2, Fig. 2). The forest engineer and the professor in forestry purposed a future management goal to develop an oak dominated stand with a well-developed understorey (Fig. 3, strategy one). The forest engineer developed this management goal from 2 particular references; first his knowledge of age-class silvicultural systems and second his experience of a specific mixed stand of beech and oak that had gone unmanaged for nearly a century. For him, this specific reference stand represented the image of desirable structure of vegetation, and the age-class silvicultural systems, where oak is grown with an understorey shading the trunks to prevent epicormic branching, presented the way to plan and think of management. This approach to the development of a long-term management goal could be described as primarily based on silvicultural arguments. Similarly, the professor of forestry developed his long-term management goal through relating stand one to his general knowledge and specific references. His argumentation was, however, based on knowledge of natural succession from pioneer to climax species drawn with a reference to a well described near-natural deciduous forest in Denmark (Emborg et al., 2000); a successional approach. In contrast the professor of landscape planning suggested developing stand 1 into a stand dominated by solitary beeches standing "shoulder to shoulder" (Fig. 3, strategy 2). These ideas originated from the visual representation of stand one, clearly depicting beeches with living branches all the way to the forest floor (Fig. 2). Despite never having seen or experienced this type of stand, he argued for this management goal as a strong contrast to the structure of vegetation in age-class forestry as well as natural forests. He suggested this objective simply because he knew it would be a unique structure of vegetation. An approach to the development of a long-term management goal which could be described as primarily based on structural/architectural arguments. These management goals were each in an innovative way based on an intuitive and detailed understanding of the potentials in the discussed stands.

This creative comparison of the actual stand with different types of general knowledge and personal references suggests that the way in which the interviewees developed management goals was largely based on comparing the specific stands with something already present in their repertoire; i.e. the sum of embodied knowledge such as mental images, experience and knowledge, as described in Schön's theory of reflection-in-action (Schön, 1983). It is this capacity to see-as and do-as that allows the interviewees to have a feel for the discussed stands and display an intuitive understanding of the potentials in the stands. This action of seeing-as happened even though they did not know the stands beforehand and the stand type is outside the norms of existing practice. Thus, the detailed, graphic illustrations of actual and desirable structures of vegetation seemed to catalyse this approach by allowing the interviewees to augment their analysis. We conclude that it was because the profile diagrams provoke thinking which calls on mental images (Taket and White, 2000) that our interviewees seemed able to tell so much about the stands; much more in fact than they were able to by working from the numerical and verbal descriptions. Paraphrasing Bradley (1994) the graphical information in profile diagrams "gave voice" to those interviewed as it seems to activate another important type of relevant information; namely their own experiences. This suggests that the way in which the interviewees contextualize is largely a flow of mental images.

Learning a new tool

Throughout the interviews an interesting shift in attitude towards profile diagrams was observed from the newly educated forest engineer. In the first interview the forest engineer thought of stand on, as well as the profile diagrams, as 'confusing' and did not engage in the discussions even though he had recently been employed in the management department responsible for the management of the stand. He explicitly expressed his difficulties in understanding the stand from analysing the profile diagrams. He seemed to be limited to synthesising on the basis of standard parameters related to age-class forestry. These did however not provide guidance for his interpretations of the complex structure of vegetation in the stand. His lack of being able to display an intuitive understanding of the stand conditions and potentials was expressed as a negative attitude to profile diagrams and the forest stand itself. He reiterated this attitude in the following interview about stand two. However, in this interview what he said was in disharmony to his actions. He now carefully studied the profile diagrams and engaged in the discussion leading to a discrepancy between his statements (espoused theory) and his actions (theory-in-use) (Argyris and Schön, 1978). Finally in the third interview his attitude had changed. He was highly engaged in the management planning and intensively used profile diagrams when explaining his arguments. Paraphrasing Dreyfus and Dreyfus (1986) the forest engineer acted as a "novice" when using the profile diagrams in the first interview as he was not able to contextualise, and by the end of the third interview he had developed to be a competent user of profile diagrams. The other interviewees were from the very beginning of the first interview confident with the meaning and accuracy of the information provided by profile diagrams, which can be explained by their previous experience of profile diagrams or similar image-based tools (see Table 3).

Conclusion

Interrogating on the interviewees' actions demonstrated that profile diagrams when used as a tool for analysis of the two stands provided them with an overview of the complex structures in mixed stands in a more expansive way than the numerical standard parameters. However, the interviewees argued that in the present context implementing profile diagrams as a tool for daily analysis of specific stands would be fare too resource demanding for most management organisations. For this reason, the use of profile diagrams as a tool to be used in the daily analysis of mixed stands in urban woodlands will not be elaborated on in this discussion.

With respect to the utility of image-based management tools in management of mixed stands, our results however indicate that profile diagrams can support the professionals' management planning in three ways, if used as a more strategic communication tool within management organisations. Firstly, the graphic illustrations seemed to communicate detailed information about the structure of vegetation to the professionals in a comprehensible way, by guiding their mental imaging of the specific stand as well as other forest stands. This helped them to display an intuitive understanding of the stands, characteristic for the proficient and expert stage (Dreyfus and Dreyfus, 1996), see Table 1. The advancement of our forest engineer showed that only little training is needed for professionals to gain from profile diagrams. This finding is supported by Oldeman and Schmidt (1986), who report that profile diagrams when used as tools for analysis and as tools for expressing long-term management goals, are an effective way to build up intuition and the capacity to visualise mixed forest stands among students.

Secondly, being a support for the mind (Aspers et al., 2004), the detailed graphic representation of stand structure augmented the discussion of stand potentials and future management goals. As dialogue is important for information to be internalised and interpreted (Schön, 1983), profile diagrams and similar image-based tools would seem to offer a way to create ownership in the development of new management paradigms (Innes, 1998; Taket and White, 2000). Thus, prospectively many professionals educated and trained within age–class forestry may express scepticism, as new management concepts and tools may appear to undermine their technical abilities and attitudes. In this context, the study indicates the importance of providing professionals with the capacity to contextualize in emerging paradigms in order to overcome scepticism. Here, the conversation generated by the profile diagram can be considered as a special form of learning process (Taket and White, 2000) in which the diagrams catalyse the interviewees' capacity to contextualize and thus guide the direction of their attitudes and actions (Innes, 1998).

Thirdly, the extended dialogue indicates the potential of profile diagrams to initiate discussions between professionals through which a shared understanding of stand conditions and future management goals can be created. With regard to the present development in urban forestry as well as commercial forestry organisations, more and more of the decisions affecting the results of the management plan are made in field by forestry workers. It is therefore important to ensure a shared understanding of stand potentials and management goals within management organisations.

For a long period, the dominant research agenda has concentrated on providing generalized and objective facts as guidance for professionals' management planning (Jönsson and Gustavsson, 2002). As there are very few older mixed stands in Denmark for professionals to experience at first hand, an important issue for future research will be to support the development and communication of references for management of mixed stands in urban woodlands to professionals. As the forest ecologist puts it: "In the past we were possessed of an inherent understanding. We could work directly from the information presented by the management tools we used (Fig. 1). However in the current context, we are called on to design, plan and manage 'new' types of forest stands for which there are no precedents, so we must form a notion of what we are heading for". Extrapolating from this idea, the use of principle profile diagrams as substitute for references to real mixed stands in maturity could form a fourth category of references of relevance for professionals in their management of mixed stands. With respect to the ongoing move from age–class forestry toward multi-functional management of mixed stands, this might be the most relevant way in which profile diagrams and similar image-based tools can contribute to the implementation of these new management paradigms. With respect to the ongoing move from age-class forestry to the multifunctional management of mixed stands this might be the most relevant way in which profile diagrams can contribute to the implementation of these new management paradigms.

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PAPER IV

Larsen JB and Nielsen AB. Nature-based forest management – Where are we going? – elaborating forest development types in and with practice.

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NATURE-BASED FOREST MANAGEMENT - WHERE ARE WE GOING? ELABORATING FOREST DEVELOPMENT TYPES IN AND WITH PRACTICE

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Abstract

The decision to transform »classical« age-class silviculture (plantation forestry) into nature-based forest management implied a paradigmatic shift in the Danish state owned forests. In order to facilitate this process of change, scientists were »smuggled« into The Danish Forest and Nature Agency and interacted with the professionals in the forest over a nearly 2-year period. Very soon it became evident that the main questions were not so much related to the process of shifting from age-class forests to nature-based silviculture, but more to the evident lack of settled long-term goals in terms of stand structure and dynamics of the »future« forests. Realizing this constraint, Forest Development Types (FDT) and their illustration by means of profile diagrams were elaborated in an adaptive, participatory process involving people both inside and outside the organization. FDT describes long-term goals for forest development on a given locality (climate and soil conditions) in order to accomplish specific long-term aims of functionality (ecological-protection, economic-production, and social-/cultural functions). It is based upon an analysis of the silvicultural possibilities in combination with the aspirations of future forest functions. It will serve as a guide for future silvicultural activities in order to "channel" the actual forest stand in the desired direction.

Looking through the lens of »social learning« this paper reflects on and discusses the adaptive management process in which the knowledge of professionals and scientists was mixed in the development of long-term goals for stand structures and dynamics in nature-based forest management. Specifically, the use of FDT scenarios and their illustration by means of profile diagrams as tools to organise and ease communication in this learning process is addressed and presented as an integrative, flexible and easily comprehensible concept for communicating long-term goals for stand development in nature-based forest management.

