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Use of National Forest Inventories to downscale European forest diversity spatial information in five test areas, covering different geo-physical and geo-botanical conditions

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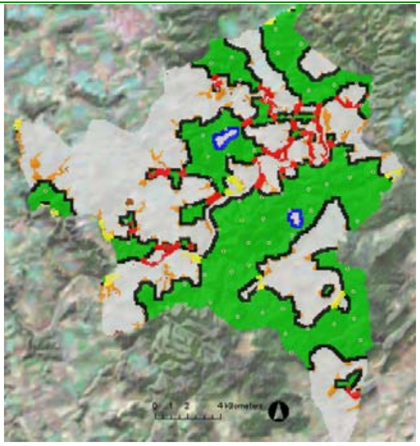

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“ Use of National Forest Inventories to downscale European forest diversity spatial information in five test areas, covering different geo-physical and geo-botanical conditions “

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Preface

The present study was developed in the context of Regulation (EC) 2152/2003 on the monitoring of forest and environmental interactions, the so-called "Forest Focus" Regulation.

The Forest Focus regulation centered specifically on the monitoring of the effects of atmospheric pollution and fires on European forests, previously addressed by Council Regulation (EEC) No 3528/86 of 17 November 1986 on the protection of the Community's forests against atmospheric pollution and Council Regulation (EEC) No 2158/92 of 23 July 1992 on protection of the Community's forests against fire. Furthermore, "Forest Focus" aimed at encouraging the exchange of information on the condition of and harmful influences on forests in the Community and enabling the evaluation of ongoing measures to promote conservation and protection of forests, with particular emphasis on actions taken to reduce impacts negatively affecting forests.

In order to promote a comprehensive understanding of the relationship between forests and the environment, the scheme also included the financing of studies and pilot projects aiming at the development of monitoring schemes for other important factors such as biodiversity, carbon sequestration, climate change, soils and the protective function of forests. The EC launched and financed a series of seven studies dealing with the following topics:

1. *Climate change impact and carbon sequestration in European forests*
2. *Development of a simple and efficient method field assessment of forest fire severity*
3. *Use of National Forest Inventories to downscale European forest diversity spatial information in five test areas, covering different geo-physical and geo-botanical conditions*
4. *Harmonizing National Forest Inventories in Europe*
5. *Development of harmonised Indicators and estimation procedures for forests with protective functions against natural hazards in the alpine space*
6. *Linking and harmonizing the forests spatial pattern analyses at European, National and Regional scales for a better characterization of the forests vulnerability and resilience*
7. *Evaluation of the set-up of the Level I and Level II forest monitoring under Forest Focus.*

This study (topic 3 in the above list) aims at addressing and demonstrating the integration of two different data sources *i.e.* forest biodiversity variables available from National Forest Inventories (NFIs) in European countries and landscape level forest spatial pattern maps easily obtained from remote sensing based forest cover maps. This study addresses the link between the two data sources. It also includes the first concrete harmonization exercise of forest biodiversity variables available from National Forest Inventories (NFIs) in five countries.

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EXECUTIVE SUMMARY

The project "Use of National Forest Inventories to downscale European forest diversity spatial information in five test areas, covering different geo-physical and geo-botanical conditions", referred also as "forest downscaling" (JRC contract 382340 F1SC) covers one of the seven topics that were studied in the frame of the Regulation (EC) 2152/2003 on the monitoring of forest and environmental interactions, the so-called "Forest Focus" Regulation.

This study was conducted by a European consortium coordinated by the Italian Academy of Forest Sciences (Italy) and included partners from the Swedish University of Agricultural Sciences, the Institute of Forest Ecosystem Research of the Czech Republic, the German Federal Research Centre for Forestry and Forest Products, and the Swiss Federal Institute for Forest, Snow and Landscape Research. The overall supervision of the project and the processing of forest spatial pattern were done by the Joint Research Centre.

This study addressed the link between field based forest biological diversity data and landscape-level forest pattern information. The former were made available from National Forest Inventories (NFIs) at plot level in five different countries; their harmonisation was implemented for the first time and benefited from outcomes of the COST Action-E43 on core biodiversity variables. For the latter, landscape level forest spatial pattern maps were automatically derived from available remote sensing based forest cover maps. The relationships between selected pattern and biodiversity variables available from the two different data sources were studied.

Seven case studies for a total area of about 100,000 km^2 were selected in five European ecological regions: one site in Germany (Atlantic zone), one in Sweden (Boreal zone), two in Czech Republic (Continental zone), one in Switzerland (Alpine zone) and two in Italy (Mediterranean zone).

Historical and recent forest maps were available at broad resolution (100m raster) and at fine resolution (25 m raster) for each site. Forest biodiversity variables were also made available from raw NFIs data (Table 1) but the lack of historical data prevented the comparison of temporal trends of the two dataset. The study therefore focussed on their linkages for one point in time only.

COUNTRY (test area)	YEAR	PLOT	TREE	DEADWOOD	SHRUB	GROUND VEGET.
CH	2000	723	9365	567	723	723
CZ01	1996	224	5934	1169	29	625
CZ01	2005	224	5757	2962	41	712
CZ02	1996	78	1714	225	125	224
CZ02	2005	78	2151	562	84	232
DE	2002	895	5778	283	0	9690
IT	2006	351	8564	1524	984	22467
SE	1999	494	3741	426	0	0
SE	2003	195	1406	166	111	0
TOTAL		**3262**	**44410**	**7884**	**2097**	**34673**

Table 1: Number of records available in the common NFI database per test area and year of acquisition

First, NFI data were stored in a common database structured in five tables (Access Database format) made of 3262 NFI plots, 44410 trees and 7884 pieces of deadwood in total (table1).

Raw data were harmonised in order to calculate forest biodiversity indicators for each of the available NFI plot. Definitions issues faced in the harmonisation exercise are illustrated for deadwood in table 2. Finally, indicators were grouped in six areas: forest types, forest structure, deadwood, naturalness, and stand age (table 3)

EXISTING DEFINITIONS AT THE INTERNATIONAL LEVEL		
Country	*Diameter*	*Length*
TBFRA2005 (FAO)		
ForestBIOTA	10 cm (diameter thicker end)	1 m
Biosoil	10 cm (minimum diameter)	1 m
MCPFE (2002)	10 cm (mean diameter)	1 m
NFI definitions		
Country	*Diameter*	*Length*
Proposition (biodiversity)	10 cm (minimum diameter)	1.3 m
CZ	7 cm median diameter	0.1 m
DE	20 cm thicker end	0.1 m
IT	10 cm minimum diameter	-
SE	4 cm minimum diameter	1.3 m
CH	5 cm minimum diameter	1 m

Table 2: Definitions for standing deadwood at international and NFI levels

Core variable	Indicator	
Forest type	The Forest type is mainly for stratification purposes of other indicators, and refers to the EU system of nomenclature developed by EEA (2006)	
Deadwood	Volume of deadwood (m³/ha) reported by size (Coarse, Fine)	
	Volume of deadwood (m³/ha) reported by spatial position (Laying, Standing)	
	Volume of deadwood (m³/ha) reported by decay class (4 classes)	
	Volume of deadwood (m³/ha) reported by woody species (Coniferous, Broadleaves, Unknown)	
Naturalness	Naturalness degree (at plot level, natural, semi-natural, plantation)	
Forest structure	Tree species composition	Relative abundance of native tree species (on basal area/total basal area in the plot and on nb of trees/ total number of trees in the plot)
		Shannon index for native tree species (on basal area and on nb of trees)
		Shannon index for tree species (on basal area, on nb of trees)
	Horizontal structure	Mean DBH of the 0.1% (1%, 5% and 10%) largest diameter trees
		Mean of DBH standard dev of plots
		Mean DBH
	Vertical structure	standard deviation of the heights
		mean tree height
		number of layers in the plot
Stand age	Dominant age (proportion of old trees)	
	Mean tree age	
	Age diversity (standard deviation of tree ages)	

Table 2: List of the indicators calculated on the basis of the common NFI database.

Second, forest original maps were collected for each test site and harmonised in terms of geometry, resolution, projection and nomenclature by adopting the European Forest Types system of nomenclature recently proposed by the European Environmental Agency. Landscape level forest spatial pattern refers to the spatial arrangement or configuration of forested ecosystems across the landscape. Forest spatial pattern maps were generated with the mathematical morphology based freeware GUIDOS (Graphical User Interface for the Detection of Objects and Shapes) from all binary forest (forest type)/non forest maps available at 25 m and 100 m spatial resolution and at four different edge sizes (from 1 to 4 times the pixel resolution of the forest input map). Forest pattern classes were core (interior forest area minus the edge size), edge (external perimeter of core patch), perforation (perimeter of perforation in core patch), branches of edges, connectors between different cores (bridge) or same core (loop) and islet/fleck (isolated non-core forest patches). From data with different spatial resolution (top maps in figure 2), the level of congruence of pattern maps, in terms of the forest proportion of core and non-core area, mainly depend on the level of forest fragmentation as observed at fine scale. At equivalent edge size (edge size 4 for 25 m resolution equivalent to edge size 1 at 100m resolution), the forest proportion of core area was found higher from maps with finer spatial resolution. Independently of the data resolution, the core forest area always decreased in favour of non-core areas (like edges and connectors) when edge sizes increased (top right and bottom maps in Figure 1).

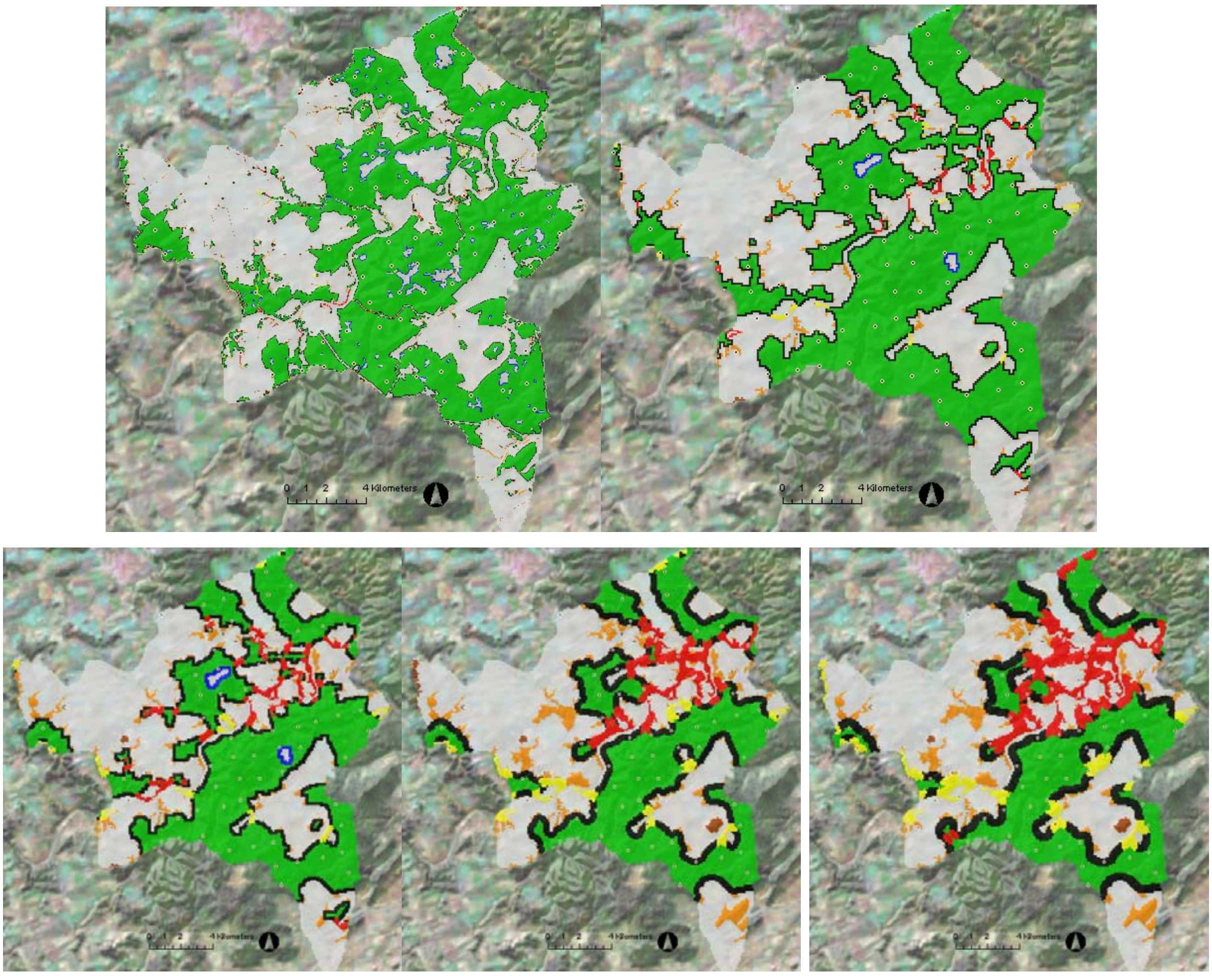


Figure 1: Top: Spatial pattern maps at 25m (left) and 100m resolution (right) in KřIvoklát site (Czech Republic) with edge size 1, and NFIs plots overlaid; Bottom left to right: maps at 100m resolution with edge sizes from 2 to 4. (core: green shade, edge: black, bridge: red, loop:yellow, perforation: blu, branches: orange, islet: brown)

For the downscaling analysis, forest spatial pattern classes were aggregated into core and non-core forest classes. At edge size 1, NFIs plots were mainly located into core forest (60% to 90% of the total plots), then into non-core forest (3% to 36%). The fraction of NFIs plots into non-forest was low for maps at 25m resolution but could reach 40 % for maps at 100m resolution.

Two main methods were tested to link the forest spatial pattern classes and the NFIs biodiversity indicators: (1) the pixel based approach simply derived the pattern class at each NFI plot (or within its close surroundings) and, (2) the area approach divided each test site into sub-areas containing at least 20 NFIs plots and calculated the average of pixel-level pattern classes and of NFIs biodiversity indicators values. The analysis was conducted for three forest biodiversity indicators frequently used in international reporting frameworks (MCPFE, FAO, EEA):

- Total volume of deadwood (m^3 ha^{-1}), index related to the habitat of saproxylic fauna and flora
- Shannon index for tree species (on basal area), being a compositional diversity index
- Standard deviation of DBH (cm), being a structural index

For the 3262 available NFI plots, these indicators proved to be uncorrelated (Figure 2).

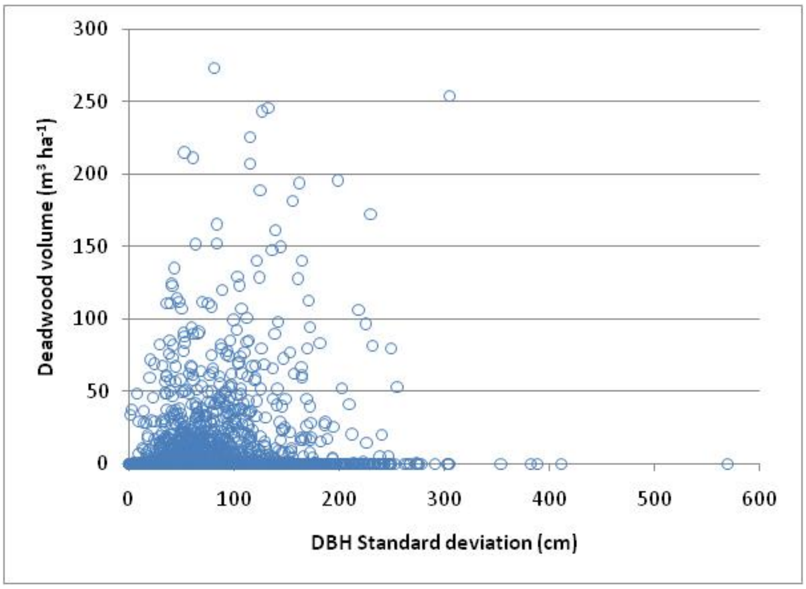


Figure 2: Correlation between Std. dev. of DBH and deadwood based on all NFI plots.

The relationships between pattern-NFIs biodiversity proved to be similar among results from the two combining methods, by applying different edge sizes and for the two observation scales (100m or 25m spatial resolution). Results are thus reported for the pixel based approach and edge size 1. The relationship between core (non-core) area and the three NFIs biodiversity indicators was not unique in all test sites. The total volume of deadwood was higher in non-core areas in 4 among the 7 sites, it was higher in core areas in the two Czech sites. In most sites (Switzerland, Germany and the two Italian sites), the diversity of tree DBH was higher in core areas but not in the two Czech sites and in Sweden. The compositional diversity as reflected by the Shannon index was higher in non-core areas except in one Italian site, Sweden and Germany. The Italian site was the only one with higher values for each of the three biodiversity indices in core areas.

It is only when all available NFI plots from all sites were aggregated that the relationship shows off more significantly and was statistically more meaningful. The three biodiversity indicators show higher values in non-core forest areas than in core areas (Figure 3).

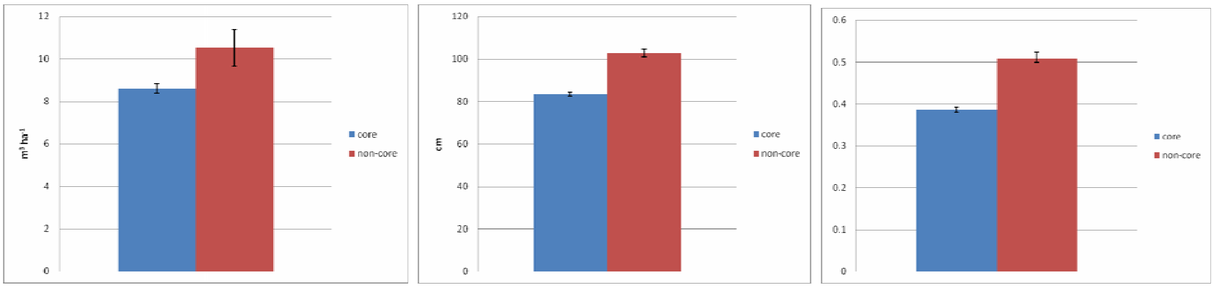


Figure 3: Average values of the three biodiversity indicators (from left to right: deadwood volume, SD of DBH and Shannon index on basal area) in core and non-core areas for all NFI plots available.

The project enabled the creation of a large harmonised multi-scale geo-database with geo-coded harmonized NFI forest biodiversity data and forest spatial pattern maps at two spatial resolutions. The integration of NFI field plot data and remote sensing based forest maps prove to be difficult for various reasons: datasets frequently developed separately, lack of statistically meaningful set of NFIs plots per forest pattern class (in particular edge classes) and co-registration issues, lack of comparability of NFIs due to different definitions, sampling designs and field national protocols, comparability that harmonisation techniques based on international references partially solve.

This pilot study showed that core and non-core forest spatial patterns classes tend to have different values in deadwood, compositional tree diversity and horizontal forest structure. This would require further investigation in particular using fine-scale forest maps and larger NFIs plot numbers. The adoption of general downscaling procedures on large areas have to be considered with caution since such multi-scale relationships may be very different depending to local environmental conditions and are strongly affected by forest management.

1. INTRODUCTION

This final report refer to the project "Pilot study on the use of National Forest Inventories to downscale European forest diversity spatial information in five test areas, covering different geo-physical and geo-botanical conditions", frequently we refer shortly to it as "forest downscaling" or just "downscaling" (contract 382340 F1SC following tender 176-174125 launched by the Joint Research Centre of the European Commission, Institute for Environment and Sustainability located in Ispra (VA, Italy), that entered in force the 21st of November 2006).

After the Kick Off Meeting held at JRC in Ispra (VA, Italy) the 19th of January 2007 a first interim meeting was organized at the Italian Academy of Forest Science in Florence (Italy) the 4th of July 2007 while the second interim meeting was at JRC in Ispra (VA, Italy) the 4th of November 2008.

This report first recalls briefly the main objectives and the WP organization of the project (chapter 1.1, chapter 1.2). Chapter 1.3 explain the main relationships with other past and present research projects that are in different ways related to the activities carried out in the "downscaling" project. Chapter 1.4 presents the original ideas presented in the project proposal and some modifications as a follow-up of discussion with JRC and within the members of this consortium. Chapter 2 focus on the results of the bibliographic review carried out within the Work Package 1. Chapter 3 introduces the test areas selected in five biogeographical regions in Europe and the raw data used for the activities of this project. Chapter 4 presents the activities carried out in Work Package 2 for the harmonisation of both the data from the National Forest Inventories (NFI) and the forest spatial pattern maps acquired in the test areas and finally in Chapter 5 the results of the combined analysis between NFI data and forest maps.

1.1. Objectives of the project

This study was designed in the framework of the research activities aimed to address the feasibility to integrate National Forest Inventories data and remote sensing derived data to downscale large-scale aspects of forest biological diversity in order to understand if different forest landscape patterns mapped with remotely sensed may be related to different forest biodiversity conditions.

The rationale of the study is that the use of information derived from remote sensing data combined with terrestrial sampling based inventories may be a feasible low cost approach for a European wide forest biodiversity assessment and monitoring system. Such a system should be able to monitor and report the status and the changes in the level of biodiversity in forest ecosystems at different geographical scales.

Remotely sensed databases (CORINE Land Cover 2000 and 1990 available at 25 ha mapping unit, Landsat TM based forest maps at 25m pixel resolution) enable to compute and monitor every 10 years or less indicators of forest biodiversity at landscape level acknowledged within the MCPFE process (MCPFE, 2003b) and the Convention on Biological Diversity.

Such landscape level analysis, which now can be easily performed in a standardised way all over Europe (Estreguil et al, 2007), suffer of two main limitations:

1) Landscape level measures of pattern must have a link to ecological and functional aspects in order to contribute to the biodiversity discussion. The relationship between different geographical levels of biodiversity analysis (alpha, beta, gamma diversity) is prevalently unknown or solely demonstrated on a case study basis. Also unclear is the relationship between landscape level indicators and other biodiversity indicators assessed in the field;

2) it is still not clear if the ecological meaning of the results obtained in such analyses (relationship of biological diversity at different scales) can be generalised or if they are related to local factors; such as, for example, the geographical location and extent of the area or the scale of the input variables.

If landscape analysis can be now performed all over Europe in a standardised way on the basis of common procedures and standard input layers, National Forest Inventories acquired routinely in the field in most of the EU countries provide a large amount of forest information. Such information is actually available with different definitions, methods and sampling schemes. Such differences made the comparison of resulting NFI statistics acquired in different Countries difficult and almost impossible. A large effort in the last years was given to set up harmonisation methods to make comparable existing NFI data.

In order to answer the above cited questions this project was structured as follow. The first year of activities was mainly devoted to the selection of test sites (located in five different biogeographical regions of Europe), to prepare the first draft bibliographic review, to define the main outlines of the methodology to be adopted in the project and to acquire and harmonise raw data in selected test sites (Figure 4). In the second year of activities the final computation of a total number of 35 biodiversity indicators was performed on the basis of the harmonised NFI data acquired in the field in a total number of 3262 plots and to derive forest spatial pattern maps from local multitemporal forest maps on the basis of the GUIDOS software developed by the JRC.

The final analysis combined multitemporal and multiscale forest spatial pattern classes calculated on forest maps with forest biodiversity indicators calculated for NFI plots. The combination is performed on the basis of the geometric coregistration between the spatial location of the NFI plots and the GUIDOS maps. The results of the analysis, performed both at pixel level and for local subareas created within the test sites, are presented to report possible significative differences in NFI biodiversity indicators for the different available GUIDOS spatial pattern classes.

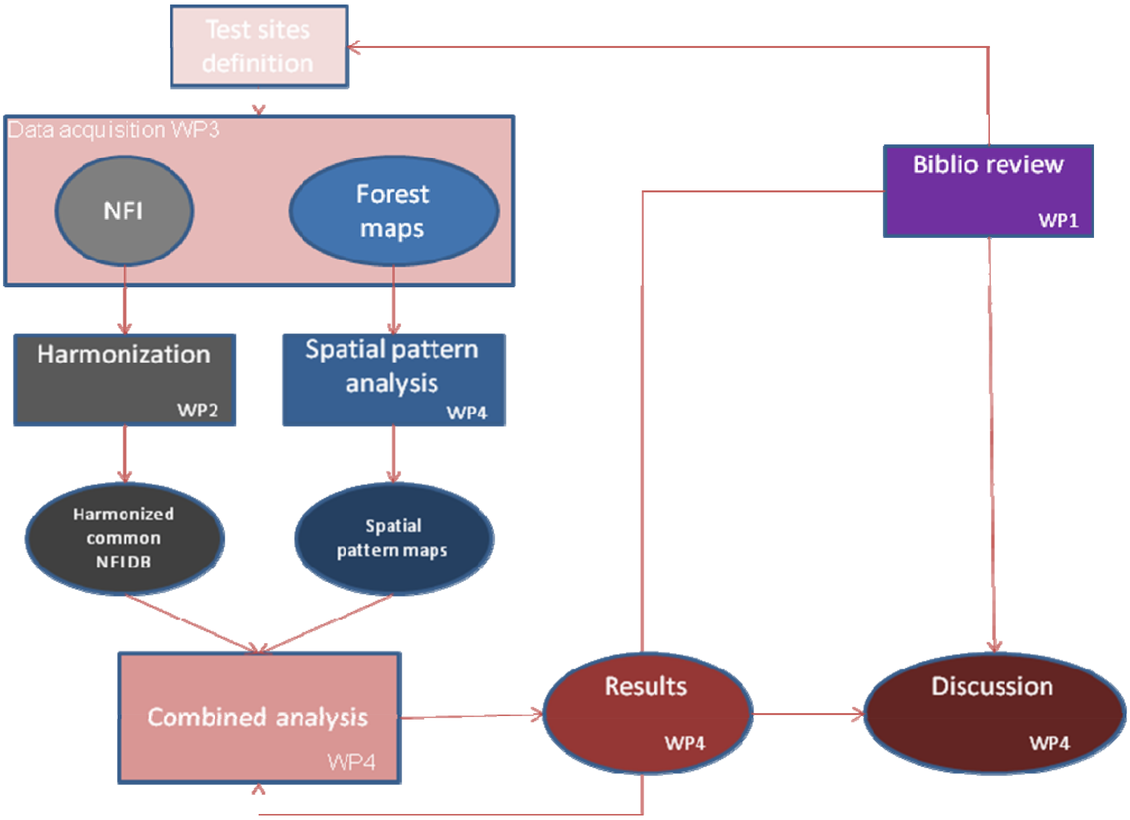


Figure 4: Flow chart of the activities carried out in the project.