Key words: Forest Development Type (FDT), nature-based forest management, profile diagram, social learning, adaptive management, action research.

Introduction

Across Europe declining health and lack of stability in age-class forests as well as growing concern about the environmental sustainability of the related management systems have led to an increasing interest in more ’nature-based’ forestry. Nature-based forest management is based on continuous forest cover, uneven-aged stand structures, selective harvest, and excessive use of natural regeneration. It is expected that moving in this direction more resilient forests and a more sustainable forestry sector can be achieved (Larsen, 1995; Koch and Skovsgaard, 1999; Franklin et al., 2002; Gamborg and Larsen, 2003; Franklin, 2004).

For the Danish Forest and Nature Agency, this development implies a replacement of 250 years of tradition and related knowledge of plantation forestry in favour of more nature-based management principles in all state owned forests (Danish Forest and Nature Agency 2002). The forests are spread all over the country covering approximately 110 000 hectares equal to 24 % of the total forest area in Denmark, with a central office formulating the management strategies and planning, while 20 local districts are implementing these in the day-to-day management.

Facing the paradigm shift it became imperative to incorporate knowledge from scientists with experiences and ideas from the professionals; ranging from forest supervisors, forest officers (both graduates in forestry) and forest rangers (bachelor of profession in forest and landscape engineering) to field staff with vocational level education (Forest and nature technicians or Nature Interpreters) and staff doing semi-skilled labour grouped as workers. Further, the size of the organisation and share of competence between the central and local units demanded a shared understanding of framework and long-term goals for ongoing conversion to more nature-based forest management. In order to meet these »demands«, scientists were »smuggled« into the Danish Forest and Nature Agency, infiltrating the organisation and interacting with people from all levels of the agency in a bottom-up participatory learning process.

Confronted with this huge conversion task one could expect that the first question asked by the professionals would be: »how do we get there?« However, this was not the case. The professionals went one step further and asked »where are we going?« It turned out that their main hesitation adopting nature-based management principles came from a pronounced uncertainty in terms of long-term goals for stand structures and dynamics. Due to a long tradition of managing uniform, even-aged monoculture stands, the professionals were short of experience with natural and semi-natural forest structures and dynamics in the temperate nemoral zone, in which Denmark is situated. Here regeneration develops in gaps resulting in a fine- to medium-grained shifting steady-state mosaic of mainly broadleaved species (e.g. Emborg et al., 2000).

This experience pinpointed that a common understanding of the nature-based management principles and long-term goals for stand development had to be created, necessarily implying the development of concepts for organising, describing and communicating these whole new management principles and desirable stand structures and dynamics to the professionals and other stakeholders.

Looking through the lens of »social learning« this paper reflects on the adaptive management process in which the knowledge of professionals and scientists was mixed in the development of long-term goals for stand structures and dynamics in nature-based forest management. Specifically, the use of FDT scenarios and their illustration by means of profile diagrams as tools to organise and ease communication in this learning process is addressed and presented as an integrative, flexible and easily comprehensible concept for communicating long-term goals for stand development in nature-based forest management.

Adaptive management and social learning – developing long-term goals

Forests, like most renewable natural resources, are complex in both their nature and their management arrangements. Hence, it is not possible to tell with certainty how the system works, or even to be able to predict precisely what the outcome of management actions might be. This basic uncertainty is increased further when moving from one management paradigm to another, as in the present case. In this context, the classical top-down management of forests is too general to account for local complexities and the uncertainties they create.

Taking the pronounced uncertainty of long-term goals for stand structures and dynamics in nature-based forest management, scientists and professionals were for nearly two years united in a demand-led adaptive management process. Adaptive management is management and capacity building which accepts uncertainties related to not having all information one would like, or not being sure what the future should be (de Boo and Wiersum, 2002). Here, concepts of relevance to practice are developed with an active focus on advancing knowledge in a social learning process; i.e. the process of framing issues through analysing and debating alternatives in the context of inclusive social deliberation (Reich, 1988). Here, the active focus on learning is providing all parties with better opportunities to understand the situation and to draw upon the different parties' experiences and knowledge (Daniels and Walker, 2001). Thus, it is not only a way to achieve objectives in ecological-technical aspects. It is also a people-oriented process involving professionals from all levels of the Agency, as in this case, in an experiential and reflective learning process of exploring problems and their solutions and uncertainties and their answers. This approach is in line with the joint recommendations from IUFRO, FAO and CIFOR which emphasises that forestry research and management should not be conducted in a vacuum but bridge the gaps between the traditional and modern pools of knowledge and experiences (Burley et al., 2001).

Recognising the interdependence among science and local knowledge in developing ideas about long-term goals for stand development in nature-based forestry, self-interest (Ruitenbeek and Cartier 2001) was used as a motivating factor for incorporating knowledge and views from professionals at all levels of the classical forestry ‘hierarchy’ in the Danish Forest & Nature Agency.

We entered the agency as participants and scientists with the dual purpose of advancing knowledge and facilitating practical transformation. Through numerous iterations where professionals and scientists were joined in various configurations (Figure 1), the task was to facilitate continuous dialogue and debate in order to encourage the encounter between the professionals’ experience-based, contextual knowledge and skills and the scientists context-free knowledge to be synthesised and adjusted in interaction with the situation (Tydén, 1993; Stringer, 1999; Huxham and Vangen, 2003). Focus was on framing the issues, advancing and locally adapting knowledge, analysing alternatives, and debating choices in inclusive deliberation. As scientists, we gave advice embracing not only what we knew beforehand, but also what we had learned in the process.

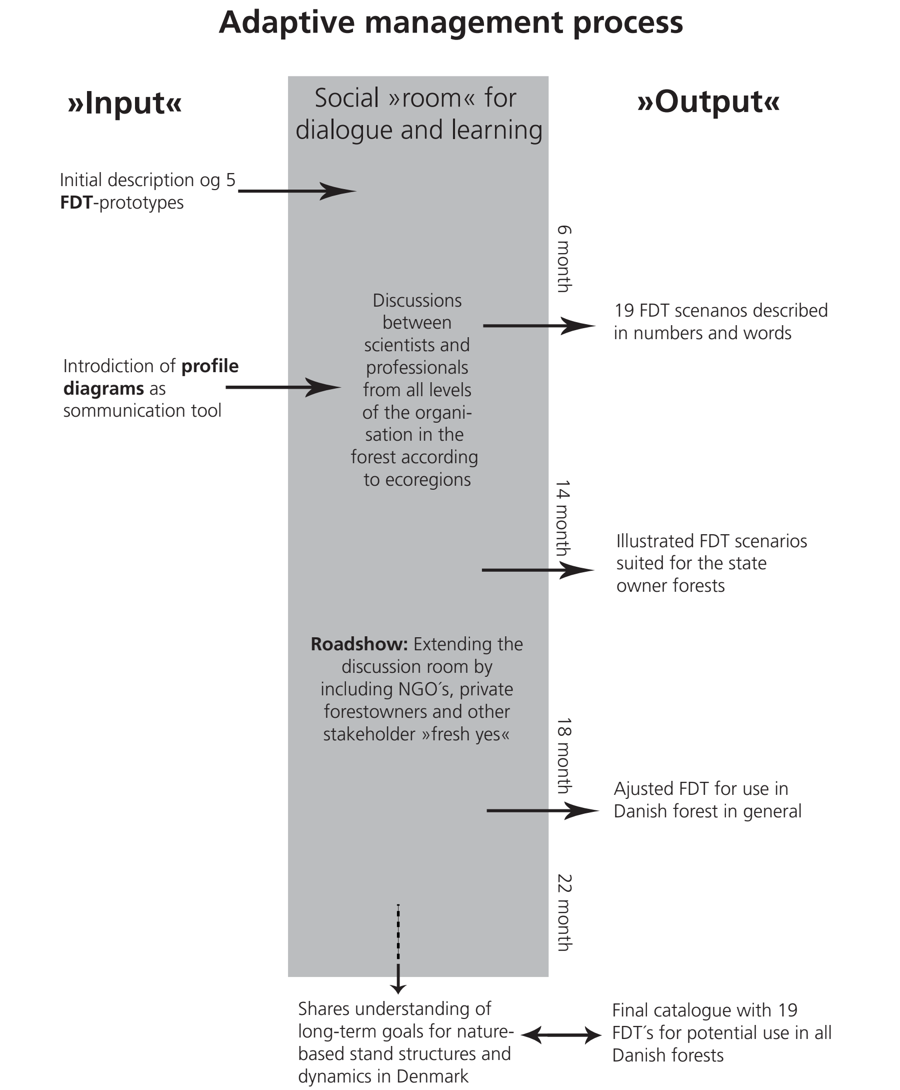


Figure 1: Diagram illustration the sequence of events in the adaptive management process of developing long-term goals for stand structures and dynamics in nature-based forest management in Denmark.

Vision scenarios – FDT

The complex nature of near-natural forest structures and dynamics and their management arrangements requires integrative and flexible management frameworks. Creating scenarios of what such structures might be are useful when complexity and uncertainty are high, because such scenarios introduce hypothetical possibilities that spur imagination and encourage interaction and debate. Thus, whether expressed visually or verbally, scenarios can be tangible ways of exchanging knowledge among people because of their inherent nature as means of expression and communication (Wollenberg et al., 2000a, 2000b; de Boo and Wiersum, 2002). Correspondingly, scenarios can be useful to stimulate new ways of thinking about uncertain and complex future stand structures and dynamics, as in this case.

FDT scenarios provide one such adequate framework for advancing and describing ideas about long-term goals for stand development in nature-based forest management (Perpeet, 2000). A major object of FDT scenarios is to describe the practical impact of the general policies for nature-based silviculture on the stand level. The concept comprises a broader understanding of natural disturbance regimes and successional processes than hitherto used. As such it has great similarities with the forest cycle models that have successfully been used to describe the temporal and spatial dynamics and cyclic preoccupation of a specific forest type in natural forest reserves (see e.g. Leibundgut, 1959; Zukrigl et al., 1963; Meyer and Neumann, 1981; Mueller-Dombois, 1987; Jenssen and Hofmann, 1996; Emborg et al., 2000; Grassi et al., 2002).

An FDT describes the long-term goal for forest development on a given locality (climate and soil conditions) in order to accomplish specific long-term aims of functionality (ecological-protective, economical-productive, and social-/cultural functions). It is based upon an analysis of the silvicultural possibilities on a given site in combination with the aspirations of future forest functions. It will serve as a guide for future silvicultural activities in order to “channel” the actual forest stand in the desired direction.

In an early stage, five FDT vision scenarios, describing in words and numbers what the long-term goals could be were initially drafted to facilitate platforms for and stimulate debate. The idea was to provide a framework that tapped the field foresters’ imagination and enabled them to articulate their ideas, to build awareness about these and to empower them to think it is possible to achieve those.

In the following stage professionals were gathered according to four eco-regions for regional discussions around these preliminary FDT scenarios in the real world, i.e. in the forest. This process had several iterations conducted over a 6 month period. The periodic confrontations allowed the original 5 FDT scenarios to be refined and modified and for an additional 14 FDTs to be developed.

This process, however, left several questions unresolved and only partly rectified the feeling of uneasiness about the long-term goals, especially among the professionals with little or no formal education. They simply were not able to translate all the words and numbers into visions. Even professionals with long education and many practical experiences came up with statements like »this will not work in reality«. As the professionals were short of experiences with the complex structures of vegetation in near-natural stands, we realised that describing the FDT scenarios in numbers and words did not provide a sufficiently common platform for discussion. The professionals simply generated different meanings and mental images from interpreting the written descriptions. This mismatch limited the discussions of the FDT scenarios to an abstract and theoretical level and impeded the creation of a shared understanding and ownership of nature-based forest management.

Lifting barriers to communication – profile diagrams

Visualising scenarios provides one way to overcome such communicative gaps, simply because every one can understand what is being shown (Taket and White, 2000; Emmelin, 1996). Further, the integration of visual with verbal and numerical information has proven to be a useful triangulation that helps to initiate dialogue and augment discussions in which a shared understanding of the information can be generated across knowledge cultures and among members of a group (Innes, 1998).

Hand drawn profile diagrams are useful tools for illustrating forest stand structures. As the name indicates, a profile diagram is a depiction of a section through a forest stand. During the last century profile diagrams have gained interest in studies of natural forests and where mixed-forest management has been practiced (Leibundgut, 1959; Gustavsson, 1986; Koop, 1989), and many textbooks in silviculture have applied profile diagrams as means to communicate silvicultural systems and their related stand structures (e.g. Mayer, 1980; Oldeman; 1990; Oliver and Larson, 1990; Otto,1994; Röhrig et al., 2006), which all indicate the potential of integrative visual tools for communication of near-natural stand structures (Nielsen and Nielsen, 2005). This might be best illustrated by drawing a parallel to architects' use of plan and cross section; architects might choose a nice photo-realistic illustration to communicate or »sell« their ideas for a new house to laypersons, while plans and cross-sections are the modes used to communicate the ideas to the craftsmen who should construct the house. Correspondingly, illustrating the FDT scenarios by means of profile diagrams were used pro-actively as a way to bridge the communicative gap: i.e. creating a shared platform for discussions about how the future forests could be »constructed« and enhance the professionals' (the craftsmen) capacity to make sense of and link the scenarios to their explicit reality.

For the illustration of each FDT scenario, a small group of local professionals (2-5 persons) were requested to identify a specific stand in the forests they managed where site conditions and forest functionalities matched the FDT scenario. This stand was used as an 'arena' for discussing and visualising the FDT scenario by means of profile diagrams. The present stand condition was depicted in a profile diagram. This served two purposes. Firstly, the purpose of depicting a stand known very well by the professionals and which they could easily envision in their mind was to make them familiar with the way in which profile diagrams represent reality. Secondly, as 'thinking calls for images' (Taket and White, 2000) the idea was to support and guide their 'thinking in pictures'. In addition, a preliminary profile diagram, of how the FDT scenario could be translated into a profile diagram was prepared. As evident from figure 2a, this »draft« was by intention made very roughly, so that it clearly indicated that further elaboration and improvement was needed.

The profile diagram documenting the present stand condition and the preliminary draft of the profile diagram visualising the FDT scenario were used to provide a link between the future FDT scenarios and the present reality in discussions with the group of professionals: 'This is how the stand you know today would look when translated into a profile diagram. How will you translate the FDT scenario into a similar profile diagram?' This question initiated detailed analysis and discussions of the scenario. The discussion was summed up in an improved draft (Fig. 2b), which was presented and discussed at a second meeting. Again discussing and developing the profile diagram added levels of detail to the understanding of the FDT scenario through which agreement on the scenario and its visualisation was achieved and the final visualisation and FDT scenario was prepared (Fig. 3). Over a period of 8 months, this sketching process was successively undertaken for each of the 19 FDT scenarios. However, each time the illustration of a FDT scenario was completed it was taken up in meetings, workshops and working documents to enable communication and learning among all people in the agency.

EXPANDING THE DIALOGUE

In order to expand the process beyond the Forest and Nature Agency and especially to incorporate the private forest sector and other user groups including NGOs we went on a "road show" with the FDT scenarios. Three meetings were arranged in the different eco-regions through Pro Silva Denmark where the FDT-concept and the preliminary drafts were presented and debated. The outcome of this was additional shared knowledge and ownership beyond the public sector, as well as substantial improvements of the FDT scenarios.

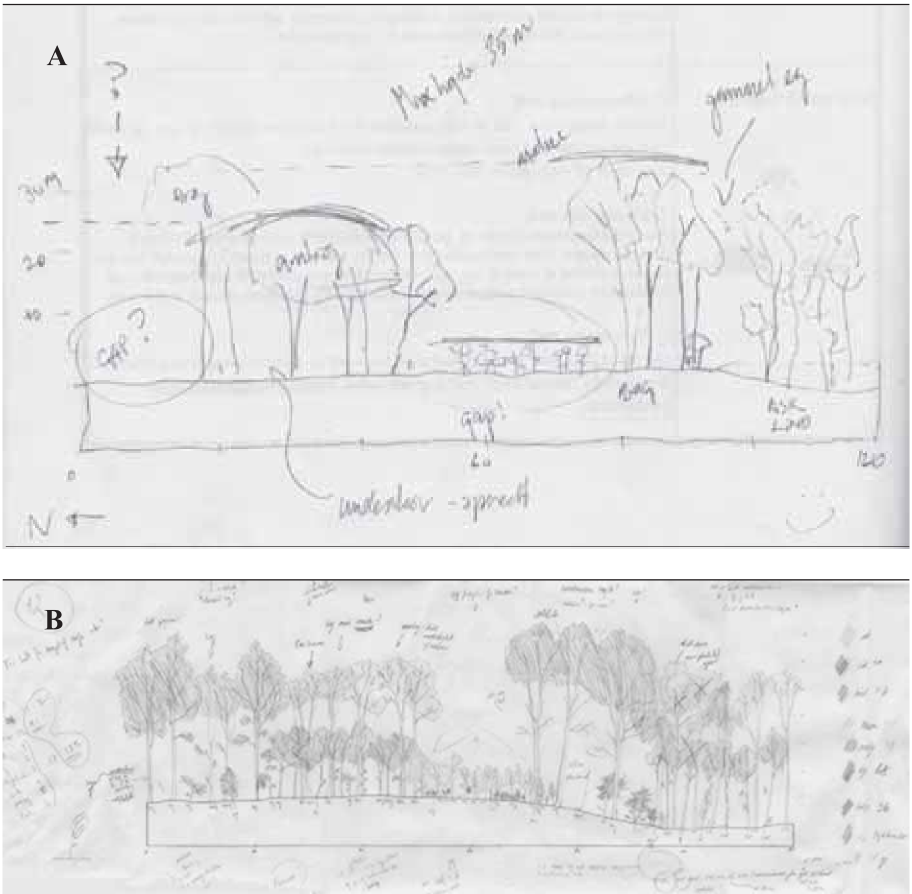


Figure 2: Drafts illustrating the process of developing the final illustration of FDT 12: Beech with ash and sycamore, which is described in figure 3.