1.2. Organization of the project

The study is based on four Work Packages (WP) which cover temporally the time schedule of 24 months and geographically five biogeographical areas in five different European Countries.

Each test area is under the responsibility of one partner of the project consortium.

The first WP is merely methodological, it's final aim is to study in synthesis existing methodologies available in literature in order to develop the final experimental protocol that will applied in the five selected test areas.

Since NFI data are one of the main source of information for the study, in the second WP the harmonisation of such a field based data is carried out in order to be able to compare as much as possible national dataset provided by the partners of the consortium.

The third WP deals on the creation of a final structured geodatabase of all the data available for the study while the last one (WP4) has the final aim of performing the analysis and to report the final results.

Each partner provided datasets for its own test area following standards protocol shared between the consortium and defined together the JRC. To ensure the homogeneity of final products the harmonisation of the dataset was performed centrally by the coordinator of the consortium (AISF) while the combined analysis was performed by WSL for the pixel level aggregation method and by SLU for the sub-area method for all the test sites.

Work Packages	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WP1	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨												
WP2	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨												
WP3			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨											
WP4														▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

Figure 5: Time schedule of the project.

1.3. Related projects

Several international research projects are related to the present study but at least five of them will directly provide input dataset or methods.

CORINE Land Cover 1:100.000 maps at the years 2000 and 1990, raster format at 100 m spatial resolution.

Within the JRC FOREST Action, the FOREST MASK of Europe, at 25 m resolution developed by semi-automatic classification of the IMAGE2000 Landsat 7 ETM+ coverage (Pekkarinen et al., 2007), year 2000.

The European Forest Types system of nomenclature developed by the EEA (2006).

Within the JRC FOREST Action (Estreguil C. and Vogt P), the in house GUIDOS software for spatial pattern analysis will be used for deriving classified landscape patterns maps on the basis of different multitemporal and multiscale binary maps provided by the partner of the consortium to JRC.

The COST action E43 "Harmonisation of National Forest Inventories: techniques for common reporting", started in 2004 and ending in 2008, is the main source for the definition of the approaches followed for the harmonisation of NFI data used in this project. The relationship between the two projects is very strong. All the partners of the consortium (with the exception of Germany) participate actively to the COST action and some of the harmonisation ideas born within the Working Group 3 (on Forest Biodiversity) of the COST action E43 have been used in the “downscaling” project. The datasets used for the two projects are anyhow maintained physically separated on the basis of the formal agreements within the partners of the consortium.

1.4. From the proposal to the operative work

The methodologies followed to reach the final aim of the project and the organization of the work have slightly changed in WP3 and 4 from the original ideas according to what was agreed in the kick off meeting (KOM) held in Ispra and the two interim meetings held in Florence and in Ispra.

WP1 – Bibliographic analysis and state of the art

The work was under the responsibility of IFER and was concluded in the first year of activity.

WP2 – Harmonisation of NFI data

The work was based on the general methods developed in the COST action E43, and specifically on WG3 activities for what concern the calculation of biodiversity indicators. The selection of the so called “Core Variables” for biodiversity assessment was done combining the results of the questionnaires compiled in the COST action with the real availability of field data in the selected Forest Inventories of the five Countries participating to the “downscaling” project. A first hypothesis of the main harmonisation rules to be applied in the “downscaling” project was set up on the basis of the NFI metadata during the first year of activity. The structure of a common project Data Base for storing the NFI data was then set up during the first year of activities (also accordingly to a similar procedure tested in the COST action E43). Then the DB was populated with real NFI data during the second year of activity, the bridging functions applied for the harmonisation of the data were operatively defined. The selected biodiversity indicators for the core variables were then calculated for each of the NFI plots (where data were available) on the basis of harmonised raw data.

Chapter 5 of this report is mainly based on the activities carried out in the first year of the project and has the aim to introduce to the following Chapter 6 were the harmonisation concepts and methods are practically applied to derive the NFI databases: one with raw NFI data and one with harmonised biodiversity indicators calculated for each of the NFI plot.

WP 3 – Data preparation

The project in this WP followed the ideas presented in the original project proposal with two exceptions.

1- The JRC required (accordingly to the Tender Specification, point 2.2, Task 2) that the multitemporal forest maps provided by the project partners in the five biogeographical areas cannot be only those ones already available at European level (Corine 1990, 2000 and Forest mask 25 m resolution). For this reason the partners were asked to provide forest maps with higher spatial and/or thematic resolution than the cited original European maps. This idea was agreed by the partner of the consortium in the first interim meeting).

2- The JRC asked for geocoded NFI data, the consortium agreed in the first interim meeting that the NFI data will be located on the basis of the relative raster resolution of the forest maps (25 m resolution maps were available, 100 m for the others). For the final aim of the project it is in fact important to spatially join the data acquired in the field with the data acquired by remote sensing in the forest maps.

Data preparation started in the first year and was concluded in the second year of the project. The description of raw data available in the test areas is presented in Chapter 3 while the description of the final list of available harmonised data is presented in Chapter 4.

WP 4 - Analysis

In the original project proposal, the analysis between NFI and remotely sensed could be from raw satellite imagery data and from map derived data. It was agreed to focus solely on this map derived data. For this reason also the possible use of estimation methods for deriving forest attributes maps (such as k-nearest neighbours) were not implemented in the project.

The analysis phase focused in understanding the relationships between spatial pattern information calculated on the basis of forest maps elaborated with the GUIDOS software and the harmonised forest biodiversity indicators based on NFI data.

The analysis was carried out on the basis of two different approaches: pixel based and area based.

2. BIBLIOGRAPHIC REVIEW

2.1. Definition of biodiversity

"*Today it is universally accepted that the conservation of biodiversity is essential for sustainable forest management*" (Ciancio and Nocentini, 2004). In this sense, the basic question that needs to be answered is what one wants to conserve, and hence, what we understand under the term "biodiversity". Kaennel (1998) who made a thorough survey of literature focusing on biodiversity revealed a variety of formal and informal definitions of the term biodiversity.

Already in 1990, Noss (1990) pointed out that "*biological diversity means different things to different people. To a systematist, it might be the list of species in some taxon or group of taxa. A geneticist may consider allelic diversity and heterozygosity…., whereas community ecologist is more interested in the variety and distribution of species and vegetation types.*"

Very often, the definition of biological diversity according to the Convention on Biological Diversity is cited. This document defines biodiversity as "*the variety and variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part*". This definition covers three fundamental components of diversity: genetic, species, and ecosystem diversity (Duelli, 1997 in Larsson 2001, Merganič and Šmelko 2004). However, also this widely accepted definition like many others fails to mention ecological processes, such as natural disturbances, and nutrient cycles, etc., that are crucial to maintaining biodiversity (Noss, 1990). The complexity of the understanding of the term biodiversity was well documented by Kaennel (1998).

Therefore, Noss (1990) suggested that for the assessment of the overall status of biodiversity more useful than a definition would be its characterisation that identifies its major components at several levels of organisation. Franklin et al. (1981) recognised three primary attributes of ecosystems: composition, structure, and function (in Noss, 1990). "*Composition has to do with the identity and variety of elements in a collection, and includes species lists and measures of species diversity and genetic diversity. Structure is the physical organization or pattern of a system, from habitat complexity as measured within communities….Function involves ecological and evolutionary processes, including gene flow, disturbances, and nutrient cycling*" (Noss, 1990). Commonly, compositional diversity was of interests and major concerns, while other (structural and functional) aspects received less attention (Franklin, 1988 in Noss, 1990). According to Larsson (2001), "*composition and structure determine and constitute the biodiversity of an area* (Noss, 1990), *and are essential to the productivity and for forest ecosystem sustainability*", while functional diversity is defined as "*the diversity of ecological functions performed by different species, and/or the diversity of species performing a given ecological function*" (Larsson 2001).

2.1.1. What scale / level is of our concern

All attributes of biodiversity can be monitored at multiple spatial scales. Noss (1990) recognised four hierarchical levels of organisations: genetic, species - population, ecosystem - community, and landscape. This multi-scaled concept of biodiversity has been realised and emphasised by a number of authors (Noss, 1990; Larsson, 2001; Humphrey and Watts, 2004; Ciancio and Nocentini, 2004; Estreguil et al., 2004, etc.). While applying this approach one should be aware of the fact that "*no single level of organization is fundamental, and different levels of resolution are appropriate for different questions*" (Noss, 1990). From an operational forestry point of view, three scales must be considered: single tree, stand and landscape (Larsson, 2001;Table 3). "*However, this categorisation can be unhelpful as it ignores the effect of ecological processes operating across scales*" (Hansson, 2001 in Humphrey and Watts, 2004).

Key factors of biodiversity are defined as factors that have a major influence on or directly reflect the variation in biodiversity. Key factors can be classified according to the different ecosystem components:

- Structural

- Compositional
- Functional

The following scale must be considered:

- National/regional scale (relevant for national overview and international reporting)
- Landscape scale (Forman, 1986: defined landscape as a heterogeneous land area composed of a cluster of interacting ecosystems that are repeated in similar form throughout. Landscape varies in size, down to a few km in diameters).
- Stand scale i.e. forest management unit, in principle defined by the silvicultural programme.

The list of key factors of European forest biodiversity was prepared by Larsson, 2001 (Table 3).

Key factors of forest biodiversity assessment at national scale	
Structural key factors	Total area of forest with respect to forest types
	Area of productive forest with respect to tree species and age
	Forest ownership
	Total area of forest with respect to legal status/utilization or protection
	Total area of old growth forest and forest left for free development
	Total area of forest with respect to afforestation/deforestation
Compositional key factors	Native species
	Non-native or not "site original" tree species
Key factors of forest biodiversity assessment at landscape level	
Structural key factors	Habitat composition
	Lakes and rivers
	Spatial continuity and connectivity of important habitats
	Fragmentation
	History of landscape use
Compositional key factors	Species with specific landscape-scale requirements
	Non- native or not "site original" tree species
Key factors of forest biodiversity assessment at stand scale	
Structural key factors	Tree species
	Stand size
	Stand edge/shape
	Forest history
	Habitat types
	Tree stand structural complexity
	Dead wood
	Litter
Compositional key factors	Species with specific stand type and scale requirements
	Biological soil condition

Table 3: List of key factors of European forest biodiversity (Larsson 2001)

Structural indicators derived from structural key factors are widely assessed in forest inventories. Therefore data availability is relatively good or can be collected at moderate costs. The methods to measure structural indicators range from national statistics, satellite observation, and other remote sensing techniques, to on-ground field observation.

The most commonly available data on landscape scale are on CORINE CLC habitat types, but this resource uses very broad forest categories and has limited resolution in relation to small patches of habitats.

Functional indicators have to be suggested as key factor of biodiversity at all scale. There are two main groups: natural disturbances (fire, wind and snow, biological disturbances) and anthropogenic influences (silviculture system, agriculture and grazing, pollution, other land/use).

Monitoring of changes in the state of forest biodiversity indicators has been optionally planned at 5 to 10 years period, which, from an ecological point of view, is optimal.

The geographical scopes, associated map scales and indicators types were hierarchically summarized and presented by Estreguil et al. (2004), Table 4:

Level	**Map scale**	**Types of indicators**
European (national aggregates)	1:500 000 1:1 000 000	Indicators for reporting and policy-making (headlines)
National	1:100 000 1:500 000	NFI, Statistics, National reporting,
Regional	1:25 000 1:100 000	Indicators for practical use in management
Local	1:25 000	Individual data

Table 4: List of different scope, map scale a indicators type (Estreguil et al. 2004)

Even if the scientific community considers essential a multiscaled approach in biodiversity monitoring to obtain consistent and meaningful results no operative monitoring systems based on such approach have been established yet on large areas. The relationships between results of forest biodiversity monitoring acquired at different scales are unclear as unclear is the temporal trends of biodiversity and the differences in such trends related to spatial scales of analysis. A large research effort is still needed in this area to have a clearer scenario and to be able to set up an operative forest biodiversity multiscale monitoring system.

Anyhow some indications may be given:

Relative monitoring vs. absolute monitoring: forest biodiversity is a complex concept. It cannot be measured as a single variable (such as forest growing stock), for this reason scientists prefer to use forest biodiversity indicators and the monitoring system have to be optimized in order to have reliable spatio-temporal trends of indicators, not of biodiversity itself. It is difficult to understand, without previous studies on large areas that are for the moment not available in Europe, which absolute values (*absolute monitoring*) of biodiversity indicators are related to "good" (high biodiversity) or "bad" (low biodiversity) conditions. For this reason it is much easier to give a clear interpretation of trends in time (*relative monitoring*) of values of biodiversity indicators.

Stratification: in order to be able to interpret the spatio-temporal trends of indicators it is essential to stratify values acquired in different ecological conditions. Without such an ecological-based stratification the interpretation of monitoring results is impossible.

Sensibility, precision and accuracy: the monitoring system should be able to register trends in values registered by the different indicators related to "real" changes in the overall biodiversity condition. Unfortunately we never exactly know the real biodiversity condition so the sensibility of the indicators is derived from general forest ecology rules. The indicators should be precise enabling the possibility to register even small spatio-temporal changes minimizing the error of the estimate/measure (maximizing the accuracy).

In this study we tried to optimize all the available resources but since the original project idea is based on the use of available already existing data we had to front some objective limitations.

The NFI data are not available with multitemporal series in all Europe. In this study for the moment we have been able to use multitemporal data just for Czech Republic and Sweden. For Italy the first NFI registered data just in an aggregated way so data at plot level are not available. In Germany and Switzerland because of internal limitations it was not possible, for the moment, to access to previous NFI. Even when they are available NFI multitemporal data soffer a number of limitations:

- Inconsistent definitions, it happens that forest variables change in time and this disable the comparability of temporal trends. A typical example is for the Italian NFI where the forest definition changed from the first to the second NFI.
- Use of non-permanent plots. Information acquired by NFI are typically used in the form of aggregated statistics for large areas for this reason in many NFIs just one part of the plots are permanently located on the ground. This condition makes difficult the elaboration of temporal trends at plot or at small area level.
- Time distribution of field measures. In those countries where a NFI permanent project exists in general the field measures are carried out every year in a subsample of the total number of the plots of the country. For this reason the temporal trends of these data are difficult to be calculated and compared with spatial data (forest maps and related information) that are instead typically acquired for large areas at the same time.

Regarding the problems related the comparison of data acquired in the project in different ecological conditions we decided to stratify all NFI plots and forest maps according to the European Forest Types system of nomenclature recently developed by EEA (2006). The project, a follow up of the previous BEAR project, is specifically developed for creating a nomenclature system to be used in reporting forest biodiversity indicators.

Regarding the selection of the spatial scale of forest maps here the problems are related mainly to the real availability of data. Maps are derived from remote sensing so the problem is which is the optimal geometric resolution for multitemporal landscape biodiversity program and which is the optimal resolution to enhance possible relationships with field measurements? Unfortunately a real evidence from experiments is not available yet. Anyhow low resolution data (pixel larger than 100 m) suffer of the limit due to the incorrect identification of forest areas. Spectral information in such pixels are in fact an average value of different land cover and for this reason the relationship with ground measures are expected quite low. On the other side very high resolution data (pixel smaller than 5 m) are operatively limited because large consistent multitemporal dataset are not available and cannot be therefore considered as an operational tool for monitoring systems. For these reasons spatial scales related to raster pixels with dimension between 10 and 100 meters can be considered potentially the most useful for multiscale and multitemporal forest biodiversity monitoring systems. In this study we selected two different spatial resolutions (25 m and 100 m) in order to evaluate the spatial dependency of multiscale biodiversity relationships and to experimentally test the implications due to the adoption of different spatial resolutions.

Regarding the availability of data in the selected study areas the multitemporal NFI data were available just in Sweden and Czech Republic, while multitemporal forest maps are available in all study areas (Table 3).

Country	Low resolution forest maps	High resolution forest maps	NFI
CH	1990	1990	2000
	2000	2000	
CZ1	1990	1993	1996
	2000	2003	2005
CZ2	1990	2000	1996
	2000		2005
DE	1990	2000	2002
	2000		
IT2		1936	2005
	1980	1954	
	1990	1992	
	2000	2005	
SE	1990	2000	1999
	2000	2005	2003

Table 5: overall situation regarding spatial and temporal characteristics of forest maps and NFI dataset available for the study areas.

On such a basis the project will be oriented both in understanding:

- the relationship between absolute biodiversity indicators measured in the field and both absolute values (one single year) and dynamic values (changes in time) of spatial pattern indicators measured on available forest maps at different resolutions in all study areas;
- the relationship between changes in time of selected biodiversity indicators and changes in time of spatial pattern indicators measured on available forest maps at different resolutions in those test areas where multitemporal NFI are available.

2.2. International projects and programmes devoted to biodiversity

The increasing biodiversity awareness has resulted in a number of activities of scientific community. Various national and international projects have dealt with the biodiversity issue. Below we briefly describe some of them.

2.2.1. (BioAssess) Biodiversity Assessment Tools

The BioAssess (*Biodiversity Assessment Tools*) project was the first project to use standardised protocols to measure several major elements of biodiversity across Europe (in eight countries and six biogeographical regions) to simultaneously develop methods for assessing biodiversity, or "*biodiversity assessment tools*", and to quantify the impact on biodiversity of land use change, a major driver of change in biodiversity in Europe and elsewhere (http://www.nbu.ac.uk/bioassess/).

"The main purpose of the BioAssess project was to develop biodiversity assessment tools for inland terrestrial ecosystems, comprising sets of indicators of biodiversity, to assess the impact of policies on changes in biodiversity in Europe. "Biodiversity assessment tools" may be defined as a set of indicators, which provides information on status and trends in biodiversity for a range of stakeholders. This approach to monitoring acknowledges that a single measure of biodiversity is unlikely to satisfy most stakeholder needs, particularly those interested in trends in biodiversity at the European level" (http://www.nbu.ac.uk/bioassess/).

In the frame of the BioAssess "under the Global Change, Climate and Biodiversity Key Action of the Energy Environment and Sustainable Development Programme, a method for rapid assessment of biodiversity was developed on a European level. Test sites in different biogeographical regions have been selected (Finland, Ireland, UK, Hungary, Switzerland, France, Spain and Portugal). Each European test site consisted of six test areas called land use units (LUU) representing a land use intensity gradient.

The land use units (LUU) in all European partner countries had each a size of 1 X 1 km and covered the same gradient from relatively natural forests to intensively managed agricultural areas.

In all LUU biologists sampled groups of plants and animals (birds, butterflies, soil macrofauna, collembola, carabids, plants, lichens) as indicator species for biodiversity (BioAssess report 2004). Parallel remote sensing images have been acquired covering all selected areas. Within remote sensing a methodology for the assessment of the landscapes and landscape structures was developed as well as diversity indices were calculated. In respect to the qualification of the remote sensing based landscape diversity indices for biodiversity assessment the indices calculated for the indicator species sampled on the ground and the values derived from remote sensing based indices were related to investigate the linkage between remote sensing and ground based methods" (Koch and Ivits, 2004).

2.2.2. BEAR (Biodiversiry Evaluation Tools for European forests)

"Bringing together 27 partners of 18 European countries, the BEAR-project aimed at identifying a common scheme of key factors of forest biodiversity, to identify and describe a set of Forest Types for Biodiversity Assessment (FTBAs) and to define lists of indicators of biodiversity across European Forest Types. Making use of the expertise in the group, the BEAR-project found one of it central tasks to cover a wide biogeographic area and viewing biodiversity across Europe at several hierachical scales" (BEAR Newsletter 3).

"The main achivements of the BEAR-project are:

• PRESENTATION OF A COMMON SCHEME OF KEY FACTORS OF BIODIVERSITY APPLICABLE TO EUROPEAN FORESTS.

Key factors affecting or determining biodiversity include abiotic, biotic and anthropogenic factors that directly or indirectly influence biodiversity and its major components.

• IDENTIFYING EUROPEAN-LEVEL FOREST TYPES FOR BIODIVERSITY ASSESSMENT FTBAS.

The relative importance of key factors vary between different European forests as do the factors themselves, e.g. the species composition. The BEAR experts recommend that the management of biodiversity is to be based upon specific Forest Types for Biodiversity Assessment (FTBAs) defined as forest types which are uniquely influenced by a set of key factors of forest biodiversity. FTBAs do not reflect the proportions of tree species only, but reflect the whole composition and characteristics of the forest ecosystem in accordance to the geological, climatical and other biogeographical conditions of the area where they appear naturally.

• INDICATORS OF FOREST BIODIVERSITY.

During the BEAR-project the experts have agreed on that it is premature to define priority lists of indicators for operational use. This view was proposed and accepted as the current EU position. However, the BEAR-project has presented a gross list of potential biodiversity indicators to assess each key factor of forest biodiversity.

• RECOMMENDATIONS FOR ELABORATING BIODIVERSITY EVALUATION TOOLS and establishing schemes of biodiversity indicators for assessment of forest biodiversity on a European level" (BEAR Newsletter 3).

2.2.3. ForestBiota (Forest Biodiversity Test Phase Assessments)

Under the ICP Forests Working Group on Biodiversity assessments the ForestBIOTA (Forest Biodiversity Test Phase Assessments) project was launched (ICP Forests, 2003).

ForestBIOTA was a joint action of 11 European countries that was carried out on 123 existing intensive monitoring (Level II) plots. It aimed at "the further development of forest condition monitoring activities by conducting a monitoring test phase under Art 6(2) of the Forest Focus regulation. Its objectives are:

1. the test wise development and implementation of additional assessments
2. correlative studies for compositional, structural and functional key factors of forest biodiversity based on existing Intensive Monitoring (Level II) plots.
3. recommendations for forest biodiversity indicators that can be applied in the context of existing national forest inventories (collaboration with ENFIN — European Forest Inventory Network)" (Haußmann and Fischer, 2004).

Specifically harmonised methods for forest biodiversity assessments have been proposed "by further development and test wise implementation of monitoring methods for 1) forest type classification, 2) stand structure assessments, 3) deadwood assessments, 4) extended grond vegetation surveys and 5) epiphytic lichen monitoring" (Stofer, 2006).

2.2.4. ALTER-Net (A Long-Term Biodiversity, Ecosystem and Research Network)

ALTER-Net is a five year project funded by the European Union's Framework VI programme, that began in April 2004. "It is integrating capacity across Europe to assess and forecast changes in biodiversity, structure, functions and dynamics of ecosystems and their services". The project involves 24 partner institutes from 17 European countries with the aim to build lasting integration of biodiversity research, monitoring and communication capacity. This is being achieved in a number of ways. "In 2005 ALTER-Net launched the International Press Centre for Biodiversity Research (IPCB), a regularly updated online source of news and press releases about international biodiversity research, serving journalists and other users". In 2006 and 2007, ALTER-Net ran summer schools aimed at equipping young researchers with the knowledge and skills to undertake integrated biodiversity research at a European level. Within the framework of ALTER-Net, two networks of sites are being developed: Long-Term Ecosystem Research sites (LTER) for European long-term terrestrial and freshwater biodiversity and ecosystem research, and Long-Term Socio-Ecological Research sites (LTSER), which could be used to determine the socio-economic implications of, and public attitudes to, biodiversity loss. Since the beginning of the project, a number of different reports have been published online dealing with various subjects related to biodiversity, e.g. its assessment, conservation, modeling and forecasting, but also different socio-economic and policy issues (www.alter-net.info).

2.2.5. SEBI 2010 (Streamlining European 2010 Biodiversity Indicators)

SEBI is joint pan-European activity with countries and other interested bodies to develop and implement biodiversity indicators for assessing, reporting on and communicating achievement of the 2010 target to halt biodiversity loss. The SEBI 2010 process consists of a coordination team and six expert groups. The coordination team is led by the European Environment Agency (and its European Topic Centre on Biological Diversity), ECNC (European Centre for Nature Conservation) and NEP-WCMC (World Conservation Monitoring Centre). The main tasks are to review, test, refine, document and help produce specific indicators in line with the 16 headline biodiversity indicators that have been agreed within the European Union (EC Biodiversity Communication 2006) and PEBLDS (Pan-European Biological and Landscape Diversity Strategy). The project was set up to coordinate activities in this field from national to pan-European level. The first completed output of the project is an initial set of indicators available at EU and pan-European levels was published (EEA Technical report 11/2007, (http://biodiversity-chm.eea.europa.eu). The set of indicators documented is not intended to be comprehensive. Some of the indicators directly track the impact the impact on a component biodiversity whereas others reflect threats to biodiversity, its sustainable use and integrity. The set as whole can be used to help assess the effect of various sectors and sectoral policies on biodiversity. The indicators represented 6 focal areas; indicators relevant to the frame of "Downscaling" project are in parentheses):

1. Status and trends of the components of biological diversity (included trends in extent of selected biomes, ecosystems and habitats and trends in the abundabnce and distribution of selected species
2. Threats to biodiversity
3. Ecosystem integrity and ecosystem goods and services (included connectivity/fragmentation of ecosystems)
4. Sustainable use (included MCPFe forest indicators: deadwood and growing stock, increment and fellings)
5. Status of access and benefits sharing
6. Status of resource transfer and use
7. Public opinion.