19 illustrated FDT scenarios

The nearly 2-year participatory process, outlined above, resulted in a catalogue with FDTs covering the range of variation in Danish growing conditions and anticipated forest functions. The catalogue as published in Larsen and Danish Forest and Nature Agency (2005) as well as Larsen et al. (2005) describes 19 different FDTs which can be grouped into broadleaved dominated (9), conifer dominated (6), and an additional 4 »historic« (Table 1). Whereas all 15 "nature-based" FDTs encompass a balance between productive, protective and recreational/social functions, the »historical« types (Nos. 91 - 94) mainly serve protective and cultural functions. As shown in figure 3, each FDT is described as follows:

Name: The name encompasses the dominating and co-dominating species. The first digit in the FDT-number indicates the main species (1 = beech, 2 = oak, 3 = ash, 4 = birch, 5 = spruce, 6 = Douglas fir, 7 = true fir, 8 = pine, and 9 indicating a »historic« FDT).
Structure: A description of how the forest structure could appear when fully developed. This description is supplied with a profile diagram depicting a 120 m transect of the forest structure at »maturity«.
Species distribution: The long-term distribution of species and their relative importance.

Dynamics: The regeneration dynamics described in relation to the expected succession and spatial patterns (species, size).

Functionality: Indication of the forest functionality (economic-production, ecologic-protection, and social-/cultural functions) and their relative importance. Further, the balance between the three »pillars« of sustainability is illustrated in the »sustainability-triangle«.

Occurrence: Suggested application in relation to climate and soil. For this purpose the country is divided into 4 sub-regions with each their typical climatic characteristics. Further, the application of the specific FDT in terms of soil conditions is stated in relation to nutrient and water supply.

In order to communicate the Danish FDTs to a broader circle including interest groups and the public in general, all 19 FDTs are depicted in profile diagrams in a poster (Fig. 4)

Table 1: The 19 Danish Forest Development Types

Broadleaved dominated:	Conifer dominated:	»Historic« forest types:
11 Beech	51 Spruce with beech and sycamore	91 Coppice forest
12 Beech with ash and sycamore	52 Sitka spruce with pine and broadleaves	92 Forest pasture
13 Beech with Douglas fir and larch	61 Douglas fir, Norway spruce and beech	93 Forest meadow
14 Beech with spruce	71 Silver fir and beech	94 Unmanaged forest
21 Oak with ash and hornbeam	81 Scots pine with birch and Norway spruce	
22 Oak with lime and beech	82 Mountain pine	
23 Oak with Scots pine and larch		
31 Ash with alder		
41 Birch with Scots pine and spruce		

Name — **Forest Development Type 12: Beech with ash and sycamore**

Structure

Species rich well structured forest with beech as dominating element mixed with ash, sycamore and cherry and in the south-eastern parts of Denmark additionally with hornbeam and lime. The in-mixed species occur mainly in groups but also as single trees. The horizontal structures arise between groups of varying size and age. Where the light demanding species such as ash, sycamore and cherry dominate horizontal structures occur with shade trees (beech, hornbeam, elm and others) in sub-canopy strata.

Species distribution

Beech: 40-60 %
Ash and maple: 30-50 %
Cherry, hornbeam, oak, lime and others up to 20 %

Dynamics

Beech regenerates mainly in groups or smaller stands. Ash and sycamore are gap specialists and regenerate mainly in smaller openings later followed by beech. Hornbeam belongs to the sub-canopy stratum and regenerates under shade, whereas the pioneer species (cherry and oak) occur after larger openings and /or in relation to edges.

Functionality

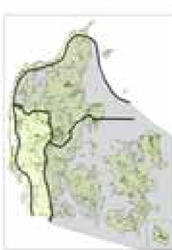
Productive: The forest development type has a high potential for production of hardwood in big dimensions and in good quality.

Protective: The beech dominated forest is in most parts of the country the potential natural vegetation; consequently many indigenous species are connected to this forest type. It has a great potential in conserving the biodiversity connected to the NATURA 2000 habitat types 9139 and 9150.

Recreational: It gives through its mixture of (indigenous) species in combination with pronounced variation in size a multitude of recreational experiences and intimacy.

Occurrence

The forest development type belongs on protected sites in the eastern and northern parts of Denmark on rich, well drained soils with good water supply as illustrated below.



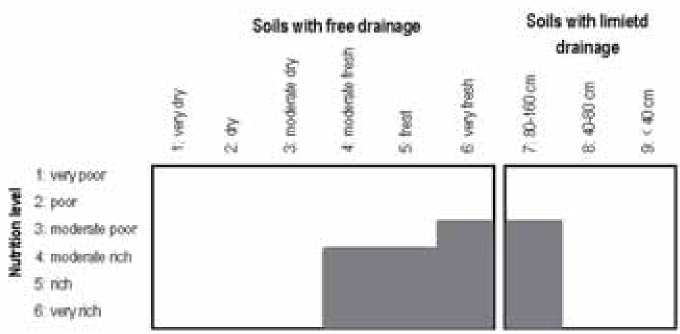


Figure 3: Description and illustration of Forest development Type 12: Beech with ash and sycamore. The DK-map in the lower left corner shows the four eco-regions, and which eco-zones the FDT will occurred in (grey raster)

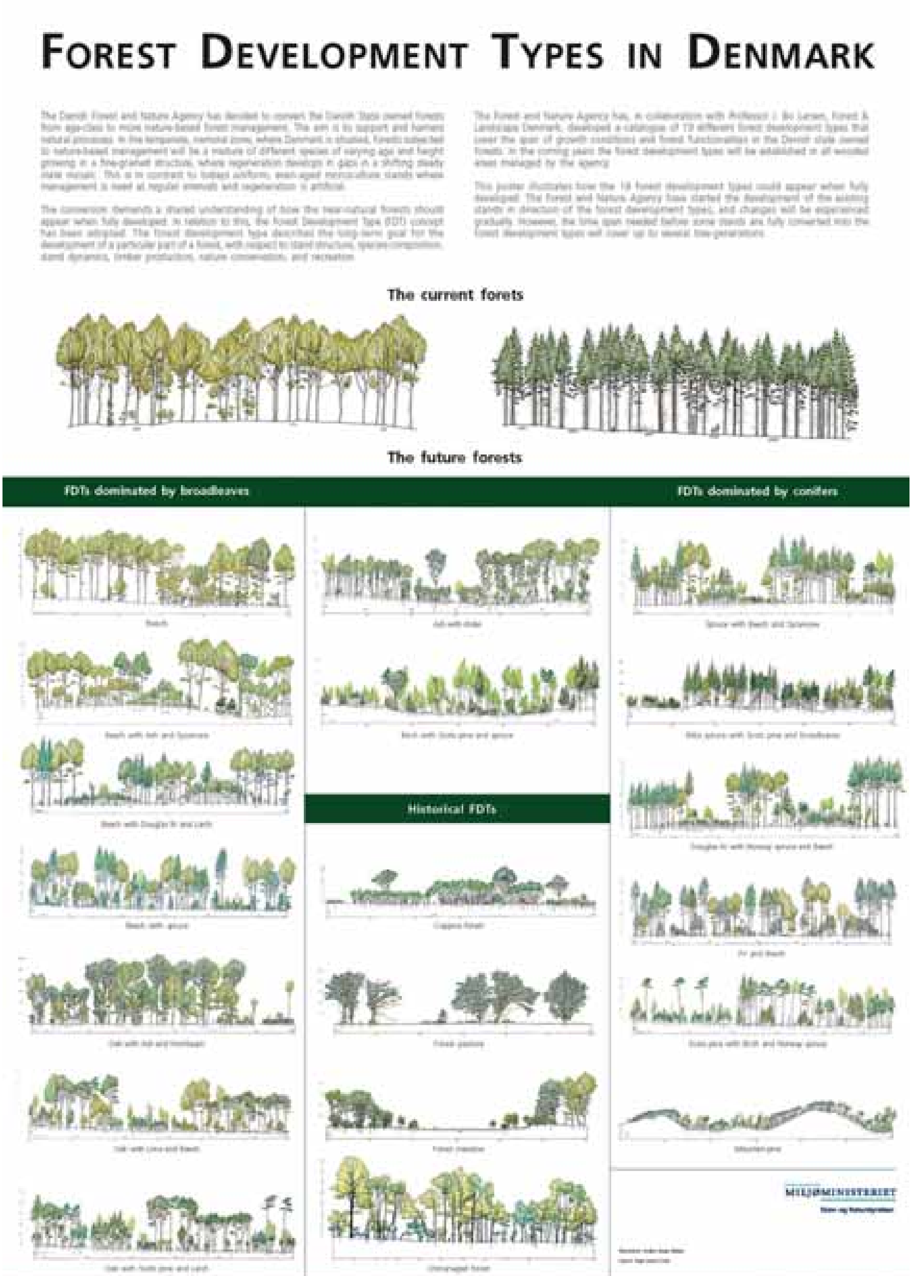


Figure 4: Poster depicting the present forest types and the future 19 FDTs in Denmark. The two upper profiles diagrams show typical forest stands at present (even-aged monocultures of beech, respectively Norway spruce). Below the 19 FDTs are grouped in broadleaved dominated (9), conifer dominated (6), and »historic« (4).

Discussion

The process of developing a catalogue of FDTs started with an outcry from professionals in the field. In the plantation forestry paradigm, the professionals possessed an inherent understanding of goals and means. However, when nature-based management was introduced, they were called on to design, plan and manage 'new' types of forest stands for which they had neither mental nor real models. Suddenly, the well-known management practices supported by years of empirical research and the governing variables behind those were questioned, which is characteristic of "double loop learning", as defined by Argyris and Schön (1974).

Taking the pronounced uncertainty of long-term goals for stand structures and dynamics in the new nature-based forest management paradigm, scientists and professionals were united in a demand-led learning process, where professionals defined the problem, which in turn helped to keep focus throughout the process and to secure commitment and an adequate and timely output. In retrospective, this process constitutes a successful example of social learning among professionals and scientists in an adaptive management context, which also contained elements of action research (Stringer, 1999; Lee, 1999; Huxham and Vangen, 2003).

From the observations throughout the process, it is, however, clear that social learning requires sharing of power, which on the one hand must be accepted throughout the whole organisation and on the other hand requires organisational flexibility. This was the case in the present study. Additionally, it requires special abilities from the scientists involved; namely the ability to listen, to pose key questions, to observe, and the will to suppress their inborn tendency to talk scholastically. Correspondingly, we worked as facilitators, whose prime task was to stimulate debate about key questions by bringing professionals at all levels of the agency hierarchy together in various configurations, co-ordinate the process, demarcate it, reflect upon it, and act according to the new insight gained. In short, we facilitated the process and led the professionals become the researchers – exploring their collective experience-based wisdom.

COLLECTIVE RESPONSIBILITY – COLLECTIVE OWNERSHIP

Standing in the forest in front of a problem, the professionals automatically enquired the scholar. Partly due to lack of good answers, we reciprocated: "But together you have been here more than 200 years, you must have some ideas!" And suddenly a dialogue between the professionals started, leaving the scientist in the role of facilitator and reporter.

This change in roles developed the professionals' perception of the information and surfaced the ways this was incorporated into the FDT scenarios. In turn, this enhanced individual and shared understanding of the situation and engagement in the development of the FDT scenarios as well as their trust in the final outcome.

THE IMPORTANCE OF DIALOGUE

The process facilitated dialogue among the professionals in various groups and configurations, utilizing knowledge and information contributed by the professionals themselves, which in turn empowered them to understand and learn about the principles of nature-based forest management and possible goals for stand development. From this perspective, the dialogue-based process activated many kinds of information which shaped perceptions that became part of the base-line assumptions. Judith Innes has highlighted this aspect of dialogue, which unfortunately is often forgotten or neglected in decision-making process: »Dialogue and other forms of communication in themselves change people and situations« (Innes, 1998).

VOICING MANY KINDS OF INFORMATION AND KNOWING

The dialogues and collaboration between scientists and professionals demonstrated the importance of paying more attention to multiple kinds of information in decision-making processes regarding natural resources. Scientific knowledge had its place in the development of the FDTs, but it was not privileged. Unless the scientific information was related to practical examples or to the context and specific realities of the professionals from the different eco-zones - i.e. until it became practically useful - they tended to reject it.

Further, scientifically validated information was only a small part of the information used in advancing and locally adapting long-term goals for stand development. Throughout the nearly 2-year period, much local information and insight into possibilities, functions, and desires surfaced. For example, local professionals managing *Pinus mugo* plantations established some 100 years ago to control the sand drifting along the west cost of Denmark opposed vehemently the scientists' rejection of a mountain pine forest development type. And the professionals succeeded since they were able to demonstrate the species stability and regeneration ability under these climatically harsh conditions and to pinpoint its cultural and recreational values. Another working example was the »creation« of forest development type 11 - beech in horizontal structured and almost pure stands. Although this FDT is only in part nature-based, it was developed as a response to different user groups' advocacy for their beloved »beech cathedral« or »pillar hall«, which they feared was threatened through »too much nature«.

An additional type of information evolved through the stories told by the different parties as typified in the following »story«: Professionals from the most western parts of Jutland along the North-Sea were somewhat reluctant in adopting the general concept of a small scale disturbance regime leading to a fine scaled mosaic forest structure. During the process a major forest fire occurred in the area, and suddenly the stories of forest fires came into »play«, resulting in the acceptance of a more coarse-grained structural dynamic and in part accepting smaller clear-cut for conifer dominated FDTs in this specific region.

Indeed, all these kinds of information, outlined above, affected the perception of the possibilities and limitations of nature-based forest management and thereby influenced the decision-making process. The value of these kinds of information in management of natural resources has also been recognised in studies of communicative planning (e.g. Innes, 1998) as well as other adaptive management activities (for reviews see e.g. de Boo and Wiersum, 2002) and action research studies (Stringer, 1999; Huxham and Vangen, 2003). These observations pinpoint the dynamic nature of collaborative decision making

The importance of appropriate sharing mechanisms / tools

The process of developing long-term goals for stand structure and dynamic in nature-based forest management, however, showed that the many kinds of information and knowing cannot be activated for social learning until comprehensible tools (platforms) to organise and enable discussions of the issues faced have been developed. Here, FDT scenarios and profile diagrams turned out to be decisive »new« tools, each in their own way.

FDT scenarios worked as a framework for organising hypothetical possibilities which encouraged interaction and debate. As such, they helped us to stimulate and organise new ways of thinking about the uncertain and complex future stand structures and dynamics (Wollenberg et al., 2000a, 2000b). In a complementary manner, the illustrations of the FDT scenarios by means of profile diagrams forced the professionals to consider the principles of nature-based management and its impact on stand structures and dynamics in a way they were unable to by means of only the verbal FDT tool. As such, the illustrations of stand structure augmented the discussion of the FDTs and were instrumental for information to be internalised and interpreted (Schön, 1983). It was evident that even very experienced professionals were decisively inspired by the profile diagrams enabling them in bridging the communicative gap between experiences and visions. Some forest officers who were highly sceptical in the beginning changed their view and joined the discussions after being exposed to the profile diagrams. One stated enthusiastically: »this language of drawing is universal, you can even discuss these visions of forest development with a Chinese!«

Over time, the FDT scenarios and their illustrations developed a status of their own. Not only did they provide a framework and a platform for discussion, they also functioned in fact as an »eye opener« for the whole agency in terms of internalizing the shift into nature-near forest management.

Concluding remarks

Hitherto, the dominant forest research agenda has concentrated on providing generalized and objective facts as guidance for professionals involved in management planning (Jönsson and Gustavsson, 2002), and most research does not legitimate the scientists to reflect on how their findings can become powerful agents in creating the desired changes (Innes, 1998).

Addressing the challenges and uncertainty experienced by the professionals when urged to move from plantation forestry towards nature-based forest management, and the parallel development in forest management where more and more decisions are made by professionals in the field, the research approach taken also needs to accept and adapt to this new agenda where uncertainty, adaptability, communication and learning are keywords.

In this context, the case presented in this paper indicates possible gains related to scientists and professionals being joined in a social learning process that allows both parties to reflect and learn from the many kinds of information and to have a stake in the process through which information becomes embedded in new management goals and practices. Further, the case underpins the importance of proper tools to organise and ease communication in such social learning processes. In relation to this our observations suggest FDT scenarios in combination with their illustration by means of profile diagrams as an integrative, flexible and easily comprehensible concept for communicating long-term goals for nature-based stand development. The validity of these observations and the more exact effectiveness of the concept as means for communication with forest professionals, however, call for further research.

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PAPER V

Nielsen AB and Larsen JB. Communication tools for nature-based forest management - Forest development types and profile diagrams. Manuscript for European Journal of Forest Research.

COMMUNICATION TOOLS FOR NATURE-BASED FOREST MANAGEMENT: FOREST DEVELOPMENT TYPES AND PROFILE DIAGRAMS

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Abstract

Conversion from plantation forestry into nature-based forest management is a leading current issue in European forestry that demands for new ways to communicate about long-term goals for stand structures and dynamics. In this paper we report the results from a questionnaire where 83 professionals from all levels of the Danish forest and Nature Agency assess *Forest Development Types* in combination with their illustration by means of *profile diagrams*. This new tool has been developed as a way to organize and describe such "novel" goals for the conversion to nature-based forest management in all Danish state forests. The results show that FDTs have taken hold amongst DFNA employees. Across all levels of the classical forestry hierarchy respondents assess the tool favourably as a way to describe long-term goals and as an aid for their work in order to realize these goals. Both managers and workers have already used and have clear ideas of a – perhaps surprisingly - wide range of future uses for the FDTs. The areas of use and expectations range from management planning and silvicultural decisions to communication with various stakeholder groups. In conclusion, the professionals' direct acceptance and implementation of the new tool indicates the potentials of FDTs to initiate and catalyse the desired changes towards nature-based forest management.

Keywords: Communication tools, Forest Development Types, Nature-based forest management, Profile diagrams.

Introduction

Conversion from plantation forestry into nature-based forest management is a leading current issue in European forestry. It is expected that moving in this direction more resilient forests and a more sustainable forestry sector can be achieved (Larsen 1995, Koch and Skovsgaard 1999, Franklin et al. 2002, Gamborg and Larsen 2003, Franklin 2004). Fore about one century, nature-based forest management has been practiced in various forms in Central and Eastern European countries like e.g. Switzerland and Slovenia (Schütz, 1999a, 1999b). However, the paradigm has only recently been officially adapted in NW European countries and regions (e.g. Wales (National Assembly for Wales 1999), Niedersachsen (Nidersächsisches Forst Plannungsamt 1991, 1995) and Denmark (Danish Forest and Nature Agency 2002)). In these countries a common challenge for management organizations is to transform the overall targets and policies into long-term goals at stand level and to implement these in practice. This is a significant challenge, especially for professionals trained and educated within the plantation forestry tradition as is the case in most NW European countries.