2.2.6. DIVERSITAS

"DIVERSITAS is an international, non-governmental programme with a dual mission:

- to promote an integrative biodiversity science, linking biological, ecological and social disciplines in an effort to produce socially relevant new knowledge; and
- to provide the scientific basis for the conservation and sustainable use of biodiversity.

DIVERSITAS achieves these goals by synthesizing existing scientific knowledge, identifying gaps and emerging issues, and promoting new research initiatives, while also building bridges across countries and disciplines. The Programme also investigates policy implications of biodiversity science, and communicates these to policy fora, including international conventions" (www.diversitas-international.org).

DIVERSITAS was established in 1991, with the goal of developing an international umbrella programme that would address the complex scientific questions posed by the loss of and change in global biodiversity. In 2001, the main task of the Programme became a development of an international framework for biodiversity research. At the end of 2002, the published Science Plan identified three interrelated areas for further development. Currently, four DIVERSITAS Core Projects are identified, while each of them covers an important aspect of biodiversity science:

- bioGENESIS aims to facilitate the development of new strategies and tools for documenting biodiversity, to understand the dynamics of diversification, and to make use of evolutionary biology to understand anthropogenic impacts;
- bioDISCOVERY focuses on developing a scientific framework to investigate the current extent of biodiversity, monitor its changes and predict its future changes;
- ecoSERVICES explores the link between biodiversity and the ecosystem functions and services that

support human well-being and seeks to determine human responses to changes in ecosystem services;

- bioSUSTAINABILITY concerns itself with the science-policy interface, looking for ways to support the conservation and sustainable use of biological resources (DIVERSITAS, 2007).

In addition, DIVERSITAS has identified four topics that merit investigation on all levels represented by its Core Projects, namely mountain, freshwater and agricultural ecosystems and the problem of invasive species. Based on these topics, four Cross-cutting Networks have been established: The Global Mountain Biodiversity Assessment (GMBA) and the Global Invasive Species Programme (GISP), agroBIODIVERSITY and freshwaterBIODIVERSITY.

Both DIVERSITAS Core Projects and Cross-cutting Networks get implemented by International Project Offices, that help to build links to existing research institutes and programmes (www.diversitas-international.org).

More information about these and other activities related to biodiversity can be found online on several web sites: e.g. the European Community Biodiversity Clearing House Mechanism (EC-CHM) site (http://biodiversity-chm.eea.europa.eu) managed by the European Environment Agency. This site contains "the Bioplatform RTD catalogue", which is a database about scientists, organisations and networks performing work in the area of biodiversity, and aiming at stimulating contacts between biodiversity scientists and end-users of research results

Another site full of up-to-date data is CORDIS (i.e. Community Research and Development Information Service) devoted to European research and development and the exploitation of the results of European research (http://cordis.europa.eu).

2.2.7. JRC activities

The FOREST Biodiversity activity of JRC focuses on developing and implementing two indicators:

- "Landscape level spatial pattern of forest cover" (MCPFE 4.7) - methods have been developed to derive spatially explicit data of forest spatial pattern over any geographical areas of interest. Forest spatial pattern maps have then been obtained over Europe at different spatial scales.
- 'Connectivity/fragmentation of ecosystems' (indicator under the theme 'Ecosystem integrity and ecosystem goods and services' of the Biodiversity Communication) with focus on forest ecosystems. Within the SEBI2010 technical reports 4 and 5 (EEA, 2009), this indicator is reported for natural/semi-natural lands and mainly for forest. Its implementation was achieved according to three methods developed (or amended) at the Joint Research Centre (Estreguil and Mouton, 2009). European-wide maps aggregated per province were provided for the change in forest connectivity, for forest fragmentation and for change in natural/semi-natural landscape types.

More information on the methods used and their implementation can be found in Estreguil and Mouton, 2009. European-wide maps related to trends in forest pattern, fragmentation and connectivity can be queried and viewed from the European Forest Data Centre JRC web site (http://forest.jrc.ec.europa.eu/efdac/). JRC activities and publications related to landscape level forest pattern and biodiversity can be search from http://forest.jrc.ec.europa.eu/forest-pattern.

2.3. Biodiversity assessment

Forest biodiversity pertains to the variety, abundance and spatial distribution of ecosystem attributes which belong to the following classification systems that characterise the (bio)diversity:

(1) Lévêque (1994) and Gaston (1996): genetic, taxonomic, and ecosystem level

(2) Whittaker (1971) three spatial types of diversity:

alpha diversity, which refers to ecosystem diversity

beta diversity, which refers to the change in diversity between ecosystem

gamma diversity, which refers to the overall diversity for different ecosystems within a region.

(3) Noss (1990): tree components: compositional, functional, which relates to ecological and evolutionary processes; and structural, which relates to physical organization of the pattern of elements.

Due to the complexity of biodiversity and of forest ecosystems, "complete assessments of biodiversity are not practically achievable" (Humphrey and Watts; 2004) because of "impossibility of monitoring all taxa"/features (Lindenmayer, 1999; Koch and Ivits, 2004). Therefore, "means to reduce complexity are necessary" (Christensen et al., 2004). "Hence the search for reliable indicators or short-cut measures of biodiversity" (Ferris and Humphrey, 1999; Jonsson and Jonsell, 1999; Noss, 1999; Simberloff, 1998 in Humphrey and Watts, 2004), while "it is most essential that any biodiversity assessment system is based on an enduring set of compositional, structural and functional characteristics" (Allen et al., 2003). In addition, "a complete long-term biodiversity strategy must take into account both interactions between the different geographical levels and the fact that different elements of biodiversity are dependent on different geographical scales, in different time perspectives" (Larsson, 2001).

2.3.1. Key factors

An interesting approach how to deal with the complexity of forest biodiversity has been applied in the BEAR project. Within the context of this project, key factors of forest biodiversity, i.e. factors that "have a major influence on or directly reflect the variation in biodiversity within European forests" (Larsson, 2001), were identified according to different ecosystem components (i.e. composition, structure, function) and at different geographical scales (national/regional, landscape, stand scale). The identification of key factors and classification of scales has resulted in an operational tool for complex biodiversity assessment at multiple spatial scales, that is also applicable to practical biodiversity management and can be used as a basis for forest policy (Larsson, 2001). This approach has been chosen because with the present knowledge it is possible to rather well identify the key factors, but their assessment through indicators needs further development and validation (Larsson, 2001). Hence, according to this author, it is better "to allow semi-qualitative assessments and a range of indicators and methods than omitting an important key factor" (Larsson, 2001). Nevertheless, from a long-term perspective, a standardised system of biodiversity indicators is needed.

2.3.2. Indicators

"The principle behind the indicator concept is that the characteristics of an easily measured feature such as an organism or aspect of forest structure can be used as an index of attributes (eg. diversity) that are too difficult or expensive to measure for other species and communities" (Williams and Gaston 1998; Landres et al. 1988 in Humphrey and Watts, 2004). Hence, "an indicator should constitute a good surrogate for biodiversity value" (Rautjärvi et al., 2005; Stokland et al., 2004).

"Ideally, an indicator should be (1) sufficiently sensitive to provide an early warning of change; (2) distributed over a broad geographical are, or otherwise widely applicable; (3) capable of providing a continuous assessment over a wide range of stress; (4) relatively independent of sample size; (5) easy and cost-effective to measure, collect, assay, and/or calculate; (6) able to differentiate between natural cycles or trends and those induced by anthropogenic stress; and (7) relevant to ecologically significant phenomena" (Noss, 1990).

0Similarly Ferris and Humphrey (1999) defined that the indicators must: "be readily quantifiable, easily assessed in the field, repeatable and subject to minimal observer bias, cost effective, and ecologically meaningful (i.e. have a close association with, and identification of, the conditions and responses of other species)".

According to other authors, a good indicator should possess two main features: (1) it should be easy to inventory, (2) it should be strongly correlated with other species it is intended to represent (Ranius, 2002, Humphrey and Watts, 2004) and "other entities for which it is hypothesized to be indicative" (Stokland et al., 2004).

Of course, there is no single perfect indicator (Rainio and Niemela, 2003) that will meet all the above stated requirements. Hence, a set of complementary indicators is needed (Noss, 1990).

2.3.3. Categorisation of indicators

A variety of indicators and indicator systems have been proposed "both at the EU level (MCPFE, 2002) and within individual countries (e.g. Ministry of Agriculture and Fisheries, 1994; Eeronbeimo et al., 1997)" (Humphrey and Watts, 2004). "The nature of the indicators depends on who is using them and for what purpose" (Humphrey and Watts, 2004).

Larsson (2001) has proposed a broad typology of indicators for assessment of biodiversity in European forests at a range of spatial scale. Estreguil et al. (2004) stated that there are three relevant sets of indicators for reporting biodiversity at European level: (1) "the improved Pan-European Indicators for Sustainable Forest Management" from the Ministerial Conference on the Protection of Forests in Europe (MCPFE), (2) the key factors of forest biodiversity defined in the BEAR (Biodiversity Evaluation Tools for European Forests) Project, and (3) Indicators core set for Biodiversity and Nature Protection and for Terrestrial environment of the European Environmental Agency (EEA).

Christensen et al., 2004 divided indicators into (1) structural indicators, and (2) indicator species, while Noss, 1990, Larsson, 2001, Bradshaw and Møller, 2004 distinguish (1) structural, (2) compositional, and (3) functional indicators based on the three aspects of biodiversity as defined by Franklin et al. (1981 in Noss, 1990).

2.3.4. Compositional indicators

"Compositional diversity encompasses the identity and variety of elements in a collection or classification systems, e.g. forest types and succession stages, species lists, the number of genes and allele variation within species" (Stokland et al., 2003).

2.3.4.1. Indicator species

Species-based indicators represent a direct approach of biodiversity assessment (Christensen et al., 2004). That is probably the main reason why this method has often been used in biodiversity studies, although different species from different groups have been surveyed depending on the goal of the work. For example, for forest conservation purposes, bryophytes have been identified as useful indicators (Sim-Sim et al., 2004). Christensen et al. (2004) documented that "fungal indicator species can add valuable information relevant for prioritisation in forest conservation".

On the basis a thorough analysis of the existing literature, Thormann (2006) stated that lichens are valuable indicators of forest health, but they have also been found as indicators of old-growth forests (Campbell and Freeden, 2004; Motiejunaite et al., 2004; Uliczka, 2003).

Arthropods have been suggested as indicators of sustainable forest management, although their use is problematic due to the difficulties in accurate species-level identification (Langor and Spence, 2006). In fact, although this group encompasses the largest number of species in the world, only a few groups are relatively well-known, e.g. epigaeic carabid and staphylinid beetles and spiders, saproxylic beetles, butterflies and larger night flying moths (Langor and Spence, 2006), while many species are still unknown. For example, of the insects as the largest group of arthropods, 50-90% of the existing species have still to be discovered (Thomas, 2005).

Carabid beetles, as the best studied group of arthropods (Langor and Spence, 2006), "are frequently used to indicate habitat alternation" (Rainio and Niemela, 2003). The beetle Osmoderma eremita is a useful indicator of stands with a rich beetle fauna in tree hollows, because it is easy to find and identify (Ranius, 2002). According to Thomas (2005), "butterflies are often the only group (from insects) for which accurate measures of change can be obtained". Based on his study the author concluded that "butterflies represent adequate indicators of change for many terrestrial insect groups", as their extinction rates in Britain were found similar to those in a range of other insect groups over 100 years once recording bias is accounted for". Nevertheless, the same author recommended that "similar schemes be extended to other popular groups, especially dragonflies, bumblebees, hoverflies and ants" (Thomas, 2005).

In European forests, invertebrates together with plants and fungi have been proposed as indicator species for assessing conservation value at the stand scale (Roberge and Angelstam, 2006). At larger spatial scales, wide-ranging vertebrates, such as birds, can be used as indicators (Roberge and Angelstam, 2006; Casanova and Memoli, 2004), because they are abundant, widely distributed, and also because of "a close connection between the overall biodiversity of an environment and the complexity of bird populations" (Casanova and Memoli, 2004). Hence, birds are "particularly useful indicators of the relations between animal communities and vegetation in forest environments" (Casanova and Memoli, 2004). The advantage of using birds as indicators is that "there are extensive databases on birds, they are easy to observe and they can be identified from their vocalizations" (Hoeven and Iongh, 1999). From the many bird species, woodpeckers have been detected as good indicators of forest diversity (Virkkala, 2006; Nilsson et al., 2001; Roberge and Angelstam, 2006).

Since mammals occur in various types of environment, their use as indicators of biodiversity has been favoured (Casanova and Memoli, 2004). The study of Azman (2001) showed that small-mammal population could be regarded as an indicator group for assessing impact of logging on a forest ecosystem. According to Casanova and Memoli (2004), from small mammals the best indicators of ecosystem functionality are carnivores, while Insectivores are sensitive indicators of the completeness of the alimentary chain, and rodents are useful in monitoring pollution. From the ungulates, "the roe deer is a good indicator of the functionality of forest systems" (Casanova and Memoli, 2004).

"The well-investigated vascular plants, which comprise approximately 300 000 species, are comparatively well suited as an indicator group in terrestrial habitats. Several examples show the good correlation of their diversity with overall diversity" (Barthlott et al., 1998) or diversity of a particular group. For example, Schmit et al. (2005) presented that "tree species richness can be used to predict macrofungal species richness". Within forest restoration processes, short-lived tree species (European mountain ash (Sorbus aucuparia L.), European white birch (Betula pendula Roth), Downy birch (B. pubescens Ehrh.), and Glossy buckthorn (Frangula alnus P. Mill.)) can serve as indicators of plant diversity (Kreyer and Zerbe, 2006).

When examining species indicators, works that compare the performance of different taxa are particularly of high value. For example, Juutinen and Monkkonen (2004) studied beetles, birds, vascular plants, wood-inhabiting fungi, and a specified subgroup of assumed indicator species. Kati and Papaioannou (2001), and Kati et al. (2004) examined woody plants, aquatic and terrestrial herpetofauna, small terrestrial birds, orchids, and Orthoptera. All mentioned authors found that woody plants seem to be the best biodiversity indicators.

In contrast to taxonomical hierarchy, Noss (1999) identified several different groups of indicator species with regard to their requirements on area, dispersal, resources, ecological processes etc. In literature the concept of keystone species, umbrella species (e.g. Bollmann et al., 2004; Suchant and Baritz, 2001; Suchant, 2001; Angelstam et al., 2000; Ranius, 2002), focal species (Lambeck, 1997), Red List species (Schmidt et al., 2006), threatened species (Martikainen and Kouki, 2003), endemic species (Cassagne et al., 2006) are often used.

Keystone species are defined as ecologically pivotal species whose impact on a community or ecosystem is large, and disproportionately large for their abundance (Noss, 1999), and "upon which a large part of the community depends" (Noss, 1991). Consequently, "loss of keystone species produces cascade effects, i.e. the loss of other species or the disruption of processes" (Larsson, 2001). "An umbrella species is a species which is so demanding that the protection of this species will automatically save many others" (Ranius, 2002).

Considering authenticity of community, Larsson (2001) proposed a category of alien (exotic, non-indigenous, introduced) species. These can be mainly found in disturbance corridors, from which they are spread to adjacent undisturbed habitats. "In general, only a few introduced species survive in their new environment and eventually get naturalised without creating any problems" (EEA, 2006). However, successful exotic species "may become a threat to indigenous species or to a whole ecosystem by disrupting the food chain or altering the habitat" (EEA, 2006). Usually, the species biodiversity connected to the alien species is lower, "because of the time needed for example for invertebrates to adjust to the new species" (Larsson, 2001).

Pros and contras of indicator species

According to Lindenmayer (1999), "the concept of indicator species can make an important contribution to biodiversity conservation because of the impossibility of monitoring all taxa in species-rich forest environments". Despite the fact that "species have high potential, as such indicators are applicable to all ecosystems" (Heer et al., 2004), this approach is not universally accepted (Williams and Gaston, 1998 in Humphrey and Watts, 2004), because "indicator function is largely hypothetical" (Gallego-Castillo and Finegan, 2004). "There is no implication of functional linkage amongst species groups, as the concept is essentially empirical" (Humphrey and Watts, 2004). For example, Bollmann et al. (2004) revealed that capercaillie (Tetrao urogallus), which is often implicitly attributed indicator function, is a good surrogate for red-listed mountain forest bird species, but its potential to indicate high species richness of beetles is limited. This example documents that "the conservation of one targeted group does not guarantee the conservation of other groups as well" (Kati and Papaioannou, 2001). Hence, before selecting the indicator species there is a need to establish the link, and to test and validate the relationships between an indicator and the elements it is intended to indicate (Stokland et al., 2004; Humphrey and Watts, 2004; Lindenmayer et al., 2000; Lindenmayer, 1999). While amongst some species groups good correlations have been found (Sætersdal et al., 2003 in Humphrey and Watts, 2004), in others they have not been proven (Johnson and Jonsell, 1999 in Humphrey and Watts, 2004). For example, Sverdrup-Thygeson (2001) found no significant correlations between wood-rooting fungus Fomitopsis pinicola and saproxylic beetles. "Thus, species richness of one single species group is unlikely to be a good indicator for total biodiversity" (Berglund and Jonsson, 2001). Due to this, "a single indicator group is not sufficient for decision-making processes in conservation" (Medellin et al., 2000). Therefore, a multi-taxa approach is preferred (Kotze and Samways, 1999), or otherwise "the use of indicator species likely results in a loss of species" (e.g. Juutinen and Monkkonen, 2004). Nevertheless, "their use appears promising as they alleviate communication among stakeholders" (Angelstam et al., 2000) and enables the participation of public in monitoring, although in such cases it is recommended to use "only few easily communicated and conspicuous species, e.g. vertebrates" (Uliczka, 2003), or bird species (Nally et al., 2004). The presence of indicator species on a particular site can also assist decision-makers and managers in e.g. assessing an area's conservation value (Uliczka, 2003; Medellin et al., 2000) "particularly if those species are at high risk of extinction or are considered ecologically, economically, or socially important" (Noss, 1999).

Information about indicator species are summarized in Table 6.

Species / Group of species	Pros	Contras
Fungi	ubiquitous indicator for assessing conservation value	cryptic and ephemeral little information about fungal diversity
Plants	many are readily observable, easy to indetify its presence indicates appropriate habitat conditions for other species indicator species for assessing conservation value at the stand scale	some may not be attractive to public as a species of concern
Vascular plants	comprise approx. 300 000 species good correlation of their diversity with overall diversity or diversity of a particular group woody plants seem to be the best biodiversity indicators	
Arthropods	the largest number of species in the world indicators of sustainable forest management	difficulties in accurate species-level identification only a few groups are relatively well-known (e.g. beetles, spiders, butterflies)
Beetles	well-known	Finding threatened beetles requires very large sample sizes
Carabid beetles	the best studied group of arthropods indicate habitat alternation	incomplete crucial understanding of their relationship with other species
Beetle *Osmoderma eremita*	easy to find and identify useful indicator of stands with a rich beetle fauna in tree hollows umbrella species for the endangered beetle fauna in tree hollows	some beetles in tree hollows are more sensitive to habitat fragmentation than O. eremita, and may go extinct if only O. eremita is taken into consideration.
Insects	the largest group of arthropods	50-90% of the existing species have still to be discovered poor baseline knowledge most attempts to generalize involve large extrapolations from a few well-studied taxa
Butterflies	well-known and easily monitored thanks to their size and beauty adequate indicators of change for many terrestrial insect groups the only group (from insects) for which accurate measures of change can be obtained	
Amphibians, Reptiles	many require healthy environment and are sensitive to disturbances	some are difficult to monitor

Birds	abundant, widely distributed, well known and familiar species easy to observe, can be identified from their vocalizations extensive databases on birds close connection between the overall biodiversity of an environment and the complexity of bird populations because of their mobility and large territory useful indicators of the relations between animal communities and vegetation in forest environments	some are migratory species some have been able to adapt to habitat loss and urban environment, some use built environments as its main nesting habitat
Capercaillie *Tetrao urogallus*	an umbrella function for a rich mountain forest community **i**ndicator for close-to-nature and structure-rich mixed mountain forests good surrogate for red-listed mountain forest bird species	limited potential to indicate high species richness of beetles
Mammals	Easily recognizable occur in various types of environment adapt themselves ethologically and physiologically to changes in the ecosystem around them, and hence, they are reliable indicators of the quality of forest habitats	some have adapted to urbanised environment (fox) feared by the general public and may not get support for an urban area (bear). some are not often seen since they are nocturnal (bat) or living underground (vole)
Small mammals	indicator group for assessing impact of logging on a forest ecosystem carnivores are best indicators of ecosystem functionality Insectivores are sensitive indicators of the completeness of the alimentary chain rodents are useful in monitoring pollution	Their populations fluctuate widely from year to year with no apparent periodicity (e.g. vole)
Weasel family *Mustelidae*	indicate the degree of naturalness	some have adapted to urbanised environment
Ungulates	roe deer is a good indicator of the functionality of forest systems	

Table 6: Candidate indicator species.

2.3.4.2. Forest types

Indicator species represent compositional indicators at stand scale. At higher level of organization, forest types are compositional indicators (Estreguil et al., 2004). They represent a very important set of habitat factors (Stokland et al., 2003).

Corona et al. (2004) cited the following definition of a forest type by Canadian Forest Service (1995): "a forest type is a category of forest defined by its composition, and/or site factors (locality), as categorized by each country in a system suitable to its situation". "Certain groups of tree species tend to co-occur at stand scale and have formed the basis for phytosociological classifications and national classifications of stand types (Peterken, 1981; Påhlsson, 1994)" (in Bradshaw and Møller, 2004). At the European scale, several hundred to thousands of such stand types could be recognized (Bradshaw and Møller, 2004). For example, "Bohn et al. (2000) presented a map of 699 potential European vegetation types" (Bradshaw and Møller, 2004). After a comprehensive inventory of pan-European natural, semi-natural and anthropogenic habitats the European Nature Information System (EUNIS) (Barbati and Marchetti, 2004) identified 377 forest types (Bradshaw and Møller, 2004).

However, such a high number is difficult to monitor and map. Therefore, a system of higher order forest types that reflects broad-scale variation was required for biodiversity assessment (Bradshaw and Møller, 2004). In the EU Habitats Directive (Annex 1, Council Directive 92/43/EEC) 51 forest types are selected (Bradshaw and Møller, 2004) to be important for biodiversity conservation and hence, to be protected under Natura 2000 network (Barbati and Marchetti, 2004). "The BEAR project (Biodiversity Evaluation Tools for European Forests) proposed 33 forest types for biodiversity assessment (FTBAs). The classification system attempted to be scale independent and applicable at regional, landscape and stand scales" (Bradshaw and Møller, 2004). The FTBAs are a heterogeneous mixture of actual and potential forest types (Barbati and Marchetti, 2004), and include also the types with a significant biodiversity value that are purely of cultural origin (hedgerow, coppice) (Bradshaw and Møller, 2004). Based on this system, Barbati and Marchetti (2004), and Bradshaw and Møller (2004) proposed a simpler qualitative classification, which comprises 14 European forest types (Table 7):

Categories	**Types**
1. Boreal forest	Spruce and spruce-birch boreal forest Pine and pine-birch boreal forest
2. Hemiboreal forest and nemoral coniferous and mixed broadleaved-coniferous forest	Hemiboreal forest Nemoral scots pine forest Nemoral black pine forest Mixed scots pine-birch forest Mixed scots pine-pedunculate oak forest
3. Alpine coniferous forest	Subalpine larch-arolla pine and dwarf pine forest Subalpine and montane spruce and montane mixed spruce-silver fior forest Alpine scots pine and black pine forest
4. Acidophilous oak and oak-birch forest	Acidophilous oakwood Oak-birch forest
5. Mesophytic decidous forest	Pedunculate oak-hornbeam forest Sessile oak-hornbeam forest Ashwood and oak-ash forest Maple-oak forest Lime-oak forest Maple-lime forest Lime forest Ravine and slope forest Other mesophytic decidous forests
6. Beech forest	Lowland beech forest of southern Scandinavia and north central Europe Atlantic and subatlantic lowland beech forest Subatlantic submontane beech forest Central European submonatne beech forest Carpathian submontane beech forest Illyrian submontane beech forest Moesian submontane beech forest

7. Montane beech forest	South western European montane beech forest (Cantabrians, Pyrenees, central Massif, south western Alps) Central European montane beech forest Apennine-Corsican montane beech forest Illyrian montane beech forest Carpathian montane beech forest Moesian montane beech forest Crimean montane beech forest Oriental beech and hornbeam-oriental beech forest
8. Thermophilous deciduous forest	Downy oak forest Turkey oak, Hungarian oak and Sessile oak forest Pyrenean oak forest Portuguese oak and Mirbeck’s oak Iberian forest Macedonian oak forest Valonia oak forest Chestnut forest Other thermophilous deciduous forests
9. Broadleaved evergreen forest	Mediterranean evergreen oak forest Olive-carob forest Palm groves Macaronesian laurisilva Other sclerophlyllous forests
10. Coniferous forests of the Mediterranean, Anatolian and Macaronesian regions	Mediterranean pine forest Mediterranean and Anatolian black pine forest Canarian pine forest Mediterranean and Anatolian scots pine forest Alti-Mediterranean pine forest Mediterranean and Anatolian fir forest Juniper forest Cypress forest Cedar forest Tetraclinis articulata stands Mediterranean yew stands
11. Mire and swamp forest	Conifer dominated or mixed mire forest Alder swamp forest Birch swamp forest Pedunculate oak swamp forest Aspen swamp forest
12. Floodplain forest	Riparian forest Fluvial forest Mediterranean and Macaronesian riparian forest
13. Non riverine alder, birch, or aspen forest	Alder forest Italian alder forest Boreal birch forest Southern boreal birch forest Aspen forest
14. Plantations and self sown exotic forest	Plantations of site-native species Plantations of not-site-native species and self-sown exotic forest

Table 7: European forest types (EEA, 2006).