During the last two centuries an inherent understanding of management goals and how to communicate these in the plantation forestry paradigm has emerged, enabling the forest ranks to translate directly between standard parameters and reality. In short, standard parameters such as species, age, height, growing stock and site is enough for the experienced forester to display an intuitive understanding of the stand conditions and long-term goals. The more irregular and diverse stand structures characterising nature-based forest management can, however, hardly be described appropriately in terms of such standard parameters (Otto 1995, Tahvanainen et al. 2001, Jensen et al. 2005). If they could, there would be a mismatch for the professionals trained and educated within plantation forestry, as they have neither mental nor real models to relate to. Correspondingly, the conversion from plantation forestry into nature-based forest management demands for development of a common understanding of the nature-based management principles and long-term goals for stand development. This necessarily implies development of new instruments to organise and communicate these whole new management principles and desirable stand structures to professionals and other stakeholders.

The Forest Development Type (FDT) is one such tool. A FDT describes the long-term goal for forest development on a given locality in order to accomplish specific long-term aims of functionality (ecological-protective, economical-productive, and social-/cultural functions). It is based upon an analysis of the silvicultural possibilities of the site in combination with the aspirations of future forest functions. Also the area of distribution is defined by those parameters as opposed to the geometric definition of annual harvest units (stands) in plantation forestry.

The FDT was developed in Germany (Waldentwicklungstypen – WET) during the 1990ies a flexible instrument for transforming the overall targets and policies for nature-based forest management into tangible guidelines and operational goals at stand level (Palmer 1994, Palmer 1996). On the one hand FDT comprises a cyclic preoccupation with the respective name-given forest type on the other hand it includes a broader understanding of natural disturbance regimes and successional processes than hitherto used (Perpeet 2002). As such FDT has great similarities with the forest cycles that have successfully been used to describe and communicate the cyclic preoccupation of a specific forest type in natural forest reserves (see e.g. Leibundgut 1959, Zukrigl et al. 1963, Meyer and Neumann 1981, Mueller-Dombois 1987, Jenssen and Hofmann 1996, Emborg et al. 2000, Grassi et al. 2002).

The goals are described qualitative as a »scenario« (Perpeet (2000) call it »outline«). Introducing hypothetical visions by means of scenarios are generally believed to spur imagination because of their inherent nature as means of expression and communication (Wollenberg et al. 2000a, 2000b, de Boo and Wiersum 2002). Correspondingly, FDTs are regarded as being a tangible tool for enhancing professionals' intuitive understanding of long-term goals for vegetation structures and dynamics in the emerging paradigm of nature-based forest management (Perpeet 2002).

FOREST DEVELOPMENT TYPES IN DENMARK

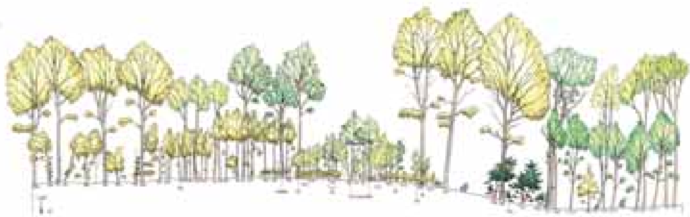
As a preparation for the World Summit on Sustainable Development in Johannesburg, South Africa 2002, a Danish National Forest Programme was developed. The programme aims at a long-term conversion towards nature-based forest management (Danish Forest and Nature Agency 2002). The Danish Forest and Nature Agency (DFNA) should lead this conversion by testing and further develop management tools, methods and operational principles in the state forests. Correspondingly, DFNA was asked to develop an action plan for the conversion to nature-based forest management by the end of 2004 (Danish Forest and nature Agency 2005, Larsen and Danish Forest and Nature Agency 2005b). In this context, the FDT tool was adapted from Germany to provide a framework for developing and describing long-term goals for stand structures and dynamics. During a period of nearly two year 19 FDTs covering all climate zones and soil types in the country were developed. For this purpose the country was divided into 4 eco-zones each with their typical climatic characteristics (Larsen and Danish Forest and Nature Agency 2005a). The FDTs were developed in close collaboration between scientists and professionals from all levels of the classical forestry hierarchy. For a period of nearly 2 years scientists interacted with the professionals in the forest in the development of the FDT (Larsen and Nielsen 2006)

For each FDT stand structure, species composition and regeneration dynamics are described both qualitatively (verbal descriptions) and quantitatively (numerical descriptions) for their mutual supportiveness, and the goal is specified with respect to production, conservation and recreation. To support the intuitive understanding of the scenario, the vegetation structure and composition at the »equilibrium state« is furthermore illustrated in a profile diagram (Fig. 1). Also a poster depicting all 19 FDTs in profile diagrams was made in order to support the communication of the FDTs to a broader circle including interest groups and the public in general (Fig. 2). As the name indicates, a profile diagram is a cross section through a forest stand. During the last century, profile diagrams have gained interest in studies of both natural forests and in nature-based forest management (Leibundgut 1959, Gustavsson 1986, Koop 1989). Many textbooks in silviculture have applied profile diagrams as means to communicate silvicultural systems and their related stand structures (e.g. Mayer 1980, Oldeman 1990, Oliver and Larson 1990, Otto1994, Larsen (ed) 2005, Röhrig et al. 2006). They all indicate the potential of integrative visual tools for communication of irregular stand structures (Nielsen and Nielsen, 2005).

The intention is that illustrated FDTs communicate long-term goals in such a way that professionals easily comprehend and thus serve as guideline for their management planning and decision making about future silvicultural actions (Larsen and Danish Forest and Nature Agency 2005a). But how do the professionals themselves assess the FDTs as a way to describe long-term goals and as an aid for their decisions regarding management planning and silvicultural actions? The potentials of FDTs to initiate and catalyze the desired changes in practice depend to a great extend on the professionals' direct acceptance of the tool and their ideas about its potentials and constrains (Palm 1994). In this context, the current development in forest management organizations, where more and more decisions are made by the people in the field, makes the acceptance from forest workers to managers more important than ever - after all it is in the forest the desired changes must take place. In order to get a hint about the professionals' assessment and attitudes toward FDTs, we developed a questionnaire and distributed it to employees at all levels of DFNA. In this paper we report and discuss the results of the survey, addressing the following research questions:

1. How do professionals assess FDTs as a way of communicating long-term goals for stand structures and dynamics in nature-based forest management?
2. How do professionals assess the suitability of FDTs for different target groups - including themselves?
3. How and where do professionals expect to use FDTs?

Name — **Forest Development Type 12: Beech with ash and sycamore**



Structure

Species rich well structured forest with beech as dominating element mixed with ash, sycamore and cherry and in the south-eastern parts of Denmark additionally with hornbeam and lime. The in-mixed species occur mainly in groups but also as single trees. The horizontal structures arise between groups of varying size and age. Where the light demanding species such as ash, sycamore and cherry dominate horizontal structures occur with shade trees (beech, hornbeam, elm and others) in sub-canopy strata.

Species distribution

Beech: 40-60 %
Ash and maple: 30-50 %
Cherry, hornbeam, oak, lime and others up to 20 %

Dynamics

Beech regenerates mainly in groups or smaller stands. Ash and sycamore are gap specialists and regenerate mainly in smaller openings later followed by beech. Hornbeam belongs to the sub-canopy stratum and regenerates under shade, whereas the pioneer species (cherry and oak) occur after larger openings and /or in relation to edges.

Functionality

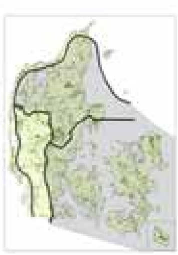
Productive: The forest development type has a high potential for production of hardwood in big dimensions and in good quality.

Protective: The beech dominated forest is in most parts of the country the potential natural vegetation; consequently many indigenous species are connected to this forest type. It has a great potential in conserving the biodiversity connected to the NATURA 2000 habitat types 9139 and 9150.

Recreational: It gives through its mixture of (indigenous) species in combination with pronounced variation in size a multitude of recreational experiences and intimacy.

Occurrence

The forest development type belongs on protected sites in the eastern and northern parts of Denmark on rich, well drained soils with good water supply as illustrated below.



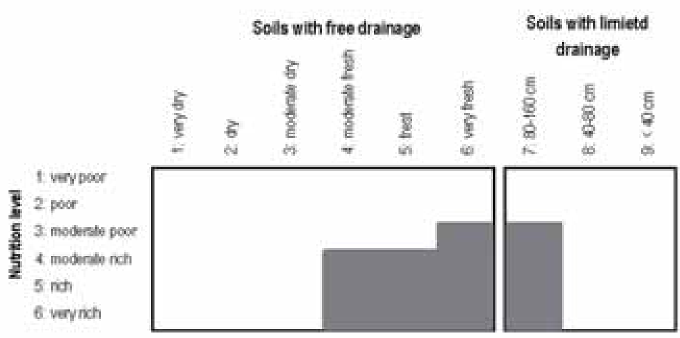


Figure 1. Example on description and illustration of a FDT scenario. The DK-map in the lover left corner shows the four eco-regions, and which eco-zones the FDT will occurred in (grey raster).

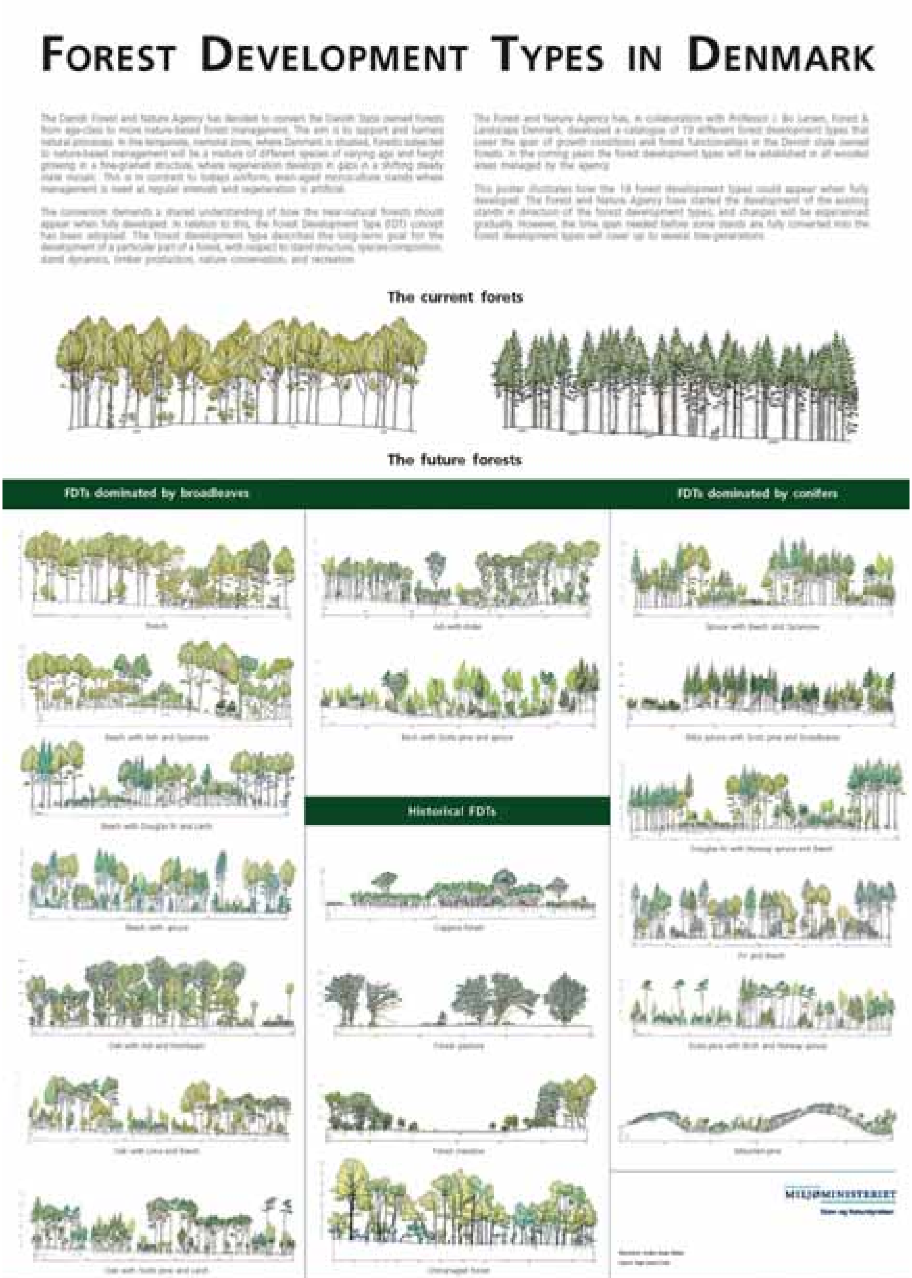


Figure 2: Poster depicting the present forest types and the future 19 FDTs in Denmark. The two upper profiles diagrams show typical forest stands at present (even-aged monocultures of beech, respectively Norway spruce). Below the 19 FDTs are grouped in broadleaved dominated (9), conifer dominated (6), and »historic« (4).

Materials and Methods

The Danish Forest and Nature Agency is organised into one central office and 20 local districts. The central office is responsible for formulating management strategies and management plans while the local districts are responsible for implementing these strategies and plans in the day-by-day management. Twelve districts were randomly chosen to participate in the survey, using equally geographical distribution as criteria.

SURVEY DESIGN

While the catalogue of forest development types in Denmark (Larsen and Danish Forest and Nature Agency 2005a) was finalised and published in May 2005, the questionnaire was postponed to August to ensure that most of the DFNA staff members had become acquainted with the catalogue. Depending of the size of the individual districts, the questionnaire was distributed to 8-12 employees in this way it was 1) only distributed to employees with forest related tasks; 2) equal distributed to forest managers and forest workers; 3) equal distributed to employees who had been actively engaged in the development of the FDTs and to those who had not. In total the survey was distributed to 130 staff members from the 12 districts.

The survey was kept anonymous, and short, using closed questions. A stamped reply-envelope was enclosed in order to minimize the time needed to fill and return it, thus motivating the respondents to do so. Beside initial questions to occupation, duration of employment in the agency, the districts eco-region, and degree of involvement in the process of FDT-development, the survey contained questions related to the three research questions. Questions addressing research question one and two were replied using five-level Likert scales. Depending on the wording of the question »1« means »very negative«/ »no importance«/ »not suitable« and »5« means »very positive« / »very important« / »very suitable«.

DATA ANALYSIS

Respondents were categorised as either forest *managers* or forest *workers* (in the following simply termed ‘managers’ and ‘workers’) to analyse whether occupation (and educational background) influence attitudes toward and assessment of the FDTs. Forest supervisors, forest officers (both graduates in forestry) and forest rangers (bachelor of profession in forest and landscape engineering) were grouped as managers whereas field staff with vocational level education (Forest and nature technicians or Nature Interpreters) and staff doing semi-skilled labour were grouped as workers.

From the questions concerning the respondents’ involvement in the process of FDT-development (described by Larsen and Nielsen 2006) the manager and worker groups were further divided into each three sub-groups to analyse whether involvement influence perception and assessment of FDT. Respondents who were members of a formal network of representatives from all districts, formed by the agency advance the knowledge about nature-based forest management together with the scientists and encourage discussions about this at the local districts, were categorised as ‘formally involved’. Managers (as categories above) are strongly supernumerary in this network (55 out of 56 persons). Respondents having participated in sketching one or more of the FDT scenarios were group with respondents having commented in text on FDT drafts and respondents having participated in workshops specifically addressing the FDT scenarios, and categorised as ‘directly involved’. Finally, respondents who had not been directly involved in the FDT-development but discussed this with colleagues etc. were categorised as ‘indirectly involved’.

For all questions answered by use of Likert scales, mean values were calculated for the total group of respondents as well as for the group of managers and workers. In all cases the closer to 5, the more favourable the response. The tables accompanying the results present these mean values as well as the scatter.

Results

83 respondents returned the survey corresponding to a response rate at 64 %. Approximately half of the survey participants were managers (44 respondents (53%)), the other half were workers (39 respondents (47%)). Respondents were also well distributed between the three categories of involvement in the process of FDT-development, with approximately one third of the respondents in each category. As expected, managers were, however, strongly supernumerary among formally involved respondents (23 out of 24), while workers clearly dominated the group of respondents that had only been indirectly involved in the process of FDT-development (23 out of 31). Only in the ‘directly involved’ group, respondents were approximately equally distributed between managers and workers. This unbalance was however expected as it reflects the reality where managers clearly dominate among employees being formally involved in the process of FDT development and workers clearly dominate among indirectly involved employees. Surprisingly, responses did not show differences between groups of different degree of involvement in the process of FDT-development. Correspondingly, this aspect is not included in the presentation of the results.

ASSESMENT OF FDTS AS A WAY TO COMMUNICATE LONG-TERM GOALS

Respondents were asked to evaluate FDT scenarios as a way to communicate the long-term goals for nature-based stand development, and to assess the importance of the verbal descriptions and the associated illustrations for their understanding of these goals. Furthermore, they were asked to assess the importance of personal knowledge and references and discussions with colleagues for their understanding of the FDTs. As shown in table 1, survey participants' in general responded favourably to FDTs as a way to describe long-term goals for nature-based stand development ($\bar{x}$ = 4.19), with nearly identical mean values for the manager and worker groups. Further, both the verbal description ($\bar{x}$ = 4.36) and its illustration ($\bar{x}$ = 4.16) were judged almost equal important for their understanding of the goals, again with hardly any difference between managers and workers. Responses were, however, even more favourable regarding the importance of 'discussions with colleagues' ($\bar{x}$ = 4.59), 'visits to nature-based managed forests' ($\bar{x}$ = 4.59) and 'own general experiences and knowledge about Danish forests'($\bar{x}$ = 4.43) for understanding of the goals. Also here, there was hardly any difference between managers' and workers' perception, with the exception perhaps that managers assessed 'general experiences and knowledge about forests' to be more important ($\bar{x}$ = 4.55) than did workers ($\bar{x}$ = 4.30).