"This essentially qualitative approach to forest type classification has the advantage that it takes into account existing ecological knowledge and highlights particular communities such as swamp forests that are not widespread but have a high biodiversity value" (Bradshaw and Møller, 2004).

On the contrary, the quantitative approach to classification of forest types brings the advantages of objectivity and repeatability (Norddahl Kirsch and Bradshaw, 2004). Norddahl Kirsch and Bradshaw (2004) analyzed data gathered within NFIs and ICP Forest Level 1 data, and identified 17 and 16 forest types, respectively, with regard to actual tree species abundance. This study showed that "the quantitative approach is considerably influenced by plantations of limited biodiversity and has difficulty resolving rare forest types of high diversity (e.g. floodplain forests)". Therefore, the authors suggest combining approaches if European forest biodiversity is to be faithfully described.

A comprehensive review of a scheme suggested by Barbati and Marchetti (2004) has resulted into a European Forest Types classification proposed for MCPFE reporting by Barbati et al. (2006, 2007). "The process of revision has been based on a review of descriptions of actual and potential forest vegetation of Europe (Ozenda, 1994; Bohn et al., 2000) or of European forest regions (e.g. Mayer, 1984; Nordiska Ministerrådet, 1984; Ellenberg, 1996; Esseen et al., 1997; Quézel & Médail, 2003). The revision has been targeted to the following issues:

(i) to ensure the European Forest Types being representative and comprehensive of the variety of forest conditions at pan-European level;

(ii) to ensure the criteria adopted to separate forest types being consistent with the purposes of MCPFE reporting" (Barbati et al., 2007).

The proposed classification system is hierarchical and is structured into 14 level I classes (Categories) and 76 level II classes (Types). The hierarchy follows the principle of increasing similarity in the natural conditions and level of anthropogenic modification. "The category level is conceived to identify and reflect significant breaking points in the continuum of natural and anthropogenic factors affecting the state of European forests, as assessed by MCPFE indicators". Types further describe the variety and the character of forest communities within each category in term of tree species composition, structural and floristic features (Barbati et al., 2007).

Regardless of the classification of forest types used in the biodiversity assessment, the benefit of forest typology is that forest types "distinguish management scenarios which are significantly different as regards the targets of biodiversity conservation, that is the maintenance of processes and factors that maintain, generate or directly reflect the variation of forest biodiversity in the forest management unit (Barbati et al., 1999). Forest typology plays an important role making easier the exchange of information among professionals and researchers, due to the language standardization, and possible the comparison between experiences in order to make the better choices regarding forest planning and management prescriptions" (Corona et al., 2004). Forest types also enable comparison of ecologically similar forests, and are meaningful units for formulating policies and management regimes (Barbati et al., 2007). The maps of the forest types are powerful tools, which can be used to better understand spatial distribution of vegetation diversity (Rego et al., 2004). They could also "give indication about where to intervene for re-establishing a more "natural" landscape biodiversity" (Corona et al., 2004).

2.3.5. Structural indicators

"Structural diversity refer to the physical organization or pattern of a system, including the spatial patchwork of different physical conditions in a landscape, habitat mosaics, species assemblages of different plant and animal communities, and genetic composition of subpopulations" (Stokland et al., 2003).

“Structural indicators used to describe the conditions for forest biodiversity include vertical structure, age class distribution and the amount of dead wood” (Christensen et al., 2004). They represent an indirect approach “as they show, typically on a rather gross scale, how the house is built, but give no information on whether the inhabitants have moved in” (Christensen et al., 2004).

2.3.5.1. Deadwood

“Dead and dying wood plays a key role in the functioning and productivity of forest ecosystems‟ (Humphrey et al., 2004). “Functionally, it represents an important component of the forest carbon pool” (Stokland et al., 2004). However, “it is not only a key factor in the nutrient cycle (Harmon et al., 1986) but also the habitat for many animals, plants and fungi (Similä et al., 2003; Bissonette and Sherbune, 1993; Sippola and Renvall, 1999; Ferris et al., 2000)” (in Montes et al., 2004), particularly “for small vertebrates, cavity-nesting birds, and a host of lichens, bryophytes, polypores and other saproxylic fungi and invertebrates (Samuelsson et al., 1994; Esseen et al., 1997; Butler et al., 2001)” (in Humphrey et al. 2004). “In Scandinavia, it has been estimated that 6000 - 7000 species depend upon dead wood. This corresponds to about 25% of all forest species in the region” (Stokland et al., 2004). Hence, deadwood is regarded as “a key factor of biodiversity in the sense of species richness” (Schuck et al., 2004; Ferris and Humphrey, 1999) and as “a key feature for the preservation of many threatened species” (Ranius et al., 2003). It also acts as “a surrogate for decomposition processes and habitat availability (Ferris and Humphrey 1999)” (in Hahn and Christensen, 2004). In addition, “certain aspects of CWD are well known characteristics of old-growth forests (Siitonen et al., 2000)” (in Hahn and Christensen 2004).

“Recognition of the ecological importance of decaying wood has led to the incorporation of quantitative measures of deadwood in national forest inventories (e.g. Fridman and Walheim, 2000) and as biodiversity indicators for use in monitoring programmes at the European level (MCPFE, 2002; Kristensen, 2003). The Ministerial Conference on the Protection of Forest in Europe (MCPFE) includes deadwood as one of 9 Pan-European sustainability indicators; the European Environment Agency (EEA) includes deadwood as one of its 15 core indicators of biodiversity (Kristensen, 2003)” (in Humphrey et al., 2004).

In USA, deadwood or “down woody material is an FIA (Forest Inventory and Analysis program of the USDA Forest Service) indicator that provides estimates of forest structural diversity, forest area fuel loadings, and national carbon sources” (Woodall and Williams, 2005).

“In order to develop proper dead wood biodiversity indicators it is crucial to understand which qualities of dead wood are important to the wood-inhabiting species” (Stokland et al., 2004). Several studies have pointed out that the mentioned roles of deadwood depend not only on its presence, but also on its amount that is accumulated in the forest ecosystem (Butler and Schlaepfer, 2004). This feature has been accounted for in the MCPFE and BEAR deadwood indicators (Stokland et al., 2004). For the proper development and application of deadwood as an indicator, volume or biomass estimates from natural forests are taken as a reference (Hahn and Christensen, 2004; Humphrey et al., 2004). “However, the knowledge on ‛natural‟ amounts of dead wood in European forests is fragmented with some forest types being intensively studied whereas others are sparsely researched” (Hahn and Christensen, 2004). Hahn and Christensen (2004) identified “the lack of data from Southem Europe, which means that guidelines are only for north and central European forest types”. As these authors pointed out, “forest type has major influence on dead wood volume in forest reserves, with a gradient from low dead wood accumulation in northern boreal forests to high levels in central-European mixed forest types” (Hahn and Christensen, 2004). According to Humphrey et al. (2004) “coarse woody debris (logs and snags) is an important indicator of biodiversity in conifer - dominated forests in the Atlantic and Boreal biogeographical zones, but is less applicable to Mediterranean forests and wood pasture systems”. Although Travaglini et al. (2007) did not detect any significant differences in total deadwood volume among forest types, their analysis also showed the highest values of deadwood volume in central Europe, while the Mediterranean forests contain relatively little deadwood. “The relation between dead wood volume and forest type is however more complex, as different forest types are characterised by different species composition, site productivity, climate, soils and disturbance regimes. Generally, site productivity in combination with a decomposition rate determines the long-term average dead wood supply, whereas the regional or local disturbance patterns cause temporal pulses of dead wood input to the stand (Siitonen, 2001)" (Hahn and Christensen, 2004).

Stokland et al. (2004) presented five attributes of deadwood important to wood-inhabiting species: (1) type of deadwood, (2) tree species, (3) stage of decay, (4) dimension, (5) landscape patterns.

There exist different classifications of deadwood types: (i) standing vs. lying dead wood, (ii) coarse woody debris (CWD) vs. fine woody debris (FWD), (iii) snag, log, fallen branch, stump; that are interconnected. For example, standing dead wood are snags or stumps, which could belong either to CWD or FWD. Presently, the official indicators (MCPFE and BEAR) distinguish only between standing and lying deadwood. "Standing versus lying dead trees represent quite different habitats for many species. Some organism groups, like birds and lichens are almost exclusively associated to standing dead trees, whereas others, like fungi and mosses primarily utilise lying dead wood" (Stokland et al., 2004).

However, as Stokland et al. (2004) found, diameter of dead trees is "the quality that most species respond to". In the studies dealing with deadwood it is customary to subdivide it into fine and coarse woody debris. "The minimum size considered coarse debris varies from 2.5 cm in diameter (Harmon, 1986) to 10 cm in diameter" (Spies and Franklin, 1988 in Montes et al., 2004). "Harmon and Sexton (1996) identified the 10 cm limit as crucial for wood decomposition rate. Below this limit, the decomposition rate increased exponentially with decreasing diameter, and above the limit it decreased slightly with increasing diameter" (Stokland et al., 2004). Hence, "coarse woody debris refers to dead wood, such as logs or branches on the ground, stumps and snags or dead standing trees, which go through a complex decomposition process" (Montes et al., 2004).

The identification of tree species, or at least the distinction between coniferous and broadleaved wood is strongly recommended as different species are associated to these groups (Stokland et al., 2004). Similarly, "the stage of decay is a very important quality for predicting the associated species composition" (Stokland et al., 2004). Veerkamp (2003) found that "the decaying stage of dead wood was the most important factor influencing the occurrence of decay fungi".

"Different dead wood qualities are not evenly distributed in the forest landscape. The variation is caused by landscape properties such as topography, soil conditions, productivity" (Stokland et al., 2004). The disturbance factors causing decay, death, and the creation of deadwood in natural forests (drought, storm, fungal pathogens, insect disease, fire, mammals, natural thinnings) "vary in scale and intensity leading to a patchy distribution of deadwood at the stand and landscape scales with greater accumulations near canopy gaps and in old - growth stands (Humphrey et al., 2002; Sippola et al., 1998 in Humphrey et al., 2004)".

"A comprehensive dead wood inventory should include all forms of woody debris including lying dead trunks (logs) and large branches, standing dead trees (snags), and ideally also dead parts of still living trees" (Stokland et al., 2004). Complete dead wood inventories of dead wood were initiated in the National Forest Inventories (NFI) in Finland, Norway and Sweden during the 1990s. However, "due to the great variability within stands and across the landscape, field recording of deadwood is labor-intensive and expensive, if adequate sample sizes have to be ensured" (Butler and Schlaepfer, 2004b). Therefore, Butler and Schlaepfer (2004b) presented a new method enabling efficient mapping and quantification of large snags by coupling color infrared aerial photographs and a geographic information system (GIS).

Factors influencing deadwood are summarized in following Table 8. Deadwood attributes importatant to biodiversity are presented in Table 9.

Factor	**Descritpion**
Location	Biogeographic region (European scale) Forest type
Climate	Temperature Humidity O_2 a CO_2 concentration
Soil	soil type
Topography	slope characteristics (e.g., slope aspect, position, and steepness).
Site productivity	
Species composition	
Disturbance	abiotic: drought, storm, wind, fire, slope failure (erosion, landslide), abiotic agents (acid rain) biotic: mammals, fungi, insects, disease (parasitic plants), natural thinning (suppression and competition), senescence
Human interventions	Logging

Table 8: Factors influencing deadwood attributes.

Attribute	**Description and Classification**
Amount	in m^3/ha or in % of living volume
Type of dead wood	(i) Standing vs. lying dead wood (ii) coarse vs. fine woody debris (iii) snag, log, fallen branch, stump
Tree species	(i) species list (ii) coniferous vs. broadleaved
Dimension	diameter, length
Decay stage	defined by wood texture, shape, portion on ground, presence of twigs and bark, amount of wood fragmentation different classification systems with min. 3 classes from recently dead to almost decomposed
Decay rate	decomposition speed generally expressed through a constant *k* which indicates the percent mass, volume or density loss over time
Mortality type	(i) natural vs. management (ii) dry snag, mechanically broken, up-rooted, broken by rot, cut by beaver
Landscape pattern	spatial distribution e.g. scattered, clumped

Table 9: Deadwood attributes important to biodiversity.

2.3.5.2. Forest fragmentation/connectivity (landscape level)

"Landscape patterns represent the core of structural ecosystem diversity" (Stokland et al., 2003) "Structural indicators related to forest spatial pattern refer to the assessment of forest connectivity, forest fragmentation, forest isolation, edge/interior forest" (Estreguil et al., 2004), while these patterns and their distributions have important implications for biodiversity conservation (Loyn and McAlpine, 2001).

Landscape fragmentation has been identified as one of the fundamental reasons for the biodiversity loss (Roy and Sanjay-Tomar, 2000). "Habitat fragmentation is the breaking up of a large portion of a forested land into several smaller portions. The forest fragmentation can be explained in two phases. The first phase results in the reduction of total amount of forest areas whereas the second phase leads to the isolation of smaller patches. (Laxmi-Goparaju et al., 2005)

"Forest fragmentation is a critical aspect of the extent and distribution of ecological systems. Many forest species are adapted to either edge or interior habitats. When the degree or patterns of fragmentation change, it can affect habitat quality for the majority of mammal, reptile, bird, and amphibian species found in forest habitats (Fahrig, 2003 in NCEA, 2007)". Due to this, "international biodiversity agreements require assessing indicators of connectivity and fragmentation in forested ecosystems (e.g. MPLO, 2000; Malahide, 2004 in Vogt et al., 2007)".

There exists a number of works dealing with forest fragmentation and its effect on biodiversity (Riitters et al., 2002; Behera et al., 2005; Roy et al., 2005; Laxmi-Goparaju et al., 2005; etc.). However, "currently, there are few tested and proven indicators for assessing and monitoring the forest fragmentation process" (Loyn and McAlpine, 2001), although the importance of landscape patterns as indicators have been recognized also in the MCPFE and BEAR systems. The methodology for their measuring and monitoring is poorly developed. Data from NFI field plots are inadequate for such purposes (Stokland et al., 2003). Holopainen et al. (2005) stated that "the fragmentation of a forest area can be characterized by using some simple metrics of landscape, e.g. biotope areas, density, size, and variability". "McGarigal & Marks (1995) have documented that the patch density and mean patch size serve as fragmentation indices" (Roy and Behera, 2002). In this content, new technologies, such as remote sensing and GIS techniques seem promising as it was already documented by e.g. Laxmi-Goparaju et al. (2005), and Vogt et al. (2007). Using these tools, pattern and fragmentation processes are mostly measured with two approaches: (1) patch based metrics often calculated over a systematic fixed area grid from freeware such as Fragstats (McGarigal and Marks, 1995) and (2) area density scaling measures from the "amount adjacency" model based on image convolution (Riitters et al. 2002).

The USDA Forest Service developed an indicator of forest fragmentation using National Land Cover Data (NLCD). Before its calculation, the four NLCD forest cover classes (coniferous, deciduous, mixed, and wetland forest) are aggregated into one forest class and the remaining land cover classes into a non-forest class and a "missing" class consisting of water, ice/snow, and bare ground (Riitters et al., 2002). A model classifies forest fragmentation based on the degree of forestland surrounding each forest pixel (a square approximately 30 meters on each edge) for various landscape sizes (known as "windows"). Three degrees of land cover were defined: (1)"core" if a subject pixel is surrounded by a completely forested landscape (no fragmentation); (2) "interior" if a subject pixel is surrounded by a landscape that is at least 90% forest; and (3) "connected" if a subject pixel is surrounded by a landscape that is at least 60% forest. Landscape sizes range from 5.6 acres (a 5 by 5 pixel square) to 13,132 acres (a 243 by 243 pixel square) (Riitters et al. 2002; NCEA, 2007).

A similar, though a more detailed classification of forest pattern was developed by Vogt et al. (2007b) who defined nine classes that cover a wide range of forest spatial pattern. According to these authors, "core" forest is the inner part of a forested region that is situated beyond a certain distance to forest boundary. In their works (Vogt et al. 2007a, 2007b), the center pixel is labeled core forest, if all 8 surrounding pixels are forest. Hence, "core forest represents un-fragmented habitat that is potentially suitable for interior forest species, while “patch‟ forests are isolated forest fragments where organisms are less likely to communicate with organisms outside the fragment” (Vogt et al., 2007b). The authors defined patch as a forested region that is too small to contain core forest. Edge is an exterior perimeter of core forest regions, i.e. „a transition zone between core forest and core nonforest‟.

Apart from the classes “core”, “patch”, and “edge”, the authors also defined ‛connecting’ features: corridors, shortcuts and branches, of which the branches could be viewed as ‛broken connections.’ The class ‛perforated‛ refers to pixels of core forest that surround a nonforest patch, i.e. it is an interior perimeter or a transition zone between core forest and non-forested area (‛holes’) inside forests. ‛Connector’, i.e. corridor and shortcut, is a set forest pixels with no core forest, that connects at least two different core forests and connects to the same core forest unit, respectively. ‛Branch’ is defined as a set of forested pixels without core forest that is connected at one end only to non-core forested area, i.e. to a connector, edge or perforation (Vogt et al. 2007b).

“Corridors and shortcuts characterize potential movement pathways, and as relatively narrow features they may be vulnerable to future fragmentation and conversion to patch” (Vogt et al., 2007b). Corridors can be either structural, i.e. physical links between large forest regions, or functional defined by the movements of organisms. However, if corridors are to be beneficial for biodiversity conservation, they have to possess certain qualities (width, height, volume, maturity, sensu Hinsley and Bellamy, 2000) that meet the requirements of the most species (Bailey, 2007). Vogt et al. (2007b) presented a method for automated mapping of structural corridors with morphological image processing. As shown in their paper, “the approach satisfies the assessment requirements of feasibility and repeatability when using continental-scale land-cover maps and it can be implemented at multiple scales” (Vogt et al., 2007b). The method was also applied in Estreguil et al. (2007).

Although habitat fragmentation per se is often considered a threat to biodiversity, “biodiversity losses are most likely a result of the amount of regional habitat loss rather than fragmentation (Harrison, 1994; Fahrig, 1998; 2001; 2003; Harrison and Bruna, 1999; Rosenberg et al., 1997; Trzcinshi et al., 1999 in Bailey, 2007)”. The review of Bailey (2007) “has indicated a lack of firm empirical evidence that species increase following attempts to increase connectivity in fragmented woods”. Hence, a scientifical demonstration of the benefits to biodiversity of increasing connectivity through the development of networks and corridors is required (Bennett, 2003 in Bailey 2007).

2.3.5.3. Forest edge

Forest edge is a specific type of ecotones that are defined as “boundaries between different land use classes” (Corona et al. 2004). The significance of forest edges in nature conservation was documented by e.g. Magura et al. (2001). “As forest fragmentation increases beyond the fragmentation caused by natural disturbances, edge effects become more dominant, interior-adapted species are more likely to disappear, and edge- and open-field species are likely to increase” (NCEA, 2007). “Forest plant and animal communities along fragmented forest edges can change with the introduction of exotic species” (Jones and others, 2000; Boulinier and others, 2001; Pearson and Manuwal, 2001 in Riitters et al., 2002).

To quantify forest edge, edge measurements such as total edge length and edge density are used (Gallego et al., 2000; Riitters et al., 2004). Edge density defined as edge length per standard area is an “indicator that does not depend on the size of the reference unit and can be computed directly for the administrative units to be compared” (Gallego et al., 2000). Riitters et al. (2004) arranged these measures into the group of fragmentation indices, since fragmentation and forest edge are interrelated.

Traditionally, the length of edges/ecotones “is determined by polygon delineation on the basis of visual interpretation of remotely sensed imagery (complete mapping) and subsequent perimeter mensuration on each delineated polygon (Haines and Chopping, 1996). However, such a procedure might have omission and commission errors, unavoidable in image interpretation and classification by polygon delineation (Carfagna and Gallego, 1999)” (Corona et al., 2004). Therefore, Corona et al. (2004) proposed a forest ecotone survey procedure based on line intersect sampling that overcomes the above-mentioned shortcomings. “Line intersect sampling (LIS) is an easy method for assessing the total length of a discrete population of land elements characterized by linear shapes, particularly when orthocorrected remotely sensed images are available (Corona, 2000). LIS is a form of cluster sampling in which population elements crossed by a line transect are selected into the sample (Gregoire and Valentine, 2003)" (Corona et al. 2004). In Corona et al. (2004) "ecotone length per unit area is estimated by visual interpretation of the changes from forest to other land use classes along each sampling line displaced on remotely sensed images from the land to be inventoried". The authors found that this method reduces time needed for the estimation of ecotone length when compared with conventional forest polygon delineation and perimeter mensuration. According to Corona et al. (2004), "the proposed procedure may also be used directly on the ground (on small areas) in the context of field surveys, e.g., by systematic selection of the sampling points (line centers) and randomly oriented line displacement with the help of a GPS device".

Vogt et al. (2007a) detected forest edge in the proces of mapping spatial pattern using morphological image processing. This method was identified as a theory and technique for analysing the shape and form of objects (Soille 2003 in Vogt et al. 2007a). Forest pattern is clasified "by a sequence of logical operations such as union, intersection, complementation, and translation using geometric objects called 'structuring elements' (SE) of pre-defined shape and size" (Vogt et al. 2007a). In their work, Vogt et al. (2007a) consider two structuring elements SEs: an 8-neighbourhood (SE1) and a 4-neighbourhood (SE2), that pre-define which and how many pixels around the examined (center) pixel are accounted for in the analysis. In addition, the shape and dimension of SEs also define the direction and extent of the morphological operations. The authors used two operations: the 'erosion' that shrinks regions of forest and the 'dilation' that expands them.

The detection of forest edge starts from the forest-nonforest map. First, the nonforest patches are identified and removed by erosion using SE1. Then, the actual nonforest area is dilated in all diretiosn using SE1????nie SE2???. Dilations are repeated until there is no difference in the area clasification between two consecutive dilations. Forest edge consists of all forest pixels that are adjacent to non-forest area after subtracting forest patch pixels (Vogt et al. 2007a).

Image convolution is another approach used for detecting forest edge. This method uses a mowing window device of a predefined size to identify forest pattern. "A moving window operates by moving a fixed-area window over the map so as to place a support region around each pixel. Measurements are made at each placement of the window, and the values are assigned to the location of the pixel at the center of the support region" (Riitters, 2005).

Various forest species react differently to edge effects. The 100m width of the border classes (edge, connector, branch, perforation) corresponds to edge effects for many interior species (e.g. birds in Forman and Alexander 1998) and can be regarded as a permeability distance for invasive species. In Canadian woodland survey, an edge width is defined between 100 and 300m. Hence, it is useful when the edge width can be predefined for the analysis, i.e. edge width can be of one or more pixels. Multiple-pixel forest edges are also of use when forest/non forest borders are not sharp, i.e. in cases when it is not possible to state which one pixel represents the edge.

Both above-mentioned techniques enable to determine the desired width of the edge by defining the size of structural elements SE and the window dimension in the case of morphological and convolution approach, respectively. Vogt et al. (2007a) analysed the behaviour of the two approaches using various edge widths. They found that "with increasing SE or window size, both methods increase the width of the perforated and edge regions at the expense of the core regions… The comparison of both methods revealed that the morphological approach is more accurate at the pixel level…Small patch regions remain patch regions and stay disconnected to neighboring core forest regions, and continuous forest boundaries are labeled as a single class" (Vogt et al., 2007a).

2.3.6. Functional indicators

"Functional diversity involves processes or temporal change, including disturbance events and subsequent succession series, nutrient recycling, population dynamics within species, various forms of species interactions, and gene flow" (Stokland et al., 2003).

From a functional point of view, species can be subdivided in categories like primary producers, herbivores, predators, and decomposers (Stokland et al., 2003). Belaoussoff et al. (2003) defined a functional group "as a group of not necessarily related species exploiting a common resource base in a similar fashion. Within a functional group there is greater similarity in ecological resource requirements than within a guild, thereby implying that there is a greater degree of interspecific competition (Arthur, 1984; Colwell and Winkler, 1984). There is an overlap in resource requirements between species in a functional group. Disturbances would affect those species evenly by disrupting resources that they all use" (Belaoussoff et al., 2003).

The BEAR-project strongly recommends to include functional indicators in any Biodiversity Evaluation Tool. Within the framework of the BEAR project, fire, wind and snow, and biological disturbance have been identified as the most important functional key factors in the group of "natural influences", while the area affected by a particular factor are suggested as possible indicators with high ecological significance (BEAR Newsletter 3).