Table 1: Respondents' assessment of FDTs as a way to describe long-term goals for stand structures and dynamics in nature-based forest management (1 = very negative; 5 = very positive) and their assessment of the importance of specific elements for their understanding of the long-term goals as described in the FDTs (1 = no importance; 5 = very important)

				Scatter				
	Respondents	**5**	**4**	**3**	**2**	**1**	$\bar{x}$	**n**
FDT as a tool to	All respondents	31	43	5	2	2	4.19	83
describe long-term	Managers	17	21	5	0	1	4.20	44
goals	Workers	14	22	0	2	1	4.18	39
Importance of specific elements								
Verbal description	All respondents	44	28	3	3	2	4,36	80
of the FDT	Managers	25	14	2	1	1	4,42	43
scenarios	Workers	19	14	1	2	1	4,30	37
illustration of the	All respondents	39	27	8	6	2	4,16	82
FDT scenarios	Managers	21	16	3	3	1	4,20	44
	Workers	18	11	5	3	1	4,11	38
Discussions with	All respondents	59	14	6	1	1	4,59	81
colleagues	Managers	31	8	2	0	1	4,60	43
	Workers	28	6	4	1	0	4,58	38
Visits to nature-	All respondents	55	20	7	0	0	4,59	82
based managed	Managers	29	12	3	0	0	4,59	44
forests	Workers	26	8	4	0	0	4,58	38
Experience and	All respondents	44	26	8	1	0	4,43	79
knowledge about	Managers	28	10	3	1	0	4,55	42
forests	Workers	16	16	5	0	0	4,30	37

ASSESSMENT OF FDTS SUITABILITY FOR DIFFERENT TARGET GROUPS

As shown in table 2 responses were favourably regarding the suitability of FDTs for DFNA employees, though generally more suitable for managers ($\bar{x}$ = 4.42) than for workers ($\bar{x}$ = 4.19). However, one should notice that workers assessed the suitability of FDT for themselves ($\bar{x}$ = 4.30) equally high as for managers ($\bar{x}$ = 4.30). Responses regarding the suitability of FDTs for fellow public or private forest owners, managers and workers was also favourably ($\bar{x}$ = 4.27), whereas suitability for communication with other stakeholder groups such as authorities, politicians, user groups and especially forest visitors were assessed less favourably ($\bar{x}$ = 3.90 - 3.30). For all of these groups there were only small differences between managers' and workers' assessment.

ACTUAL AND EXPECTED AREAS OF USE OF FDTS

Only three month after the catalogue of FDTs in Denmark was finalized and published, 30 respondents, equalling to 36 % of the survey participants, had already used the FDTs for decisions-making regarding silvicultural actions (n = 21), afforestation (n = 1), management planning (n = 14), communication with users (n = 14), and/or communication with politicians and authorities (n = 15) (Table 3). As shown in table 4, these areas of application and the rate of recurrence were clearly reflected in respondents' expected future use of FDTs. For example was 'silvicultural decisions' the topic where most managers and workers (16 respectively 5) had applied the tool in advance, and also the matter where most respondents expected to use the FDTs in their future work (32 managers and 19 workers) followed by 'management planning' and 'communication with user groups', which was also the second and third most common areas of application.

Table 2: Respondents assessment of the suitability of FDT scenarios for different DFNA staff members and different stake holder groups (1 = very unsuitable; 5 = very suitable).

		Scatter						
Stakeholder group	**Respondents**	**5**	**4**	**3**	**2**	**1**	$\bar{x}$	**n**
DFNA forest managers	All respondents	45[a]	23a	10[a]	1[a]	0[a]	4.42	80
	Mangers	28[a]	12[a]	4[a]	0[a]	0[a]	4.56	44
	Workers	17[a]	12[a]	6[a]	1[a]	0[a]	4.30	36
DFNA forest workers	All respondents	30[b]	39[b]	7[b]	3[b]	1[b]	4.19	80
	Mangers	14[b]	22[b]	5[b]	1[b]	1[b]	4.10	43
	Workers	16[b]	17[b]	2[b]	2[b]	0[b]	4.30	27
Other forest owners, managers and workers	All respondents	34	37	8	2	0	4,27	81
	Managers	18	21	3	1	0	4,30	43
	Workers	16	16	5	1	0	4,23	38
Authorities	All respondents	12	39	23	6	0	3,70	81
	Managers	7	22	10	4	0	3,74	43
	Workers	5	17	13	2	0	3,58	38
Politicians	All respondents	13	37	20	9	0	3,68	79
	Managers	6	20	11	4	0	3,68	41
	Workers	7	17	9	5	0	3,68	38
Representatives for user groups	All respondents	18	43	15	4	1	3,90	81
	Managers	10	23	8	2	0	3,95	43
	Workers	8	20	7	2	1	3,82	38
Forest visitors	All respondents	9	29	24	13	5	3,30	80
	Managers	4	16	9	11	2	3,21	42
	Workers	5	13	15	2	3	3,39	38
Other stakeholder groups[c]	All respondents	2	0	4	0	0	3,67	6
	Managers	2	0	2	0	0	4,00	4
	Workers	0	0	2	0	0	3,00	2

[a] the scatter for DFNA managers is calculated as the mean of the scatter for the four sub-groups forest supervisors; forest officers central office; forest officers; forest rangers.
[b] The scatter for DFNA workers is calculated as the mean of the scatter for the sub-groups nature interpreter; forest workers and staff doing semiskilled labour.
[c] Other stakeholder groups mentioned was the press and students of forestry.

Table 3: Decision-making processes and communication activities where respondents have applied FDT.

Area of use	Managers	Workers	Total
Silvicultural decisions	16	5	21
Afforestation decisions	1	0	1
Management planning	13	1	14
Communication with user groups	13	1	14
Communication to politicians and authorities	7	0	7
Other activities*	6	2	8

* Other activities mentioned were PR, lectures, excursions, education of staff.

Table 4: Decision-making processes and communication activities where respondents expect to apply FDT.

Area of use	Managers	Workers	Total
Silvicultural decisions	32	19	51
Afforestation decisions	14	7	21
Management planning	27	6	33
Communication with user groups	21	3	24
Communication to politicians and authorities	16	1	17
Other activities*	5	6	11

* Other activities mentioned were PR, lectures, user facilities, education of staff, communication with other forest-owners.

Discussion

The results show, that only three month after their completion the FDTs have taken hold amongst both DFNA managers and workers. Respondents assess the tool favourably for both describing long-term goals for nature-based stand development and as an aid for their work in order to realize these goals. As such the results confirm German assumptions (Perpeet 2002) and the observation during the collaborative process in which the FDTs were developed in Denmark (Larsen and Nielsen 2006).

Both managers and workers have already used and have clear ideas of a surprisingly wide range of future uses for the FDTs, ranging from management planning and silvicultural decisions to communication with various stakeholder groups. This indicate that agency staff have been eager to test the "new" tool – maybe because the conversion to nature-based forest management principles has been administratively decided since 2002 (Danish Forest and Nature Agency 2002).

Respondents judges the FDT scenarios more favourable in communication between peoples within the forest sector such as forest owners, managers and workers, whereas the suitability for communication with other stakeholder groups such as authorities, politicians, user groups and especially forest visitors were assessed less favourable. This can be explained by the respondents being aware that these »not forester« groups are likely to have much less knowledge and experiences about forest to »read« into the FDT scenarios. At least, respondents emphasis their own personal knowledge and experiences – especially visits to nature-based managed forests – as having utmost importance for their own understanding of the long-term goals for nature-based stand development as described in the FDTs (Table 1). The importance of "reference landscape" for professionals' capacity to contextualize in new management paradigms is confirmed by both theory (e.g. Schön 1983, Kjørup 2000) and empirical research (Jönsson and Gustavsson 2003, Nielsen and Nielsen 2005).

From this perspective, the results indicate that the creation of meaning from the FDTs is an interaction between human mind and the information provided in the FDTs. Correspondingly, the professionals might generate very different meanings and mental images from interpreting the FDTs. The quantitative nature of the present study does, however, not allow for any conclusions regarding what meanings the respondents make of the FDTs and to what extend these meanings constitute a common understanding of the principles and the long-term goals for nature-based stand development. In relation to this, the importance of a shared understanding of the principles and long-term goals for successful implementation of the nature-based management calls for further and more qualitative research into what meaning professionals from all levels of the classical forestry hierarchy create from the FDTs, and the importance of specific elements such as the illustrations, the verbal descriptions, reference landscapes, personal knowledge etc. in this respect. Such studies could provide valuable information about the needs for further activities to support and accelerate the development of a common understanding as well as identify what these activities might be. In this context, experience show that FDTs will become shared knowledge only if there is provided room for plenty of talk about their meaning, accuracy and implication (Innes 1998). The respondents themselves indicate this aspect of dialogue, as they rank »discussion with colleagues« as the single element that has the greatest importance for their understanding of the long-term goals for nature-based stand development as communicated in the FDTs.

In conclusion, it is therefore important to stress, that the professionals' positive assessment and general acceptance of the FDTs is not only attributed to the »tool« itself but also to the engagement of the professionals themselves in its development. The collaborative process provided room for plenty of discussions of the meaning, accuracy and implications of the FDTs. Further, the eagerness of developing and testing the »new« tool was for sure boosted by the fact, that the conversion to nature-based forest management already was decided politically beforehand (Danish Forest and Nature Agency 2002). Hence, the professionals' direct acceptance of the FDTs may to a large extent reflect the political-administrative preparations. However, all in all the professionals' direct acceptance of the FDTs and implementation of it in various aspects of their work indicates the tools potential to initiate and catalyse the desired changes toward nature-based forest management across all levels of the classical forestry hierarchy. After all, the observed positive attitude and assessment of FDTs (paper V) is the precondition for the tool to become a powerful agent in the future development of a shared understanding of the principles and long-term goals for nature-based stand development.

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