Although "ecosystem function in many cases might be more important than species diversity in gaining an understanding of ecosystem dynamics" (Sobek and Zak, 2003), "structural and compositional indicators are considered to be more tractable for end-users (Angelstam et al., 2001 in Humphrey and Watts, 2004)".

Human induced factors (forest management, agriculture, grazing, fire, pollution, other land use) are considered as a functional key factor of forest biodiversity. As expressed by Naveh (1974) it is obvious that fire has acted, not as a wholly destructive force, but as a powerful selective and regulatory agent. The role of livestock in the change of the Mediterranean forests have been stressed by Thirwood (1981), who considers grazing by domestic animals among the major causes of forest degradation.

Forest management practices often have a major impact on biodiversity, causing complex changes to site conditions, tree species composition and forest structure (Mitchel and Kirby 1989). The potential effects on forest management on biodiversity occur at several scales:

- At the stand scale removal or destruction of important habitat structures such as coarse woody debris, during traditional boreal forest clear-cutting may affect species composition (Burschel 1992, Östlund 1993).
- At the landscape scale, fragmentation, alteration and loss of previously continuous habitat (e.g. natural old growth forests, forest fire areas, areas with a long continuity of decaying wood and old broad-leaved trees) may cause local extinctions and hamper the recolonization of maturing sites by old growth specialists (Niemelä 1999).

The major effect of forest management is a general reduction in stand age (Christensen and Emborg 1996, Esseen et al. 1997). This directly affects the diversity of species restricted to old trees and woody debris, whilst organisms primarily related to the innovation phases are less affected. The light open conditions at the forest floor after thinning or clearcutting may even be beneficial for these organisms (Christensen and Emborg 1996). Silvicultural system influence disturbance patterns and processes in the forests: when trees are thinned, remaining tree often succumbs to high winds in their new opened canopy. Increased numbers of wind – throws are documented in thinned stands, especially where topographic risk factors are high, and where thinned stands are also fertilized.

2.3.7. Pros and contras of indicators

"It is an underlying assumption that biodiversity indicators predict the forest biodiversity" (Stokland et al., 2004). In fact, many of the proposed indicators need to be tested and require rigorous validation in order to be interpreted (Corona and Marchetti, 2007). Failing and Gregory (2003) identified "10 common 'mistakes' in developing and using forest biodiversity indicators from the standpoint of making better forest management choices. The mistakes relate to a failure to clarify the values-basis for indicator selection and a failure to integrate science and values to design indicators that are concise, relevant and meaningful to decision makers”.

One common mistake in the construction and application of biodiversity indicators is mixing means and ends (Failing and Gregory, 2003). For example, “the amount and quality of dead wood is hardly a biodiversity value itself, but instead a means to enhance the diversity of wood-associated species. Thus, one should not judge the success of a biodiversity policy on dead wood only on the basis of whether a well-defined indicator target is reached or not‟ (Stokland et al., 2004). In this context, “it is crucial to establish the link between different indicator states and the biodiversity component it is intended to indicate” (Stokland et al. 2004) in order to get an idea what the consequences of managing an indicator might be for dependant flora and fauna (Humphrey et al., 2004).

In addition, if the application of indicators is to be useful for monitoring trends in biodiversity it is necessary to ascribe quantitative values to them (Humphrey et al., 2004). However, “data on indicator states alone does not say very much unless they are put into perspective” (Stokland et al., 2004). Thus, e.g. Humphrey et al. (2004) suggested a range of possible values for each examined measure (e.g. deadwood). The upper limit of the range can be defined by so called *natural reference values* (Stokland et al., 2004), i.e. the values from natural or virgin stands. However, for some areas such information is missing or occurring only sparsely (Hahn and Christensen, 2004). Hence, where the information from such forests is unavailable, the values from ´best´ examples are used (Humphrey et al., 2004). The lower range limit for the different measures is more difficult to define, since there is very little information available on threshold values for sustaining key populations of species (Humphrey et al., 2004). A similar way how to determine the desired biological state of a forest indicator is to use baseline values together with some measure of variability under natural conditions (Ghazoul, 2001). Nevertheless, when applying these values, one must bear in mind that “indicators are useful in the monitoring process that must sustain adaptive forest management, but not for predetermining `optimal` levels, e.g. of deadwood or other biodiversity indicators” (Ciancio and Nocentini, 2004). In addition, due to high variability of natural conditions and anthropogenic influences within the world forest area, the values of biodiversity indicators are meaningful only if they refer to specific environment (Barbati et al., 2007; Travaglini et al., 2007). In this context, Barbati et al. (2007) suggested to use soundly ecologically based forest types classifications, e.g. European Forest Types classification proposed by Barbati et al. (2006, 2007). Another possibility comes, if repeated measurements of the biodiversity component of interest, i.e. information from two different time points time T1 and time T2, are available. In such a case, it is possible to compare time T1 with time T2 and detect the temporal trends of the component, i.e. if they are in a positive or a negative direction.

Considering the policy making, Failing and Gregory (2003) note that “many of the proposed indicators remain cumbersome for managers to work with and, by sheer number, retain some of the drawbacks of the ‘listing’ approach. For example, although measurements of ‘predation rates’ or ‘nutrient cycling rates’ (listed under the function category at the community/ecosystem scale) may be useful information to a scientist trying to understand ecosystem processes and define hypotheses, they do not inform a stakeholder or decision maker (or, we suspect, most scientists) about the current status of biodiversity. Nor do such comprehensive listings provide a useful means for discriminating among policy alternatives that affect biodiversity. From the perspective of forest managers, a useful approach seems to be a combination of 2-3 compositional and 2-3 structural indicators, while the compositional indicators should be functionally linked to a broad range of other species (e.g. the extent and species composition of the broadleaved component in conifer forests); and the structural surrogates should act as surrogates for general species richness or diversity (e.g. the quantity and quality of deadwood)” (Ferris and Humphrey, 1999).

Since “decision makers need a concise summary of biodiversity implications of a proposed policy, so that they can compare them with other bottom-line impacts and make informed choices about the inevitable trade-offs" (Failing and Gregory, 2003), the authors propose weighting of indicators to reflect their importance to biodiversity and to construct a summary indicator or an index.

2.3.8. Biodiversity indices (species level)

Biodiversity indices are measures that quantify diversity using different statistical and mathematical approaches.

"A useful biodiversity index should be flexible enough to enable the use of different biodiversity indicators for different ecosystems and spatial scales. It should be possible to calculate the index at different geographic locations and scales: for a particular project footprint, a larger landscape or ecoregion, an ecosystem type, a province or state, or the nation as a whole. And it should be scalable: that is, it should be possible to aggregate across regions at different scales and subsequently disaggregate in order to diagnose the source of major trends or unmask hidden trends. This approach allows both the presentation of a simple summary metric that can be used for communicating major trends and for making trade-offs with other social, economic or environmental objectives, and as well provides a basis for appropriate management action in response to observed trends" (Failing and Gregory, 2003).

2.3.8.1. Indices characterizing one component of biodiversity (species level, composition)

"A great number of different methods can be used for the evaluation of species diversity" (e.g. see Krebs, 1989, Ludwig and Reynolds, 1988). All of the proposed methods are usually based on at least one of the following three characteristics (Bruciamacchie, 1996):

- species richness – the oldest and the simplest understanding of species diversity expressed as a number of species in the community (Krebs, 1989);
- species evenness – a measure of the equality in species composition in a community;
- species heterogeneity – a characteristic encompassing both species abundance and evenness.

2.3.8.2. Richness indices

"The most popular methods for measurement and quantification of species diversity are species diversity indices. During the historical development, the indices have been split into three categories: indices of species richness, species evenness and species diversity (Krebs, 1989; Ludwig and Reynolds, 1988). The indices of each group explain only one of the above-mentioned components of species diversity" (Merganič and Šmelko, 2004).

The term species richness was introduced by McIntosh (1967) to describe the number of species in the community (Krebs, 1989). Surely, the number of species S in the community is the basic measure of species richness, defined by Hill (1973) as diversity number of 0th order, i.e. N0. "The basic measurement problem is that it is often not possible to enumerate all of the species in a natural community" (Krebs, 1989). In addition, S depends on the sample size and the time spent searching, its use as a comparative index is limited (Yapp, 1979). "Hence, a number of indices have been proposed to measure species richness that are independent of the sample size. They are based on the relationship between S and the total number of individuals observed" (Ludwig and Reynolds, 1988). Two such well-known indices are R1 and R2 proposed by Margalef (1958) and Menhinick (1964), respectively. Hubálek (2000), who examined the behavior of 24 measures of species diversity in a data from bird censuses, assigned to the category of species richness-like indices also the index α (Fischer et al., 1943, Pielou, 1969), Q (Kempton and Taylor 1976, 1978), and R500 (Sanders 1968, Hurlbert 1971).

2.3.8.3. Heterogeneity (diversity) indices

This concept of diversity was introduced by Simpson (1949) and combines species richness and evenness. "The term heterogeneity was first applied to this concept by Good (1953), and for many ecologists this concept is synonymous with diversity" (Hurlbert 1971 in Krebs, 1989). "There are, literally, an infinite number of diversity indices" (Peet, 1974 in Ludwig and

Reynolds, 1988). To investigate how communities are structured, two statistical distributions have been commonly fitted to species abundance data: logarithmic series and lognormal distribution. Due to the complexity of these statistical distributions and the lack of a theoretical justification, nonparametric measures of heterogeneity have been developed that assume no statistical distribution (Krebs, 1989). Simpson proposed the first heterogeneity index λ, which gives the probability that two individuals picked at random from the community belong to the same species. It means if the calculated probability is high, then the diversity of the community is low (Ludwig and Reynolds, 1988). "To convert this probability to a measure of diversity, most workers have suggested using the complement of Simpson´s original measure", i.e. 1-λ (Krebs, 1989).

Probably the most widely used heterogeneity index is the Shannon index H�much (or Shannon-Wiener function), which is based on information theory (Shannon and Weaver, 1949). It is a measure of the average degree of "uncertainty" in predicting to what species an individual chosen at random from a community will belong (Ludwig and Reynolds, 1988). Hence, if H´ = 0, then there is only one species in the community, whereas H´ is maximum (= log(S)) if all species present in the community are represented by the same number of individuals. Shannon index places most weight on the rare species in the sample, while Simpson index on the common species (Krebs, 1989).

From other heterogeneity measures we mention Brillouin Index H (Brillouin, 1956), which was first proposed by Margalef (1958) as a measure of diversity. This index is preferred being applied for data in a finite collection rather than H´. However, if the number of individuals is large, H and H´ are nearly identical (Krebs, 1989). The indices N1 and N2 from Hill`s family of diversity numbers (Hill, 1973), which characterize the number of "abundant", and "very abundant" species, respectively, also belong to diversity measures. "The McIntosh index is based on the representation of a sample in an S-dimensional hyperspace, where each dimension refers to the abundance of a particular species" (Bruciamacchie, 1996). According to the evaluation performed by Hubálek (2000), NMS "number of moves per specimen" proposed by (Fager, 1972), H´adj, which is an adjusted H´ by the d(H) correction (Hutcheson, 1970), and R100 (Sanders, 1968; Hurlbert, 1971) can also be regarded as heterogeneity indices.

2.3.8.4. Evenness (equitability) indices

Lloyd and Ghelardi (1964) were the first who came with idea to measure the evenness component of diversity separately (Krebs, 1989). "Evenness measures attempt to quantify the unequal representation of species against a hypothetical community in which all species are equally common. The most common approach has been to scale one of the heterogeneity measures relative to its maximal value when each species in the sample is represented by the same number of individuals" (Krebs, 1989). Ludwig and Reynolds (1988) present five evenness indices E1 (Pielou, 1975; 1977), E2 (Sheldon, 1969), E3 (Heip, 1974), E4 (Hill, 1973), and E5 (Alatalo, 1981), each of which may be expressed as a ratio of Hill´s numbers. The most common index E1, also known as J�much suggested by Pielou (1975, 1977) expresses H‘ relative to maximum value of H‘ (= log S). Index E2 is an exponentiated form of E1. Based on the analysis of Hubálek (2000), McIntosh`s diversity D (McIntosh, 1967; Pielou, 1969), McIntosh`s evenness DE (Pielou, 1969), index J of Pielou (1969) and G of Molinari (1989), are also evenness measures.

2.3.8.5. Complex diversity indices

On the contrary to species diversity indices that describe only one of the biodiversity components, the model BIODIVERSS proposed by Merganič and Šmelko (2004) estimates the species diversity degree of a stand from 5 diversity indices (R1, R2, λ, H‘ and E1) and thus integrates all the partial biodiversity components. The fundamental method of the model BIODIVERSS is a predictive discriminate analysis (StatSoft Inc., 1996; Huberty, 1994; Cooley and Lohnes, 1971). Using four discriminate equations, each for one species diversity degree, an evaluated forest stand is classified into one of the four pre-defined species diversity degrees. The method is based on the assumption, that if high species diversity is observed on a small area within the forest stand, we can presume that the species diversity of the whole examined forest stand will also be high. The probability of correct classification of the species diversity degree using the model BIODIVERSS is relatively high. Having only 1.5% sampling intensity, the success of classification already reaches approximately 90%. Although the model BIODIVERSS was designed for the determination of biological species diversity of the tree layer on a forest stand scale, the method can also be applied to regional or large-scale inventories if we assume that species diversity index determined on a sample plot represents a certain part of the evaluated area (Merganič and Šmelko, 2004).

2.3.8.6. Structural indices (species level, structure)

Structural diversity is defined as the composition of biotic and abiotic components in forest ecosystems (Lexer et al., 2000), specific arrangement of the components in the system (Gadow, 1999) or as their positioning and mixture (Heupler, 1982 in Lübbers, 1999). According to Zenner (1999) the structure can be characterized horizontally, i.e. the spatial distribution of the individuals, and vertically in their height differentiation. Gadow & Hui (1999) define the structure as spatial distribution, mixture and differentiation of the trees in a forest ecosystem.

To describe the structure and its components, "the classical stand description (qualitative description of stand closure, mixture, density, etc.) and different graphical methods (diameter distribution, stand height distribution curve, tree map, etc.) can be very useful. However, they may not be sufficient to describe stand structure in detail since subtle differences will often not be revealed" (Kint et al., 1999). Therefore, a number of quantitative methods have been proposed. Partial reviews can be found in Pielou (1977), Gleichmar and Gerold (1998), Kint et al. (1999), Pielou (1977), Füldner (1995), Gleichmar and Gerold (1998), Kint et al. (1999), Lübbers (1999), Gadow and Hui (1999), Neumann and Starlinger (2001), Pommerening (2002), etc.

2.3.8.7. Indices characterizing horizontal structure

"The indices for spatial distribution or horizontal structure compare a hypothetical distribution with the real situation" (Neumann and Starlinger, 2001). Probably the most well-known index is the aggregation index R proposed by Clarḳ Evans (1954) that describes the horizontal tree distribution pattern (or spacing as named by Clarḳ Evans (1954), or positioning as defined by Gadow & Hui (1999)). It is a measure of the degree to which a forest stand deviates from the Poisson forest, where all individuals are distributed randomly (Tomppo, 1986). It is the ratio of the observed mean distance to the expected mean distance when individuals were randomly distributed. A similar measure is the Pielou index of no randomness (Pielou, 1959), which quantifies the spatial distribution of trees by the average minimum distance from random points to the nearest tree (Neumann and Starlinger, 2001). The Cox index of clumping (Strand, 1953; Cox, 1971) is the ratio of variance to mean stem number on sub-plots. Gadow et al. (1998) proposed an index of neighborhood pattern based on the heading angle to four next trees. Another commonly used measures of horizontal structure are indices proposed by Hopkins (1954), and Prodan (1961), and methods by Köhler (1951) and Kotar (1993 in Lübbers, 1999).

According to Gadow & Hui (1999), mixture is another component of structure. For the quantification of mixing of two tree species, Pielou (1977) proposed the segregation index based on the nearest neighbor method like the index A of Clarḳ Evans, while the calculated ratio is between the observed and expected number of mixed pairs under random conditions. Another commonly used index is the index DM (from German Durchmischung) of Gadow (1993) adjusted by Füldner (1995). On the contrary to the segregation index, DM accounts for multiple neighbors (Gadow, 1993 used 3 neighbors) and is not restricted to the mixture of two species (Kint et al., 1999).

Differentiation is the third component of structure (Gadow & Hui, 1999), that describes the relative changes of dimensions between the neighboring individuals (Kint et al., 1999). Gadow

(1993) proposed the differentiation index T, which is an average of the ratios of the smallest over the largest circumference calculated for each tree and its n nearest neighbors. Instead of the circumference, diameter at breast height can be used in this index to describe the horizontal differentiation as presented by Pommerening (2002). Values of the index T close to 0 indicate stands with low differentiation, since neighboring trees are of similar size. Aguirre et al. (1998) and Pommerening (2002) suggested scales of five or four categories of differentiation, respectively.

2.3.8.8. Indices characterizing vertical structure

While there are many indices that measure horizontal structure, there are only few for vertical structure (Neumann and Starlinger, 2001). "Simple measures such as the number of vegetation layers within a plot can be used as an index of vertical differentiation" (Ferris-Kaan and Patterson, 1992 in Kint et al., 1999). The index A developed by Pretzsch (1996; 1998) for the vertical species profile is based on the Shannon index H'. In comparison with H' the index A considers species portions separately for a predefined number of height layers (Pretzsch distinguished 3 layers). The index proposed by Ferris-Kaan et al. (1998) takes the cover per layer into account, but needs special field assessments (Neumann and Starlinger, 2001). Therefore, using the same principles as Pretzsch (1996), i.e. Shannon index and stratification into height layers, Neumann and Starlinger (2001) suggested an index of vertical evenness VE that characterizes the vertical distribution of coverage within a stand. The differentiation index T of Gadow (1993) is also applicable for the description of vertical differentiation, if the index is calculated from tree heights.

2.3.8.9. Complex structural indices

Complex structural indices encompass several components of structural diversity. For example, Jaehnẹ Dohrenbusch (1997) proposed the Stand Diversity Index that combines the variation of species composition, vertical structure, spatial distribution of individuals and crown differentiations. The Complexity Index by Holdridge (1967) is calculated by multiplying four traditional measures of stand description dominant height, basal area, number of trees and number of species. Hence, this index "contains no information on spatial distribution nor a accounts for within stand variation" (Neumann and Starlinger, 2000). Zenner (1999), and Zenner and Hibbs (2000) developed the Structural Complexity Index, that is based on the vertical gradient differenced between the tree attributes and the distances between the neighboring trees. "When all trees in a stand have the same height, the value for SCI is equal to one, the lower limit of SCI" (Zenner and Hibbs, 2000).

2.3.8.10. Complex indices combining more components of biodiversity

An example of a complex index is LLNS index proposed by Lähde et al. (1999). The index was suggested for calculating within-stand diversity using the following indicator variables: stem distribution of live trees by tree species, basal area of growing stock, volume of standing and fallen dead trees by tree species, occurrence of special trees (number and significance), relative density of undergrowth, and volume of charred wood. The LLNS index is calculated as the sum of diversity indices describing particular components (i.e. living trees, dead standing trees etc.). However, the index can also be applied during the field work, as the authors developed a scoring table for the indicator variables. The final value of LLNS is then obtained by adding all the scores together. The evaluation of this index using Finnish NFI data revealed, that the LLNS index differentiates even-sized and uneven-sized stand structures, the development classes of forest stands and site-types fairly well (Lähde et al., 1999).

Another complex index named as Habitat Index HI was also developed in Findland by Rautjärvi et al. (2005). The authors also use the name habitat index model as it was produced as spatial oriented model. The inputs in the model come from thematic maps from Multi-source NFI (MS-

NFI) (predicted volume of growing stock, predicted stand age, and predicted potential productivity) and kriging interpolation maps from NFI plot data (volume of dead wood, and a measure for naturalness of a stand; more on naturalness see chapter 4.4). The input variables were selected based on the forest biodiversity studies in Scandinavia. The index is of additive form where all input layers contribute to the result layer. All input variables (layers) are reclassified and enter the model as discreet variables, while each input layer is assigned a different weight according to its importance to biodiversity.

Meersschaut and Vandekerkhove (1998) developed a stand-scale forest biodiversity index based on available data from forest inventory. The index combines four major aspects of a forest ecosystem biodiversity: forest structure, woody and herbaceous layer composition, and deadwood. Each aspect consists of a set of indicators, e.g. forest structure is defined by canopy closure, stand age, number of stories, and spatial tree species mixture. The indicators are given a score determined on the basis of a common agreement. The biodiversity index is calculated as the sum of all scores, while its maximum value is set to 100.

2.3.9. Pros and contras of indices

Indices are regarded useful because they provide rapid, and easily calculated, ecological measures (Belaoussoff et al., 2003). Since they quantify biodiversity with a single summary statistics (Hubálek, 2000; Merganič, 2001), it makes comparisons between samples, communities and similar studies which use the same indices possible (Hubálek, 2000; Belaoussoff et al., 2003). The indices can be used "to determine quantitative critical values which need to be exceeded to ensure a minimal amount of biodiversity" (Pommerening, 2002). Moreover, quantitative values cam be easily transformed into qualitative evaluation (low, medium etc. biodiversity degree), which is easier to understand outside the scientist community (Merganič, 2001). "Another important benefit of a forest biodiversity index is that it would facilitate learning over time" (Failing and Gregory, 2003). As indices belong to non-parametric methods, their use eliminates some theoretical problems of application of parametric methods (Krebs, 1989). In addition, usually their calculation is a simple procedure, that does not require large material supply and technical facilities (Merganič, 2001).

The major criticism of biodiversity indices is that a number of them are only statistical artifacts and do not have any intrinsic biological meaning (Belaoussoff et al., 2003). In particular, this refers to diversity indices, since they attempt to combine, and hence to confound a number of variables that characterize community structure. In addition, the same diversity index value can be obtained for a community with low richness and high evenness as for a community with high richness and low evenness. This adds to the interpretation problem, making comparisons difficult and confusing (Ludwig and Reynolds, 1988). Nevertheless, this is not the case of all indices. Values of some indices, e.g. Hill`s family of diversity numbers, can be easily ecologically interpreted (Ludwig and Reynolds, 1988).

Regarding the interpretation, Belaoussoff (2000) showed that "the use of different indices with the same data can result in different conclusions" (Belaoussoff et al., 2003).

Another shortcoming of species diversity indices is that they are strongly correlated to plot size or an area of the evaluated forest stand. Therefore, it is suggested that if the biodiversity are to be appropriately presented, plot size should also be given (Merganič et al., 2004; Eckmüllner, 1998).

A general problem with evenness measures is that they assume the total number of species in the whole community is known (Pielou, 1969 in Krebs, 1989). Since the observed species number in the sample is often less than true species numbers in the community (mainly in species-rich communities), the evenness ratios are usually overestimated (Sheldon, 1969 in Krebs, 1989). This is particularly true for the indices E1, E2, and E3 (Ludwig and Reynolds, 1988). On the other hand, E4 and E5 are relatively unaffected by species richness and sampling variations, and hence tend to be independent of sample size (Ludwig and Reynolds, 1988). In addition, an evenness index should be independent of the number of species in the sample, i.e. its value should stay constant regardless of the number of species present. However, as Peet (1974) and Ludwig and Reynolds (1988) showed, the indices E1, E2, and E3 are very sensitive to species richness, while the addition of one rare species to a sample containing only a few species greatly changes their values.

A thorough study of the performance of 24 species diversity indices based on 20 criteria was presented by Hubálek (2000), who for the estimation of species diversity within community suggested to use Fager´s `number of moves per specimen`, exponential Shannon`s information, reciprocal Simpson`s lambda, and species richness (number of species).

2.4. Data sources and method used in biodiversity assessment

2.4.1. National Forest Inventories (NFI)

"For an overview, the use of forest resource inventory data can be a cost effective method to obtain information for large areas" (Söderberg and Fridman, 1998), because "forest inventories are a major source of information at least for traditional variables describing tree species composition, age, etc." (Estreguil et al., 2004). According to Corona and Marchetti (2007), "NFIs have the advantage of providing objective information on key components of forest ecosystems, characterized in terms of amount, spatial and temporal distribution, and interaction on a multiple scale". Data from NFIs are also usefull for biodiversity assessment. For example, for the biodiversity indicators that are related to forest composition, mainly in terms of species richness and the presence of species of particular conservation concern (threatened or endemic species), data from NFIs and other survey types can be used "to generate species lists, which can be cross-referenced to national and international assessments of species status such as Red Lists and the appendices to the Convention on International Trade in Endangered Species of Wild Fauna and Flora" (Corona and Marchetti 2007).

Basically, NFIs provide us with the information about the following themes: 1) forest area and land cover, 2) resource management (growing stock and the balance between increment and felling), 3) forestry methods and land use (felling systems, regeneration methods, road network density, specific methods such as ditching of swamp forests and soil scarification), 4) forest dynamics with regard to different disturbance factors (fire, storm, insect, browsing, 5) forest state (tree species composition, age distribution, dimension of living trees, tree mortality and deadwood), and partly also about 6) conservation measures, i.e. protected forest areas (Stokland et al., 2003).

Newton & Kapos (2002) distinguishes eight groups of biodiversity indicators appropriate for implementation at the forest management unit level: forest area by type, and successional stage relative to land area; protected forest area by type, successional stage and protection category relative to total forest area; degree of fragmentation of forest types; rate of conversion of forest cover (by type) to other uses; area and percentage of forests affected by anthropogenic and natural disturbance; complexity and heterogeneity of forest structure; number of forest-dependent species; and conservation status of forest dependent species (in Corona and Marchetti, 2007).

"The aim of the traditional National Forest Inventory (NFI) was to describe the main features of forests in terms of size, condition and change. But it was more concerned with their productive features than an extensive description of the forests" (Rego et al., 2004). Only recently, variables more related to biodiversity have been introduced to NFIs (Söderberg and Fridman, 1998). For example, "recognition of the ecological importance of decaying wood has led to the incorporation of quantitative measures of deadwood in NFIs (e.g. Fridman and Walheim, 2000 in Humphrey et al., 2004)". "Integration of ecological assessment in the NFIs is a challenging task, in order to: (i) report on the status of forest ecosystems as per national and international requirements, (ii) assess the effectiveness of management, and (iii) improve our knowledge of ecosystem dynamics to design effective management systems" (Corona and Marchetti, 2007).

An increasing demand for information on non-productive functions of forests has caused that NFIs "are developing as more comprehensive natural resources surveys, broadening their scope in two major directions (Kleinn et al., 2001): (i) including additional variables (such as biodiversity attributes), and (ii) expanding the target population towards non-traditional objects, like non-wood forest products and trees outside forests" (Corona and Marchetti, 2007).

However, "in many cases simply adding some new attributes to existing lists of attributes and depending on traditional, established FI approaches fails to satisfy current information needs. To support the increasing demand for additional information on forest resource attributes (Corona et al., 2003), FIs must basically provide (Gillis, 2001): updated information; data types with uniform definitions, collected to the same quality standards; data that reflects consistent and complete area coverage; data suitable for accurate assessment of trend (change)" (Corona and Marchetti 2007).

In addition, as Stokland et al., 2003 pointed out "NFI field plots are inadequate for measuring landscape patterns" of structural ecosystem diversity because of the small plot size. In addition, in many cases precision guidelines for the estimates of many variables cannot be satisfied due to budgetary constraints and natural variability among plots, as McRoberts et al. (2005) stated for the USA. In neither of the cases it is efficient to increase the plot size or their number. Instead, other data sources, e.g. remote sensing, can be used more efficiently. In addition, "projects in natural sciences face growing demand for rapid data generation, which results in the increasing application of integrated geoinformatics technologies such as: Digital Photogrammetry; Geographical Information Systems (GIS), Digital Elevation Model (DEM), Global Positioning System (GPS) or Remote Sensing (Gallaun et al., 2004, Kias et al., 2004)" (Wezyk et al., 2005). Field work itself "has been enhanced by satellite positioning systems (GPS), automatic measuring devices, field computers and wireless data transfer" (Holopainen et al., 2005). "The geoinformatic techniques make 3D spatial analyses possible, but if supplemented by the time factor (4D analyses), they allow determining the dynamics of changes within the natural environment (Agouris and Stefanidis, 1996, Nayr and Reinhardt, 1996, Armenakis and Regan, 1996 in Wezyk et al., 2005)".

2.4.2. Specific monitoring programmes

For special purposes, specific monitoring programmes are needed. These programmes attempt to investigate particular features of a forest ecosystem that are of specific interest and their monitoring is not included within NFIs. Many of such surveys have been performed by NGOs (Heer et al., 2004). Although this kind of information can be of high value at a local or national scale, its applicability at a higher level (region, Europe) is restricted and requires pre-processing of data with regard to their quality, and biases and gaps in time and space (Heer et al., 2004).

"Besides the species trend data which are collected by the NGOs, specific forest monitoring programmes are aiso increasingly collecting biodiversity trend data" (Heer et al., 2004).

"The International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established in 1985 under the UNECE Convention on Long-range Transboundary Air Pollution. From 1986 onwards ICP Forests estabhished in close co-operation with the European Commission a large forest biomonitoring network with the objective to provide a periodic overview on the spatial and temporal variation in forest condition and to contribute to a better understanding of the relationship between forest condition and stress factors in particular air pollution. To follow these main objectives, a systematic large scale monitoring network (Level I) and an Intensive Forest Monitoring Programme (Level II) have been set up" (Haußmann and Fischer, 2004). "The strengths of the programme are its well established transnational monitoring and reporting infrastructure based on a common legal basis" (Haußmann and Fischer, 2004).

"The strength of the Level I network is its representativity and the vast extent of its approximately 6000 permanent plots, arranged in a 16 x 16 km grid, throughout Europe" (Haußmann and Fischer, 2004). However, its value for representative biodiversity information is limited (Packalen and Maltamo, 2001 in Haußmann and Fischer, 2004) since in many cases only main tree species are assessed (Haußmann and Fischer, 2004).

"For intensive monitoring, more than 860 Level II plots have been selected in the most important forest ecosystems of the participating countries. A larger number of key factors are measured on these plots, including information on tree crown condition, foliar chemistry, soil and soil solution chemistry, atmospheric deposition, tree growth, ground vegetation, meteorology; the data collected enable case studies to be conducted for the most common combinations of tree species and sites in Europe" (Haußmann and Fischer, 2004). "The monitoring programme of ICP forests has included the monitoring of ground vegetation in the Level II plots since 1996 (EC-IJNJECE 2002)" (Heer et al., 2004).

2.4.3. Remote sensing

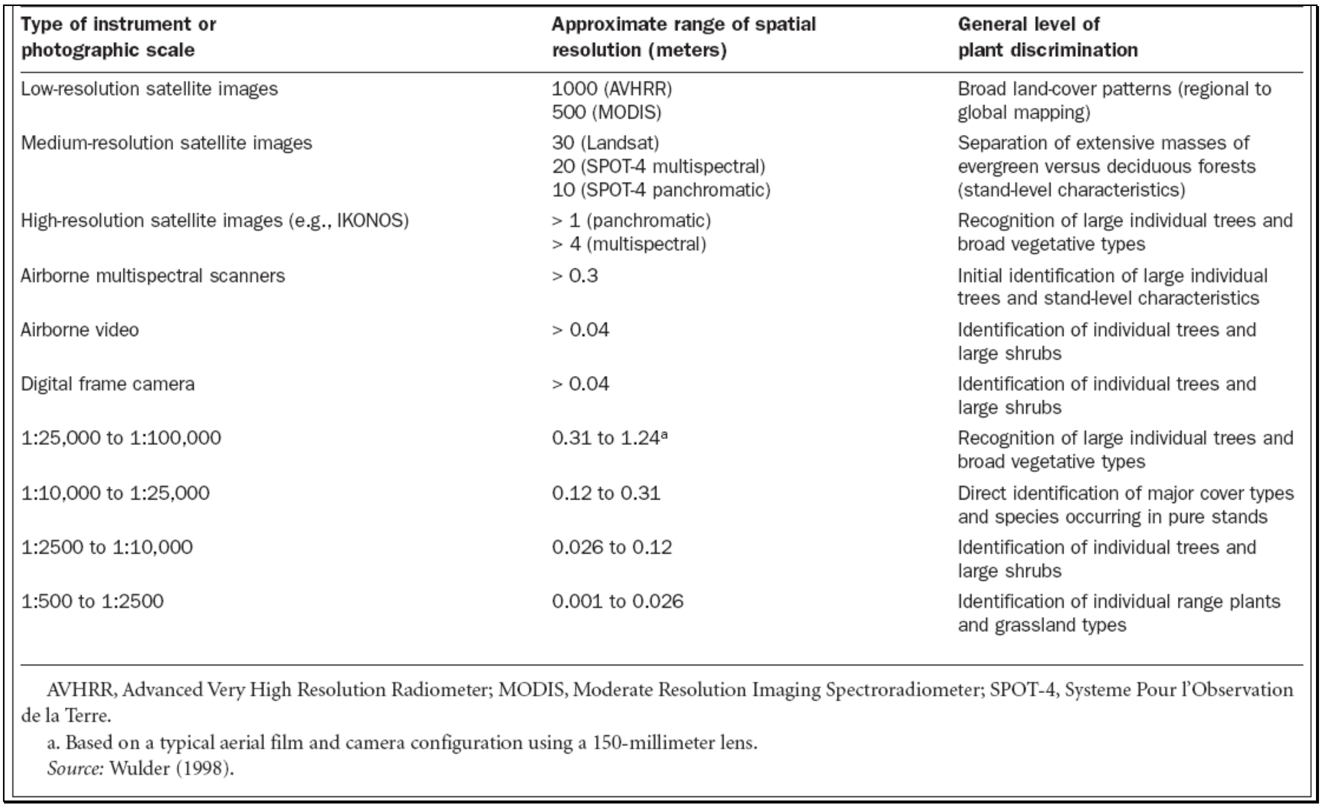
Remote sensing represents a powerful and useful tool for biodiversity assessment at the ecosystem and landscape level (Ghayyas-Ahmad, 2001; Innes and Koch, 1998; Foody and Cutler, 2003). "Modern remote sensing provides cost efficient spatial digital data which is both spatially and spectrally more accurate than before" (Holopainen et al., 2005). Moreover, "remote sensing technology can provide the kind of information that was previously not available to forestry management departments or which was not available on a scale appropriate for comprehensive analyses and planning projects" (Schardt et al., 2005).

A dramatic progress in remote sensing technology during recent decades and years has resulted in numerous biodiversity applications across range of spatial scales. These are primarily determined by the available resolution of the technology applied (Table 10).

Remote sensing data have been successfully used for:

1. landscape characterization (Roy and Sanjay-Tomar, 2000; Laxmi-Goparaju et al., 2005 – forest fragmentation, Kozak et al., 2007 – identification forest and non-forest land);
2. habitat categorization and estimation of their changes over large area.s (Brotherton 1983; Cushman and Wallin, 2000 in Humphrey and Watts, 2004);
3. classification and mapping of land cover types (Ozdemir et al., 2005);
4. estimation of forest characteristics (Reese et al., 2003; Tuominen and Haakana, 2005; Maltamo et al., 2006 - stand volumes of standing trees, Ingram et al. 2005 - stem density and basal area);
5. measuring vegetation (forest) structure (Maltamo et al., 2005, Ingram et al., 2005, Prasad et al., 1998, Wack and Oliveira, 2005);
6. analysis of canopy surface and canopy gaps (Nuske and Nieschulze, 2005);
7. identification of dead standing trees (Butler and Schlaepfer, 2004) and estimation of their amount (Uuttera and Hyppanen, 1998);
8. stratification for ground inventory (Roy and Sanjay-Tomar, 2000; Ghayyas-Ahmad, 2001; Jha et al., 1997) or to increase the precision of estimates (McRoberts et al., 2003; 2005; Olsson et al., 2005)

Table 10: Ranges of spatial resolution associated with different instruments or photographic scales and corresponding levels of expected plant recognition (Wulder et al. 2004)



Type of instrument or photographic scale	Approximate range of spatial resolution (meters)	General level of plant discrimination
Low-resolution satellite images	1000 (AVHRR) 500 (MODIS)	Broad land-cover patterns (regional to global mapping)
Medium-resolution satellite images	30 (Landsat) 20 (SPOT-4 multispectral) 10 (SPOT-4 panchromatic)	Separation of extensive masses of evergreen versus deciduous forests (stand-level characteristics)
High-resolution satellite images (e.g., IKONOS)	> 1 (panchromatic) > 4 (multispectral)	Recognition of large individual trees and broad vegetative types
Airborne multispectral scanners	> 0.3	Initial identification of large individual trees and stand-level characteristics
Airborne video	> 0.04	Identification of individual trees and large shrubs
Digital frame camera	> 0.04	Identification of individual trees and large shrubs
1:25,000 to 1:100,000	0.31 to 1.24[a]	Recognition of large individual trees and broad vegetative types
1:10,000 to 1:25,000	0.12 to 0.31	Direct identification of major cover types and species occurring in pure stands
1:2500 to 1:10,000	0.026 to 0.12	Identification of individual trees and large shrubs
1:500 to 1:2500	0.001 to 0.026	Identification of individual range plants and grassland types

AVHRR, Advanced Very High Resolution Radiometer; MODIS, Moderate Resolution Imaging Spectroradiometer; SPOT-4, Systeme Pour l'Observation de la Terre.

a. Based on a typical aerial film and camera configuration using a 150-millimeter lens.

Source: Wulder (1998).

According to Innes and Koch (1998), "remote sensing provides the most efficient tool available for determining landscape-scale elements of forest biodiversity, such as the relative proportion of matrix and patches and their physical arrangement. Intermediate scale requires information with a resolution ranging from under a meter to tens of meters. Here, remote sensing can use and/or combine two different technologies, namely satellite data and aerial photography. Both proved to be useful for quantitative assessment of edges, while the qualitative assessment of edges (e.g., exposition, structure) can be conveniently aided by aerial stereophotography. Similarly, both satellite data and aerial photography are suitable for mapping and analyzing the geometry and spatial organization of corridors.

At the stand scale, remote sensing technologies are likely to deliver an increasing amount of information about the structural attributes of forest stands, such as the nature of the canopy surface, the presence of layering within the canopy and presence of coarse woody debris on the forest floor".

Nagendra (2001) who evaluated the potential of remote sensing for assessing species diversity distinguished three types of studies:

1. direct mapping of individuals and associations of single species,
2. habitat mapping using remotely sensed data, and prediction of species distribution based on habitat requirements,
3. establishment of direct relationships between spectral radiance values recorded from remote sensors and species distribution patterns recorded from field observations.

"Direct mapping is applicable over smaller extents, for detailed information on the distribution of certain canopy tree species or associations. Estimations of relationships between spectral values and species distributions may be useful for the limited purpose of indicating areas with higher levels of species diversity, and can be applied over spatial extents of hundreds of square kilometres. Habitat maps appear most capable of providing information on the distributions of large numbers of species in a wider variety of habitat types. This is strongly limited by variation in species composition, and best applied over limited spatial extents of tens of square kilometres" (Nagendra, 2001).

Turner et al. (2003) recognise two general approaches to the remote sensing of biodiversity. "One is the direct remote sensing of individual organisms, species assemblages, or ecological commu-nities from airborne or satellite sensors. … The other approach is the indirect remote sensing of biodiversity through reliance on environmental parameters as proxies" (Turner et al., 2003), that can be clearly identified remotely.

"Many different forms of remote sensing are available. Recently, interest has increased in laser scanner and synthetic aperture radar data, although most work to date has used photographs and digital optical imagery, primarily from airborne and space-borne platforms" (Innes and Koch, 1998). The utility of different remote sensing data for assessment purposes of various forest characteristics has been excessively studied in a number of works, e.g. Hyyppa et al. (2000), Lefsky et al. (2001), Tuominen and Haakana (2005), Thompson and Whitehead (1992).

2.4.4. Geographic Information Systems (GIS)

Geographical Information Systems also have a high potential in biodiversity assessment (Ghayyas-Ahmad, 2001; Mironga, 2004; Wallerman, 2003). "GIS provides the way to overlay different 'layers' of data: the ecological conditions, the actual vegetation physiognomy and human pressure indices (e.g., as deduced from the density of population or road network). It helps to assess disturbance levels; the spatial distribution of several species in order to determine biodiversity hotspots; past and present maps for monitoring land cover and land use changes. It provides possibilities to extrapolate observations e.g., to automatically define and map the potential area of a given species and to com-pare it with the locations where, it has been actually observed; or to combine different data sets for defining the potential list of species for a given forest type. GIS provides a database structure for efficiently storing and managing ecosystem-related data over large regions. It enables aggregation and disaggregation of data between regional, landscape and plot scales. It also assists in location of study plots and/or ecologically sensitive areas. GIS supports spatial statistical analysis of ecological distributions. It improves remote sensing information extraction capabilities, and provides input data/parameters for ecosystem modelling. The data generated through ground truthing and inte-gration of related attributes when used in GIS application result into significant features of biodi-versity and genetic resources" (Roy and Behera, 2002).

Mironga (2004) defined "seven functions of GIS that are important for biodiversity modelling are database structure, ground surveys, spatial and statistical analysis, remote sensing integration, terrain analysis, data integration and data visualization. Terrain analysis can be used to identify micro, meso and macroterrain indices. Data integration can be used to determine the environmental characteristics of known habitats of species. Data visualization uses maps, graphs and statistics to process and facilitate understanding of the enormous amount of data that can be derived from the analysis of a species' habitat".

2.4.5. Combination of different data sources

2.4.5.1. Why to combine different data sources?

The combination of different data sources is advantageous from several aspects. Probably the most important fact is that it reduces costs of data acquisition (Schmidt et al., 2005) and data processing in comparison to purely field-based methods. In addition, as McRoberts et al. (2005), Olsson et al. (2005) and others showed, the combination of satellite imagery and NFI at the same time increases precision of estimates of inventory variables (e.g. forest area, volume) as well as their changes. Integrating modern technologies can also be time efficient. An important aspect of the combination of field data and modern tools is that it enables spatial depiction of forest resources (Moisen and Edwards, 1999; McRoberts, 2005). In addition, since the use of aerial imagery is an old and widely used remote sensing technique, retrospective analyses can be accomplished (Nuske and Nieschulze, 2005).

2.4.5.2. How are different data sources combined?

The combination of field data and data obtained from other sources, e.g. GIS, RS, can be performed in different ways depending on the purpose as shown below.

(1) Identification of the areas for ground survey

Prior to fieldwork, remote sensing data can be used to determine which plots are to be visited. Several NFIs use forest/nonforest classification of RS data. For example, in Canada`s NFI ground plots are only established in forested locations, which are determined from aerial photographs (Omule and Gillis, 2005). In addition, the accessibility of the plots is also examined on RS images. While in Canada, "inaccessible plot locations are replaced with suitable subjectively selected matches, and difficult-access plot location are subsampled" (Omule and Gillis, 2005), in the US Forest Inventory field crews visit only the plots determined from aerial photography to have accessible forest land (McRoberts et al., 2005).

(2) Increase precision of estimates

The precision of estimates of many variables can be enhanced using ancillary data. "One source of ancillary data used by the US Forest Inventory and Analysis (FIA) program is classified satellite imagery in the form of land cover maps. These maps are used to derive strata which are then used with stratified estimation" (McRoberts et al., 2005). Stratified estimation requires that (1) the plots are assigned to strata, and (2) that the proportion of land area for each stratum is calculated. "The first task is accomplished by assigning plots to strata on the basis of the stratum assignments of their associated pixels." The proportion of pixels in strata is calculated from the number of pixels with centers in each stratum. McRoberts et al., 2001 recommended creating four strata: forest F, non-forest NF, forest edge FE, non-forest edge NFE (see McRoberts et al., 2005). Similar post-stratification on the kNN dataset with the aim to improve estimates of variables of interest, e.g. tree species composition, have been implemented in the Swedish NFI from 2005 onwards, while their results showed that 3-5 strata should be used (Olsson et al., 2005).

Another possibility to increase precision of estimated attributes is to derive the regression or ratio between the information obtained from RS data and those collected in the field. This is the principle of two-phase sampling, while RS data represent the first phase and ground data the second phase. Scheer and Sitko (2005) applied this method for the estimation of timber growing stock by combining field data with IKONOS satellite data, while different spectral signatures were used as auxiliary variables to derive their relationship (spectral reflectance models) with timber stock Holopainen et al. 2005 proposed a similar method based on two-phase sampling for the inventory of drought damages.

(3) Regionalization of information

Field data is supplemented by RS data in order to characterize certain areas, e.g. state, regions, municipalities and forestry holdings (Tomppo, 1996; Kangas, 1996 in Katila, 2005), or even forest stands (Tomppo, 1987 in Katila, 2005). For this purpose, "some prediction method is needed in order to transfer information gathered in the field to locations of the image not corresponding to field plots. One of the most successful prediction methods in this context is the non-parametric k-nearest neighbors (k-NN) method" (Koistinen et al., 2005). This method has been found as one of the most used and efficient non-parametric classification procedures, which are needed for modeling the complex relationships between spectral signatures and forest attributes (Maselli et al., 2003). The principle of the k-NN technique is that each pixel is assigned a vector of forest variables interpolated from the k spectrally nearest field plots (Olsson et al., 2005). "This technique is a non-parametric approach to predicting values of point variables and nearest neighbor techniques with resulting root mean on the basis of similarity in a covariate space between the point and other points with observed values of the variables" (McRoberts et al., 2002). "It provides wall-to-wall maps of forest attributes, retains the natural variation found in the field inventory (unlike many parametric algorithms), and provides precise and localized estimates in common metrics across large areas and various ownerships" (Finley et al., 2005).

Besides the k-NN method, there are several other possible smoothing and nonparametric regression methods, e.g. kernel smoothers, orthogonal series estimators (e.g. wavelet estimators), spline smoothers, local polynomial regression, or a nonparametric Bayesian regression method (Koistinen et al., 2005).

Koistinen et al. (2005) tested the applicability of local linear regression (LLR) and of its special case local linear ridge regression (LLRR). Based on their results, they concluded that LLR is not suitable for regional prediction with data from NFI and two adjacent Landsat 5 (tm) images due to statistical reasons, since its pixel-level bias deviated significantly from zero. In addition, when applying LLR, they encountered "numerical problems due to singularities which arose from the discrete nature of the feature vectors. Although LLRR is better suited, it did not seem to have a clear advantage over the 5-NN (i.e. k=5) method. The authors suggest that further work is needed to determine the advantages of applying LLRR, mainly for smaller target regions.

Another way of regionalizing forest attributes is to utilize the principles of geostatistics. "The concept of geostatistics is quite simple: it arises from the assumption that near sample data are more related than distant ones. The analysis of data spatial variability and autocorrelation in geographical space (domain) is the basis for all geostatistical approaches" (Scheer and Sitko, 2005). "Several geostatistic tools exist to measure the spatial variability. The best known tool is the semivariogram, also called variogram" (Buddenbaum et al., 2005), which is a discrete function of spatial variability depending on the distance between the sample plots. The experimental variogram and fitted variogram models are then used for interpolation in a spatial domain employing kriging methods, from which ordinary kriging is the most widely used method. The advantage of geostatistical interpolation is that it provides us with the information about the estimation error (Scheer and Sitko, 2005). An example of such a regionalization of tree species diversity degree from regional forest inventory data was presented by Merganič et al. (2004). Similarly, by combining ground and satellite IKONOS data Scheer and Sitko (2005) regionalized timber growing stock. Wallerman (2003) examined the applicability of different kriging methods as well as the Bayesian state-space model for the prediction of stem volume per hectare using Landsat TM and field sampled data. The author compared the prediction accuracy of the analyzed methods with Ordinary Least Squares regression using only RS data. Based on his results, ordinary and simple kriging methods seem promising because of the large reduction of root mean square error and other practical aspects. Although the Bayesian state-space model did not provide improved prediction, this model may be of use in higher complexity modeling (Wallerman 2003).

(4) Identification and mapping of specific areas

A number of works presented how RS can help in identification, mapping, and monitoring of areas of specific interest. For example, Kozak et al. (2007) quantified changes of forest cover in the Carpathians using Landsat images for the years 1987 and 2000, while the single-date forest-non-forest maps were derived with the help of ancillary data, i.e. CORINE Land Cover and the Shuttle Radar Topography Mission digital elevation model. In urban and peri-urban areas in Sweden colour infrared aerial photographs have been interpreted in stereo models to obtain spatial and temporal information on biodiversity necessary for spatial planning for biodiversity (Groom et al., 2006). Groom et al. (2006) also presented that RS data can be used for mapping and monitoring disturbances in mountain vegetation cover. "Fires can be monitored and analysed over large areas in a timely and cost-effective manner by using satellite sensor imagery in combination with spatial analysis as provided by Geographical Information Systems” (Sunar and Özkan, 2001).

Fuller et al. (1998) combined field surveys of plants and animals with satellite remote sensing of broad vegetation types in order to map biodiversity. Using a statistical classifier, they produced a land cover map from satellite images (Landsat TM), on which 14 land-cover classes were identified. Validation of this clasification recorded 86% correspondence between field and map data. “The species data were used to generate biodiversity ratings, based on species `richness' and `rarity', which could be related to the vegetation cover. This inter-relationhelped to generate a biodiversity map of the Sango Bay area which has since been used to aid conservation planning” (Fuller et al., 1998). “Debinski et al. (1999) had used remotely sensed data and GIS to categorize habitats, and then determined the relationship between remotely sensed habitat categorizations and species distribution patterns” (Roy and Behera, 2002).

According to Nagendra (2001), direct estimations of spectral radiance values may be useful for indicating areas with different levels of species diversity. While this technique “provides indicators for further data collection on the ground, relationships between spectral values and species diversity may have to be calculated afresh for each image, thereby reducing its generality” (Nagendra, 2001).

(5) Prediction of species distribution

“Remote sensing, geographic information systems (GIS) and spatial modelling in combination make a rapid tool for converting species observations to predictions of current or future species ranges based on environmental surrogates. When analyzing species distributions varying spatial scales, different environmental surrogate variables are considered important. General climatic variables are utilised for defining global scale niches of species and habitats (Peterson & Vieglais, 2001; Pearson & Dawson, 2003) while topographic and geologic variables are taken into account at more limited, regional scales (Thuiller et al., 2003). At landscape scales, patterns and dynamism of land cover (Griffiths & Lee, 2001), vegetation (Austin, 1999) or land use are regarded (Dale et al., 2000, Vellend, 2004 in Toivonen, 2005)”.

Luoto et al. (2002) predicted plant species richness using generalized linear modeling (multiple regression models), environmental variables derived from Landsat TM images and topographic data extracted from a digital elevation model. According to this study, “utilization of satellite imagery and GIS to study and predict vascular plant species rich-ness shows promise for revealing distributional patterns that might not otherwise be apparent”. Multiple regression models have also been used to study avian species richness, while climatic variables (precipitation, temperature, radiation etc.), topography, ecosystem diversity estimated as the number of ecosystems per quadrat from a map of global ecosystems, and latitude were used as independent variables (Rahbek and Graves, 2001).

Accurate, remote sensing based habitat maps, in conjunction with detailed information on species requirements on habitat, can generally be used to model the distribution of species (Nagendra, 2001). “In a detailed analysis in the tropical forests of the Western Ghats of India, Nagendra and Gadgil (1999b) mapped a landscape into seven habitat types ranging from secondary evergreen forests to paddy fields, using supervised and unsupervised classification of IRS 1B LISS 2 satellite imagery. Plant communities (angiosperms excluding grasses) distributed in these habitat types were surveyed in the field using 246 plots of 10 m by 10 m. Habitat types could be identified on the basis of supervised classification with an accuracy of 88%, and plots belonging to different habitat types differed significantly in their species composition ($p<0.05$)” (Nagendra, 2001). According to Nagendra (2001), “the degree of correspondence between habitat maps and species distributions depends on the degree of habitat map generalization” (Nagendra, 2001). For biodiversity assessment, habitat mapping appears limited to the scale of tens of kilometres (He et al., 1998), because “species diversity varies not only between, but also within habitats” (Nagendra, 2001).

Buehler et al. (2006) successfully modelled cerulean warbler (Dendroica cerulea) habitat from remotely sensed vegetation and landform data based on the Mahalanobis distance statistics

D2. “D2 is a measure of dissimilarity and represents the difference in the standard multivariate squared distance between the ideal cerulean location and other locations on the study area (Clark et al., 1993)” (Buhler et al., 2006). Seven explanatory variables (average solar exposure pre year, d istance to nearest stream, elevation, slope, relative slope position, terrain relative moisture index, coverage of mature decidous forest) were selected a priori with regard to cerulean habitat requirements. The coverage of mature (>30 years old) deciduous forest was derived through a supervised classification of LandSat TM satellite imagery. Elevation was taken from the United States Geological Survey digital elevation model. A slope coverage was generated using the ArcGIS Spatial Analyst SLOPE command, and the remaining variables (average solar exposure pre year, distance to nearest stream, relative slope position, terrain relative moisture index) were calculated in ArcInfo. The model was developed in ArcView (Environmental Systems Research Institute, Redlands, California) extension (Jenness Enterprises, Flagstaff, Arizona), while the known cerulean locations mapped in the field represented the response variable. After the model was developed, a cutoff vaue of the Mahalanobis distance was selected so that it “maximized the difference in cumulative frequency between the cerulean locations and the study area as a whole (Browning et al., 2005). By setting the cutoff value in such a manner, we maximized the ability of the model to discriminate between cerulean habitat and conditions available on the rest of the study area” (Buehler et al., 2006).

The potential of different remote sensing indices to describe and monitor species richness was examined by Koch and Ivits (2004) using the data sampled within the BioAssess project. Within this research a fused Landsat-IRS image was selected as a standard dataset. “Furthermore, a digital elevation model (DEM) in 25 m resolution and a digital surface model (DSM) in 1 m spatial resolution was included in the study using information like slope, aspect, curvature, and texture”. A hierarchical segmentation based classification scheme based on the CORINE database was used. With this scheme, the segments were classified into two levels: (1) project coarse level, (2) country level based on country specific characteristics. “Extracted classes from visual interpretation and segmentation-based classification were used to quantify the land use intensity gradient and to calculate landscape indices”. The calculated landscape metrics were then related to terrestrial based species diversity indices. “Stepwise linear regression was applied to model species richness for woody plants, carabids and birds as dependent variable”. The results of the analysis showed that “the derived remote sensing indices showed good potential in predicting species diversity data” (Koch and Ivits, 2004).

Griffiths et al. (2000) who examined the potential to predict plant diversity only from landscape structure measures derived from remotely sensed data presented that the results obtained from such a model proved difficult to interpret, which “highlighted the need to obtain data on both landscape quality and landscape structure”. “The key habitats of species can be identified by combining satellite- and field-based habitat data, landscape structure and species abundance information (Saveraid et al., 2001; Scribner et al., 2001)” (Kerr and Ostrovsky, 2003).

(6) Development of indicators

“The ENVIP Nature project is an example of the application of remote sensing and GIS techniques in landscape ecology and conservation biology, targeted at the development of indicators for nature conservation” (Groom et al., 2006). Within this project, the indicators for the criteria ‚naturalness‘, ‚vulnerability‘, and ‚threat‘ have been developed based on the analysis of the extent, spatial configuration and selected shape parameters of the habitat map (Groom et al. 2006).

2.4.6. Downscaling

The term downscaling (named also disaggregation in McBratney, 1998, Rajat-Bindlish and Barros, 2000, Hopmans et al., 2002, Arnell et al., 2004, Bougadis and Adamowski, 2006 or top-down approach in Gon et al., 2000; Roy and Behera, 2002) refers to transfering information estimated/obtained at a very large scale to a fine resolution (Seem, 2004) in such a way that "it can be interpreted in light of local circumstances" (Riitters, 2005).

According to Tatl et al. (2004), downscaling is a solution of the problems that arise when modelling interconnections between global and regional scales, "such as prediction of regional, local-scale climate variables from large-scale processes" (Tatl et al., 2004). Downscaling coarse resolution data is particularly useful for impact assessment studies (Miller et al., 1999), because such data are an inadequate basis for the assessments (e.g. of the effects of climate change on land-surface processes) at regional scales (Wilby et al., 1999). This is because the resolution of data sources (e.g. of Remote Sensing sensors, General Circulation Model GCM, etc.) is too coarse to resolve important sub-grid scale processes and because the output of specific models (e.g. GCM) is often unreliable at individual and sub-grid box scales. By establishing relationships between grid-box scale indicators and sub-grid scale predictands, downscaling represetns a practical means of bridging this spatial difference (Wilby et al., 1999).

The term downscaling is most often used in climate studies. In this field, there exists a number of different downscaling methods "from simple interpolation to more sophisticated dynamical modelling, through multiple regression and weather generators" (Prudhomme et al., 2002). They are divided into two main categories with regard to the approach used:

- statistical (empirical) downscaling

In climate studies, statistical downscaling relates large-scale circulation patterns to local weather records (Bugmann et al., 2000). "Statistical downscaling (SD) methods apply climate variables from General Circulation Models (GCMs) to statistical transfer functions to estimate point-scale meteorological series" (Diaz-Nieto and Wilby, 2005). "Statistical downscaling adopts statistical relationships between the regional climate and carefully selected large-scale parameters (von Storch et al., 1993; Wilby et al., 2004; Goodess et al., 2005). These relationships are empirical (i.e. calibrated from observations) and they are applied using the predictor fields from GCMs in order to construct scenarios" (Schmidli et al., 2007).

"Several SD methods have been proposed in recent years" (Nguyen et al., 2006). From general statistical methods, regression models (Murphy, 2000; Schoof and Pryor, 2001; Wood et al., 2004; Spak et al., 2007), and artificial neural network (ANN) (Schoof and Pryor, 2001; Harpham and Wilby, 2004; Harpham and Wilby, 2005; Khan et al., 2006) are most popular, but other methods are also applied. In the last IPCC report, three regression-based methods that try to overcome the imperfection of point-wise variability of empirical downscaling were mentioned: randomization, inflation, and expanded downscaling (Burger and Chen, 2005). Mpelasoka et al. (2001) adapted ANN and multivariate statistics (MST) in order to derive changes of site precipitation and temperature characteristics. For downscaling climate model outputs for use in hydrologic simulation Wood et al. (2004) applied three SD methods: linear interpolation, spatial disaggregation, and bias-correction and spatial disaggregation. The K-nearest neighbour (K-nn) as an analog-type approach is used in Gangopadhyay et al. (2005). Other popular specific SD methods in climatic and hydrologic studies are based on the Statistical Downscaling Model (SDSM) (Nguyen et al., 2006; Harpham and Wilby, 2005; Khan et al., 2006), which is a conditional resampling method (Harpham and Wilby, 2005), and the Stochastic Weather Generator (LARS-WG) (Nguyen et al., 2006; Khan et al., 2006).

- dynamical downscaling

"Dynamical downscaling uses regional climate models (RCMs) to simulate finer-scale physical processes consistent with the large-scale weather evolution prescribed from a GCM (Giorgi et al., 2001; Mearns et al., 2004)" (Schmidli et al., 2007). While statistical downscaling methods are based on empirical models, regional models explicitly describe the physical processes affecting climate (Giorgi, 2001). "These models are able to generate a dynamically consistent suite of climate variables, but there is significant uncertainty in parameterization of sub-grid-scale processes, and the computational costs of RCMs are high" (Spak et al., 2007). There exists a number of RCMs developed by different institutes that cover different parts of the world (see e.g. Schmidli et al., 2007; Spak et al., 2007). The RCMs have also been used to derive hydrologic model (Wood et al., 2004; Payne et al., 2004).

In addition, Bouwer et al. (2004) identified kriging as a spatial downscaling technique.

In biodiversity studies, the term downscaling is not as common as in the papers dealing with climate and hydrology, although the scaling problem has been recognised by several authors (see e.g. Nagendra and Gadgil, 1999; Kerr and Ostrovsky, 2003). Roy and Behera (2002) used the term "top down" approach instead and identified its four main features: (1) stratified approach, (2) extrapolation on large areas, (3) systematic monitoring, (4) spatial environmental database.

Although it is generally accepted that for large-scale biodiversity assessments "remote sensing is by far the best technique to gather information on large areas" (Jongman et al. 2006), because, when compared to other survey techniques, remote sensing is "unique in its possibilities for providing census data, i.e.complete large area coverage that can complement sample data" (Inghe, 2001 in Groom et al., 2006), the information gathered in this way is constrained by the resolution of the sensor (Jongman et al., 2006). Therefore, in the downscaling process the image data need to be combined with ancillary information. For example, in the ENVIP Nature project, a ‚normal' land cover map was transformed into an ecologically meaningful data set called the ‚broader habitat map' using ancillary GIS data such as digital terrain model or specific management information derived from topographical maps (forest road network, tourist hot spots) (Groom et al., 2006). Similarly, in order to derive the forest-non-forest maps from Landsat imagery, Kozak et al. (2007) used a digital elevation model and the Corine Land Cover data.

Riitters (2005) demostrated downscaling using the results of U.S. national assessments from land-cover maps that were derived from satellite imagery (Landsat Thematic Mapper). The author identified the map extent, map resolution in terms of the land cover classes, and the "habitat model" as candidates for downscaling.

"Considering map extent, it is trivial to examine the indicator values at any particular location, or to summarize the values within and arbitrary map extent such as watershed" (Riitters, 2005).

Considering resolution, more specific land cover classes can be identified for a specific analysis using either the original map or local maps that can provide more detailed thematic resolution (Riitters, 2005).

The author identified the most opportunities for downscaling in the domain of the habitat model. A moving window device was used to measure habitat structure characterized by habitat amount and habitat spatial pattern (connectivity). "A moving window operates by moving a fixed-area window over the map so as to place a support region around each pixel" (Riitters, 2005). Habitat amount is defined as the proportion of pixels in the support region that are forest, while connectivity is estimated as the percent of {forest, forest} adjacent pixel pairs in the support region. The term support region refers to a shape and size of a moving window. "Measurements are made at each placement of the window, and the values are assigned to the location of the pixel at the center of the support region" (Riitters, 2005).

"Choosing a particular support region size based on home range size (Riitters et al., 1997) constitutes downscaling in the domain of the habitat model" (Riitters, 2005). "Scaling in the habitat model domain include choosing a specific indicator, or setting a threshold value for an indicator" (Riitters, 2005). Riitters (2005) presented a number of approaches how the indicators ‚habitat amount' and ‚connectivity' can be used for downscaling in the habitat model domain. Considering specific habitat or movement requirements (e.g. size, density, adjacency, corridors, etc.) of a particular species, it is possible to pre-define a threshold value for habitat amount and/or habitat spatial pattern and thus to find suitable habitats for the species.

The same sort of analysis based on the threshold value of an indicator can be combined with downscaling in the spatial domain. Riitters (2005) showed how the reduced map extent affects the results of the analysis. While for reasonably large extents (e.g. millions of hectares) the types of trends are usually monotonic, "for smaller extents (e.g. thousands of hectares), departures from monotonic forms create the opportunity for very localized interpretations of structure” (Riitters 2005).

Although with the moving window device any indicator can be measured, according to Riitters (2005) the amount and connectivity of habitat seem to be sufficient, while other indicators, e.g. those obtained from a patch-based approach, such as perimeter-area ratio, or amount of core forest, can be recovered from a moving window analysis by combining the two mentioned indicators.

Another approach how to identify suitable habitats for a species of interest was presented by Buehler et al. (2006), who developed the Mahalanobis distance statistic model of potential habitat for cerulean warbler (for details see Chapter 4.5.2, point 5).

As an alternate method to the moving window, Vogt et al. (2007a) used morphological image processing for mapping land-cover spatial pattern. Classification algorithm is here “defined by a sequence of logical operations such as union, intersection, complementation, and translation using geometric objects called ‘structuring elements’ (SE) of pre-defined shape and size” (Vogt et al. 2007a). In their work, Vogt et al. (2007a) consider two structuring elements SEs: an 8-neighbourhood (SE1) and a 4-neighbourhood (SE2), that pre-define which and how many pixels around the examined (center) pixel are accounted for in the analysis. In addition, the shape and dimension of SEs also define the direction and extent of the morphological operations. The authors used two operations: the ‘erosion’ that shrinks regions of forest and the ‘dilation’ that expands them. The image processing starts with the forest - non-forest map, in which core forest is identified by applying erosion on SE1. It means that “the center pixel of SE1 is core forest if all eight neighbors are forest” (Vogt et al., 2007a). Similarly, patch, edge, and perforated forests were detected in successive steps. The result was a forest pattern map with four classes: core, patch, edge, and perforated forest (Vogt et al., 2007a). The comparison of the morphological image processing and image convolution (i.e. window approach) revealed that the morphological approach is more accurate at the pixel level. Hence, “summary statistics and trend analyses at landscape level will also be more accurate. These improvements will allow an unsupervised and precise spatial pattern analysis at both, the pixel and landscape level” (Vogt et al., 2007a).

Vogt et al. (2007b) presented an extension of the described morphological image processing for identifying and pixel-level mapping of structural corridors. In this paper, the authors applied a more detailed clasification of land cover, since they considered nine classes of forest pattern including corridors. Apart from the two fundamental operations used in the previous study, an additional morphological operation known as ‘skeletonization’ (Calabi and Hartnett, 1968 in Vogt et al., 2007b), that refers to “a process which iteratively removes the boundary pixels of a region to its line representation” (Vogt et al., 2007b), was used in this application. The paper shows “how the approach can be used to differentiate between relatively narrow (‘line’) and wide (‘strip’) structural corridors by mapping corridors at multiple scales of observation, and indicate how to map functional corridors with maps of observed or simulated organism movement” (Vogt et al., 2007b).

In forestry, regression models are often used to estimate properties of a single tree, a stand or a whole region. The models are “usually developed to estimate a measure which is expensive, slow or even impossible to gauge, such as a height or volume of a tree. Normally these variables are predicted with models, which are estimated from a sample of the population in question or from another similar kind of population” (Räty and Kangas, 2007). If a regression model was fitted to a large study area, it may have poor statistical properties when applied to smaller sub-regions. Räty and Kangas (2007) presented an approach how to localize general regression models. The authors understand under the term ‚localization‘ a refitting (or adjusting) of the original model to the sub-area data in order to improve the estimates of the model parameters, while no new elements (e.g. variables) are added to the model. The necessity for a localization is indicated by the performance of the residuals of the model. “If there is a global trend in the residuals, the localization is surely worthwhile. A global trend means a change in the residual values which follows spatial location in the area. A global trend is a phenomenon which is on average true”. For the selection of localization areas, Räty and Kangas (2007) used the local indicators of spatial associations (LISA) derived from global indices Moran ’s coefficient I and Geary ’s ratio c. “LISAs were calculated from the residuals of a form height regression model,which was fitted to the original data". The improvement of the model performance in localization versus global fitting was measured with a standard deviation, a root mean square error (RMSE) of model residuals, and a relative bias. The study revealed that the localization removed the local bias of the global model.

According to Räty and Kangas (2007), "another method could be a localization based on kriging. A variogram could be used to determine an appropriate size for a localization area. However, the simplicity of the LISA method may then be lost".

2.4.7. Conclusion to bibliographic review

On the basis of the information fount in this bibliographic review we have been able to set up the final procedre for the implementation phase of the project.

The basic idea of the project is to downscale biodiversity related information from the landscape level (spatial pattern information acquired a on the basis of forest maps) to site level based on field data acquired within NFI. This approach is speculative since the relationship of biodiversity related information acquired at the two different levels is, from the literature, clear just on a theoretical point of view. No clear direct relationships have been proved to exist until now If this relationships will be proved to exist a clear ecological meaning could be associated to landscape analysis results.

On the basis of the literature review we have been able to select biodiversity related information to be acquired both at landscape level and at site level. Since the project is based meanly on the use of already existing data, this selection had to take care of the real availability of data.

At landscape level we decided to focus the analysis on the use of fragmentation/connectivity method provided by the GUIDOS software developed by JRC.

At site level we decided to focus the analysis on the use of a set of forest biodiversity indicators related to five different core variables: forest types, deadwood, naturalness, forest structure and stand age.

3. TEST AREAS

The partners of the consortium represent five biogeographical regions (Figure 6): Alpine, Atlantic, Boreal, Continental, Mediterranean (Table 11).

COUNTRY NAME	COUNTRY CODE	BIOGEOGR. REGION
ITALY	IT	MEDITERRANEAN
CZECH REPUBLIC	CZ	CONTINENTAL
GERMANY	DE	ATLANTIC
SWITZERLAND	CH	ALPINE
SWEDEN	SE	BOREAL

Table 11: List of Country code and biogeographic region.

Each partner selected one or more test sites for which both forest maps coverage and Forest Inventory data are available. The selection of this areas was carried out by each partner of the consortium with the coordination of AISF and in open discussion with JRC.

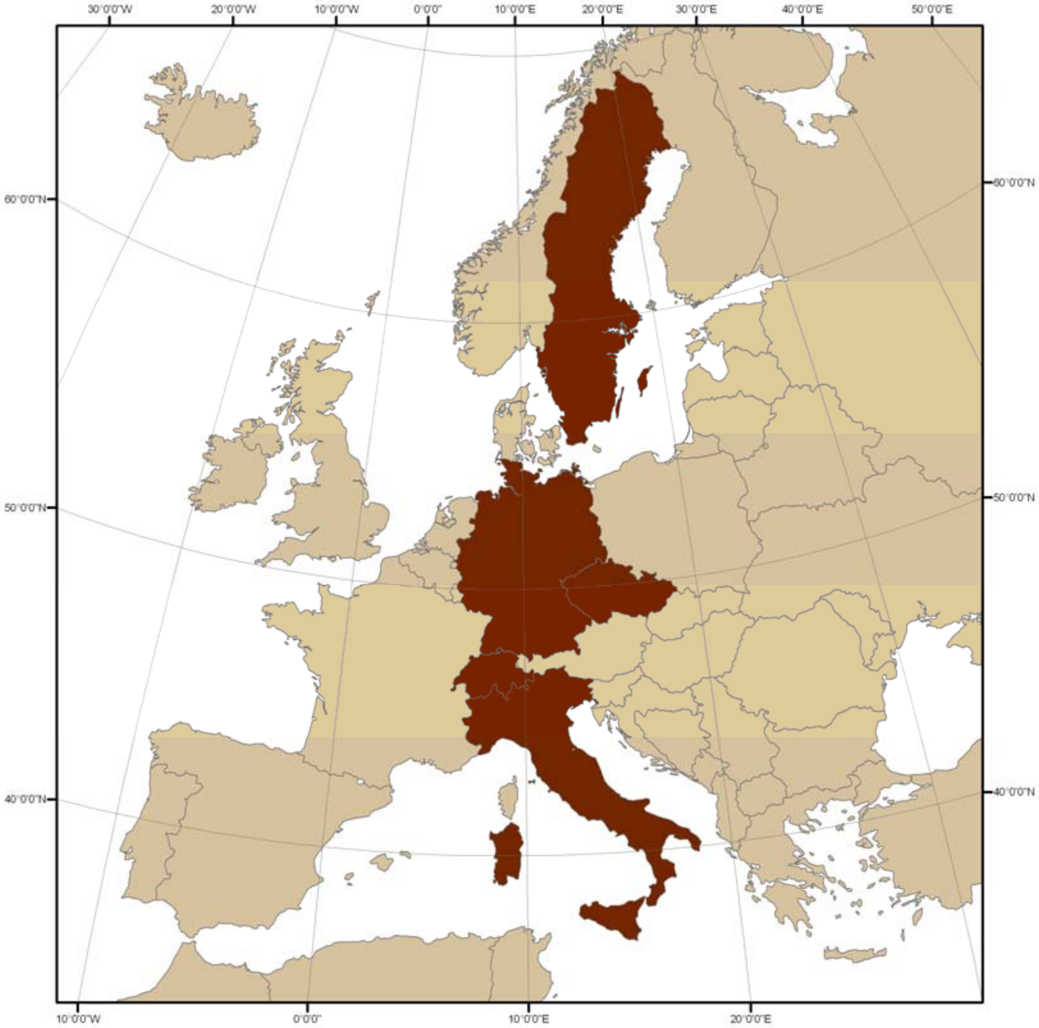


Figure 6: Country involved in the project.

3.1. Test data for the Mediterranean test site (Italy)

- **NFI data**

NFI plots are located on the basis of a non-aligned systematic sampling based on a grid of 1 x 1 km. Data are available for the year 2006.

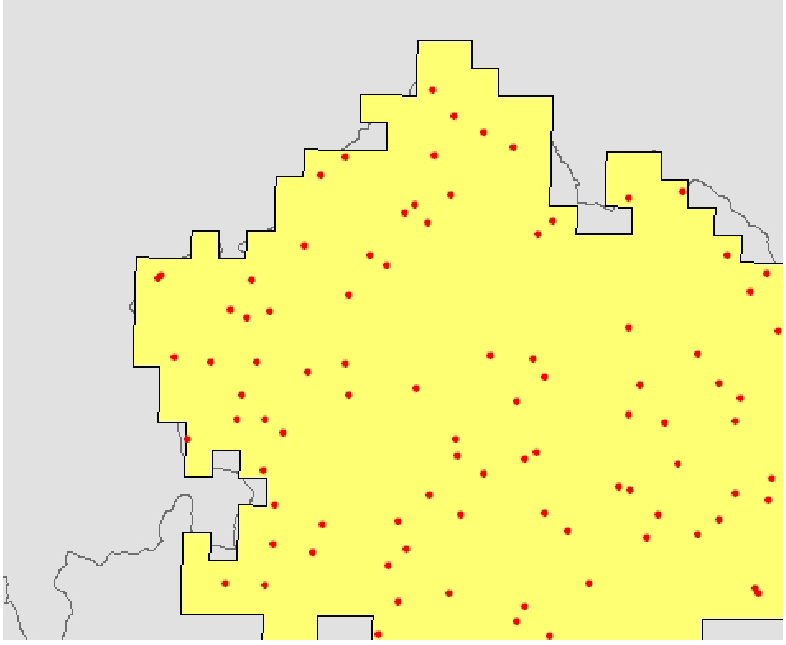


Figure 7: An example of Inventory plots distribution in Italy.

- **Multitemporal forest maps**

Forest maps adopted in this area comes from the Corine Land Cover project. Corine Land Cover 1990 and 2000 are developed at a IV legend category level with 12 classes (white fir/norway spruce, chestnut, exotic conifers, beech, exotic broadleaf, hygrophilous broadleaf, mediterranean broadleaf, holm oak, high maquis, mediterranean pines, mountain pines, other oaks). Minimum mapping unit of 20 ha.

Several high resolution forest maps are also available (scale from 1:10.000 to 1:50.000) at the dates: 1936, 1954, 1992, 2006. They have originally different systems of nomenclature with several forest categories: 6 in 1936, 5 in 1954, 12 in 1992 and 36 in 2006.

1936	1954	1992	2006
Chestnut	Chestnut (for fruit production)	Chestnut (for fruit production)	Primitive Quercus ilex
Beech	Artificial coniferous plantations	Quercus ilex	Termophilus Quercus ilex
Quercus robur or Quercus petrea	Other broadleaf	Quercus pubescens	Mesoxerophilus Quercus ilex
Degradeted forest	Other coniferous	Carpinus-Ornus ssp	Secondary Quercus pubescens
Coniferous	Mixed coniferous-	Riparial forests	Termophilus Quercus

	broadleaf		pubescens
Other, mixed		Quercus cerris	Mesoxerophilus Quercus pubescens
		Chestnut	Mesoxerophilus Quercus cerris
		Beech	Mesophilus Quercus cerris
		Mediterranean coniferous	Acer-Fraxinus-Tillia ssp
		Mixed Mediterranean coniferous-broadleaf	Primitive Carpinus-Ornus ssp.
		Mixed mountain coniferous-broadleaf	Secondary Carpinus-Ornus ssp.
		Artificial coniferous plantations	Mesoxerophilus Ornus ssp.
			Mesophilus Ornus ssp.
			Chestnut
			Abies alba
			Submountain beech
			Mountain beech
			High mountain beech
			Riparial forest
			Robinia-Ailantus
			Plantations (according to species)
			OWL (in five classes)

Table 12: Systems of nomenclature of the forest maps.

3.2. Test data for the Continental test site (Czech Republic)

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- **NFI data**

NFI plots are located on the basis of a randomized systematic sampling (randomization up to 300 m from basic grid intersections) based on a basic grid of 1.4 x 1.4 km. Plots are grouped in clusters (2 circular plots of 500 m^2 connected by 300 m transect). Data are available for the year 1996 (first survey) and 2005 (second survey).

Figure 8: NFI plots distribution in a Czech test area.

- **Multitemporal forest maps**

The multitemporal forest maps available are developed within Corine Land Cover Project. Corine Land Cover 1990 and 2000 are developed at a III legend category level with detailed information about species composition (see Table 13). Minimum mapping unit is 100*100 meters (1ha MMU).

Two forest management plan (FMP) are also available with detailed information about species composition, species share and mean age. Those maps could be re-classified into defined classes. First FMP is from 1991-1994, second one from 2001-2004.

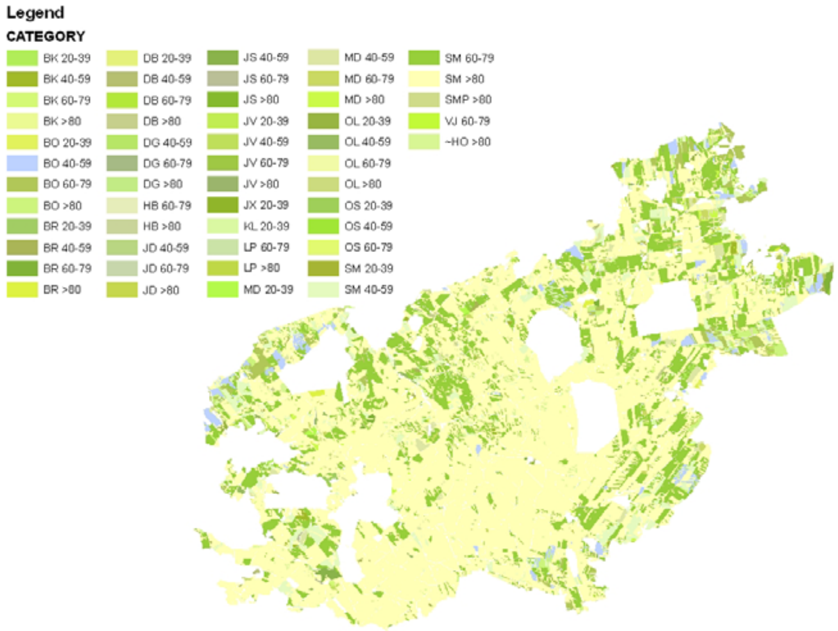

Figure 9: Example of re-classification of FMP map in a Czech test area.

For some study areas are also available orthophoto (COT format, 0,5 m/pixel) from 2006 and Digital Elevation Model (DEM) with resolution 6 x 6 m.

Latin name	**English name**	**ICP code**
Fagus sylvatica	European Beech	036.001.001
Pinus sylvestis	Scotch Pine	026.007.007
Pinus nigra	European Black Pine	026.007.006
Betula pendula	European Birch	034.001.001
Quercus petraea	Sessile Oak	036.004.011
Quercus rubra	Red Oak	036.004.001
Quercus robur	Pedunculate Oak	036.004.014
Pseudotsuga menziesii	Douglas Fir	026.002.001
Carpinus betulus	European Hornbean	035.001.001
Abies alba	Silver Fir	026.001.006
Abies grandis	Grand Fir	026.001.002
Salix caprea	Goat Willow	031.001.041
Sorbus acuparia	European Mountain Ash	080.028.002
Fraxinus excelsior	European Ash	139.004.003
Acer platanoides	Norway Maple	095.001.001
Acer pseudoplatanus	Sycamore Aple	095.001.005
Tilia cordata	Small-leaved Linden	105.001.005
Larix decidua	European Larch	026.005.002
Alnus glutinosa	Common Alder	034.002.002
Alnus incana	Speckled Alder	034.002.004
Populus tremula	European Aspen	031.002.004
Picea abies	Norway Spruce	026.004.001
Picea pungens	Blue Spruce	026.004.005
Pinus strobus	Eastern White Pine	026.007.018

Table 13: list of species for the Czech test areas.

3.3. Test data for the Altantic Test Site (Germany)

The study area for the Atlantic Biogeographical region is located in northern Germany (Federal State of Lower Saxony, Figure 10).

- **NFI data**

NFI plots are based on the Gauß-Krüger coordinate system on a grid of 4 x 4 km. Data are available for the years 1988 and 2002. Each plot is a quadrate with side of 150 meters and four subplots in each corner.

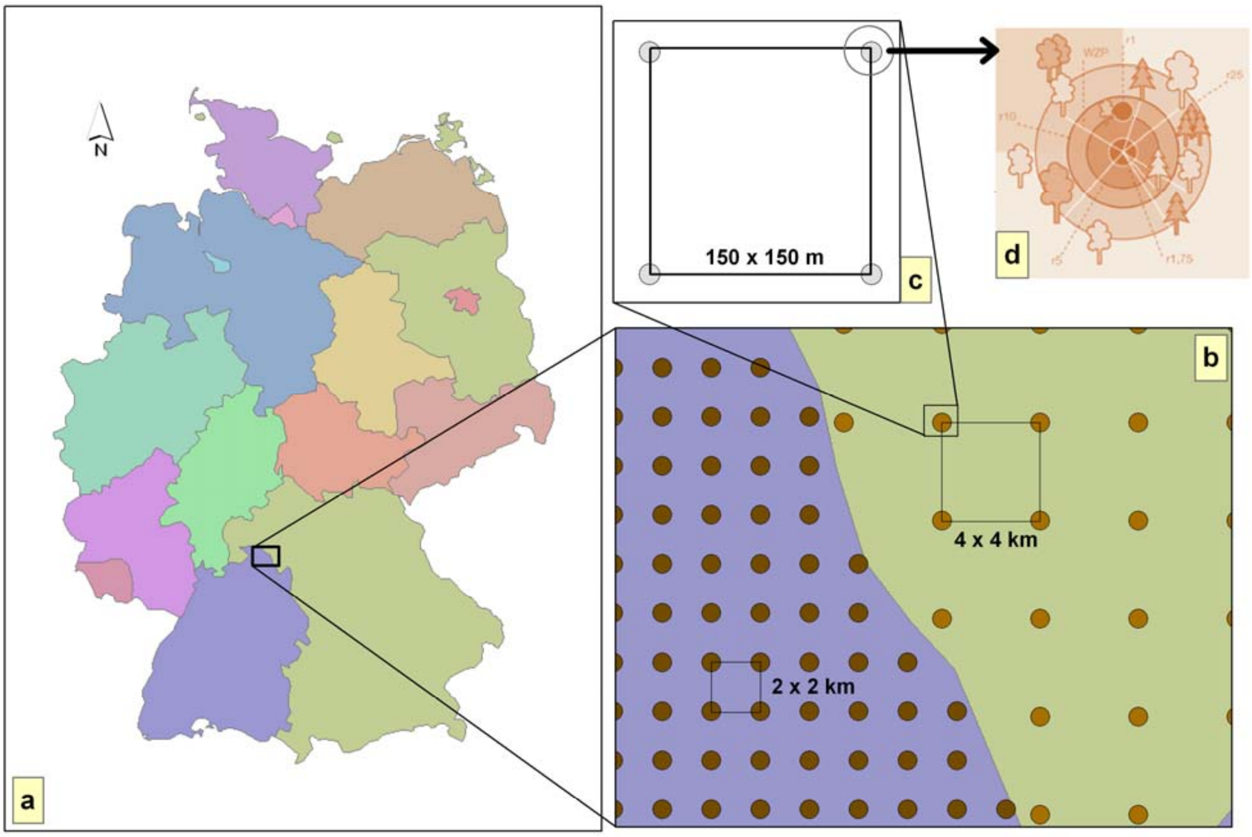

Figure 10: Germany study area location and NFI plots distribution.

- **Multitemporal forest maps**

Two multitemporal forest maps developed within the Corine Land Cover project are available. Corine Land Cover 1990 and 2000 are developed at IV legend category level with several forest categories (acidophilous oak-birch forests; beech forests; floodplain forests; mesophytic decidous forests; mire and swamp forests; nemoral coniferous and mixed broadleaved-coniferous; non-riverine alder, birch or aspen forests; other mixed and broadleaved forests; plantations). The MMU is 10 ha.

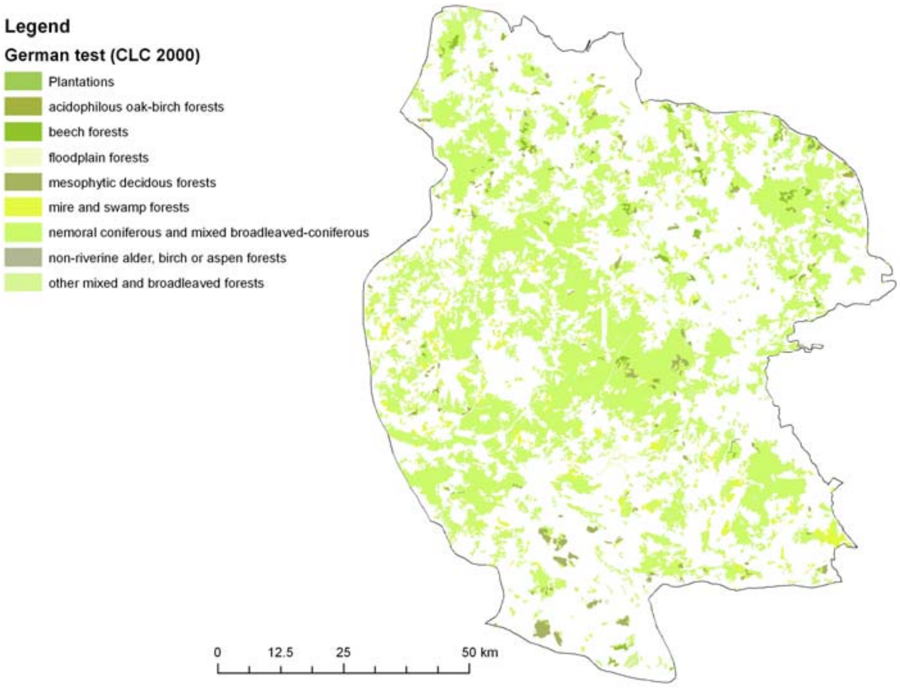

Figure 11: CLC 2000 maps in German test area.

3.4. Test data for the Alpine Test Site (Switzerland)

The study area is located in north-eastern part of Switzerland (

Figure 12).

- **NFI data**

1. NFI plots are located on the basis of a systematic sampling based on a grid of 0.5 km x 0.5 km. Data are available for the years 2000's.
2. NFI plots for 1990's
3. NFI plots for 1980's

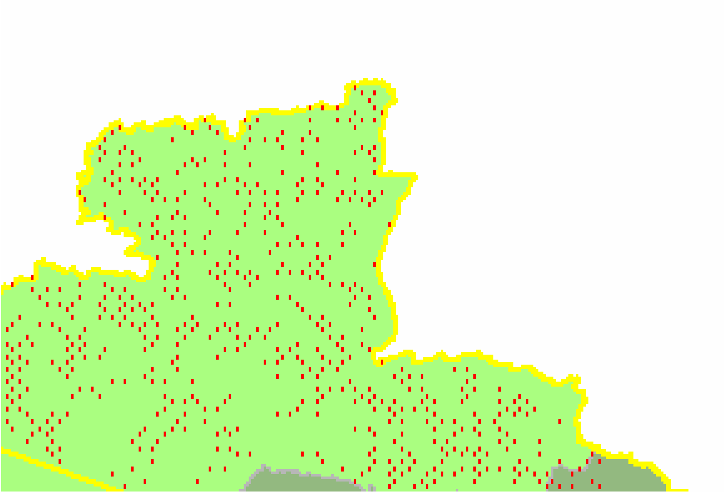

Figure 12: Example of plots distribution in Switzerland study area.

- **Multitemporal forest maps**

For the study area two different types of forest maps are available.

1. Forest from topographic maps 1:25'000 (forest - non forest)
2. Forest map derived from Landsat images with 2 different scales; 25m, 100m

Database: 1990 -1992; 4 classes (mixture degree).

3.5. Test data for the Boreal site (Sweden)

The study area is located in the northern parts of Sweden and correspond (Figure 13).

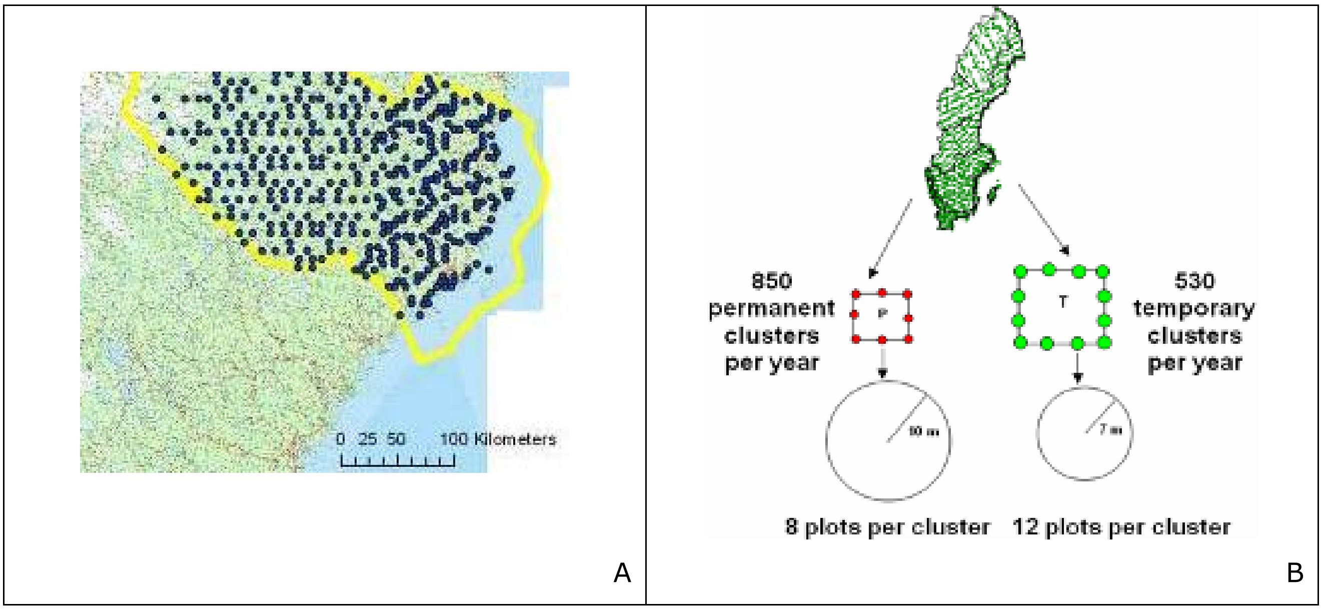

Figure 13: Example of Sweden study area plots distribution (A) and structure (B).

- **Multitemporal forest maps**
  - CORINE database according to EEA definitions, minimum mapping unit (MMU) 25 ha, base year 2000.
  - National refinement of the CORINE database with 7 forest classes (Clearcut or sparse forest; Pinus sylvestris and Pinus contorta; Picea abies; Birch and other deciduous; Mixed coniferous forest; Mixed deciduous forest; Mixed forests), MMU 1,0 ha, base year 2000.
  - kNN data base with estimated forest variables, based on 25*25 m pixels Landsat TM data and NFI plots, base year 2000.
  - kNN data base with estimated forest variables, based on 10*10 m pixels SPOT 5 HRG data and NFI plots, base year 2005.

4. MAPS HARMONISATION

In order to compare the analysis at landscape level all the forest maps have been harmonised following the same rules.

All the maps have been rasterized with two different resolutions. When the scale of the original vector map was around 1:10.000 or 1:25.000 we adopted a pixel size of 25 m, when the scale was around 1:100.000 we adopted a pixel of 100 m. The maps are projected in ETRS-LAEA (pan-European CRS with datum ETRS89 in European lamberth azimuthal equal area projection).

When possible we have reclassified all the available maps developed with different systems of nomenclature according to the EU Forest Types system of nomenclature (category level) developed by EEA (2006).

The overall situation of forest maps is reported in the following Table.

	COUNTRY	DATE	PIXEL SIZE	NOMENCLATURE	Availability in FTP site
CH	Switzerland	1990	25 m	4 classes: 1. coniferous 2. broadleaves 3. mixed with prevalence of coniferous 4. mixed with prevalence of broadleaves	yes
		2000	25 m	forest - no forest	yes
CZ	Czech Republic (test area 1)	1990	100 m	EEA	yes
		2000	100 m	EEA	yes
		1993	25 m	EEA	yes
		2003	25 m	EEA	yes
	Czech Republic (test area 2)	1990	100 m	EEA	yes
		2000	100 m	EEA	yes
		2000	25 m	EEA	yes
DE	Germany	1990	25 m	EEA	yes
		2000	25 m	EEA	yes
IT	Italy (testa area 1)	1936	25 m	EEA	yes
		1980	100 m	EEA	yes
		1990	100 m	EEA	yes
		2000	100 m	EEA	yes
	Italy (testa area 2)	1936	25 m	EEA	yes
		1954	25 m	EEA	yes
		1980	100 m	EEA	yes
		1990	100 m	EEA	yes
		1992	25 m	EEA	yes
		2000	100 m	EEA	yes
		2005	25 m	EEA	yes
SE	Sweden	2000	25 m	EEA	not yet
		2005	25 m	EEA	not yet

Table 14: situation of forest maps availability after the harmonisation process (at 03/03/2008).

5. HARMONISATION OF NATIONAL FOREST INVENTORIES

National Forest Inventories (NFI) have traditionally been designed to assess the productive functions of forests. During the last decades, the demand and need for information on non-productive forest functions has increased. A primary information need is an harmonised assessment of the current state and of the trends in time of forest biodiversity. NFIs are conducted in many European countries and may contribute with relevant information for describing aspects of forest biodiversity in Europe.

National forest inventories are participating within the European Cooperation in the field of Scientific and Technical Research (COST) program Action E43 "Harmonisation of National Forest Inventories in Europe: techniques for common reporting". 27 countries in Europe, the United States of America, and New Zealand have joined the COST action E43 with the aim of improving and harmonizing the existing national forest resource inventories in Europe. This initiative has been driven by the need to meet national, European and global level requirements in supplying up-to-date, harmonised and transparent forest resource information for policy making, and to promote the use of scientifically sound and validated methods in forest inventory designs, data collection and data analysis.

In COST action E43 "Harmonisation of National Forest Inventories in Europe: Techniques for Common Reporting" the Working Group 3 (WG3) is working on the harmonisation of information acquired in the field by NFI potentially useful for forest biodiversity assessment.

The objectives of this group are threefold:

1. to develop a general European-wide agreement on the most important variables (core variables) or proxy variables acquired in NFIs for reporting on forest biodiversity;
2. comparing methods used in the field in NFIs for acquiring information used for calculating selected core variables;
3. to develop reference definitions and methods for measuring the selected core variables in the field and to define methods for harmonising existing NFI measurement data for the selected core variables to facilitate European-wide comparisons (i.e., to find bridging functions);
4. to test bridging functions data and other harmonisation techniques to make comparable existing available NFI data.

The first part of the work done in WG3 of COST action E43 was devoted for selecting core variables that could be used operatively for forest biodiversity assessment within NFIs all over Europe and USA. On the basis of a questionnaire answered by NFI representatives it was possible to understand for each biodiversity variable how often it is assessed in NFI programmes and, for each NFI programme, how many biodiversity variables are assessed in the field.

The questionnaire addressed 41 forest variables potentially related to forest biodiversity. This initial selection of the variables was driven by the information requirements of international agreements, mainly the Convention on Biological Diversity (CBD 1992, UNEP 2003) and the indicators for sustainable forest management established by the Ministerial Conference on the Protection of Forest in Europe (MCPFE 1997, 2003 a and b), we took into consideration also the Biodiversity Evaluation Tools for European Forests developed in the BEAR project (Larsson 2001), and the European Environmental Agency Core Set Indicators for Biodiversity and Nature Protection (EEA 2003).

The questionnaire had three primary objectives:

i) to select robust and feasible variables from forest biodiversity assessment in current NFIs, ii) to evaluate the relevance of different components of forest biodiversity,

iii) to get an overview of the main differences between countries in terms of number and type of forest biodiversity variables assessed in NFI.

On the basis of the COST action E43 WG3 questionnaire the 41 forest variables were ranked on the basis of their potential usefulness in monitoring different component of forest biodiversity, detailed results of the questionnaire are in Winter et al. (2008).

Following the ranking analysis of the questionnaire both in COST action E43 and in "downscaling" the harmonisation process was focused on a selected number of so called "core variables". In COST action E43 the selected core variables are FOREST TYPE, DEADWOOD, GROUND VEGETATION, FOREST STRUCTURE, NATURALNESS, PROTECTED FOREST, FOREST AGE, these are intended as "general chapters" for which NFI methods and definitions are acquired and harmonisation tools have to be defined and tested.

In downscaling, focusing just on five Countries, we decided to concentrate our effort on the harmonisation of biodiversity indicators forest types, deadwood, naturalness and forest structure. Protected forest was excluded because this information is not coming from the field work but can be assessed with GIS tools joining the geographical position of NFI plot with protected areas boundaries. For ground vegetation (including all non-trees vegetation) in "downscaling" we decided to acquire anyhow this information but for the moment the methods and the approaches used in the five NFIs to acquire thin information are so different to dissuade from a formal harmonisation tentative. Anyhow the data are available in the DB of the project.

Here follow, for each of the four core variables, the description and comparison of the definition and of the methods used for acquiring this information in the five NFI and a first description of the harmonisation approaches.

This by core variable detailed description is introduced by a short general paragraph dealing on the general issue of the harmonisation problem.

5.1. The harmonisation process of NFI

The harmonisation is a process to made NFI reports prepared by different Countries comparable and consistent even if the raw data acquired in the field are based on different methods and definitions. These final results can be accomplished in many different ways so in general speaking the harmonisation methods and approaches can be very different depending of the problems to be solved.

If the homogenization of NFI statistics is instead carried out changing the field work protocols and the related forest variable definitions in order to apply in different Countries the same NFI protocol, than we talk about *standardization* (Köhl et al., 2000).

The standardization is carried out defining international *standards* that have to be applied in the field in a new assessment. The standardization of NFI is a critical process because changing the definitions adopted in one NFI means to lose the comparability of new forest statistics with the previous one, if specific (and expensive) activities are not carried out in the field (for example acquiring in the same location the same variable with different definitions).

For this reason the harmonisation is less critical at Country level because it does not require to change national field methods and definitions. On the other side it is not possible, without a specific field work, to harmonize with good results all possible forest variables.

If the standardization process is based on the development of a standard, the harmonisation is accomplished on the basis of a *reference*. A reference is an intermediate definition of a forest variable useful to made comparable different national definitions available at Country level.

Instead of comparing directly the definition A the definition B it is preferable to create a reference X and to create a bridging function between A and X and B and X. This particularly true when the harmonization have to accomplished in between many definitions and method.

The harmonisation in general is based on two different types of bridging functions:

LABEL based: when two different systems of nomenclature classify in different ways the same forest attribute (a categorical forest variable) it is possible to try a label to label approach creating a relationship between each class/category of one system for each class/category of the other system. In this approach NFI data can be manipulated in an aggregated way at plot level. The system fails when a clear relationship between the two systems cannot be established.

DATA based: when a label to label approach cannot be performed it is still possible to create a relationship between raw data (not aggregated at plot level) acquired in the field.

Note that a reference is not automatically a standard. The reference is the easiest way to make comparable data acquired in two different NFIs on the basis of different methods and definitions without acquiring new data in the field. This doesn't mean that in case of a new inventory the reference will be the best option for the acquisition of new data in the field.

What we can harmonize and what we cannot harmonize

The harmonisation process in "downscaling" is carried out on existing data to make comparable information at plot level. For this reason we cannot adopt methods such as:

- the use of external standard data to correct forest statistics (for example correcting forest area estimations based on different forest definitions using a standard forest map statistics, such as CORINE). This method can be applied just on aggregated forest inventory statistics, not at plot level data as required in "downscaling";
- the use of new standardized field work to be carried out in the plots.

For these reasons in "downscaling" we will not be able to take into account some basic differences existing in the five considered NFIs such as: basic definitions (forest, trees, etc.), network design and design of the sampling units.

In "downscaling" we focus on a model based approach to evaluate the relationships between biodiversity indicators assessed in the field in NFI plots and spatial patterns variables assessed on remotely sensed derived maps, for this reason we focused just on those variables interesting for forest biodiversity assessment.

In the following paragraphs NFI country definitions and harmonisation methods are described for selected core variables. Unfortunately different tree definitions and different dimensions of sampling units adopted in the considered NFIs won't make comparable the resulting per plot statistics based in all the selected indexes.

5.1.1. Forest type in NFIs

Forest types (FT) are a flexible approach to collect and organize information on forests of a given territory, according to a typology useful for understanding differences in the character of forest ecosystems which are relevant to a specific application: e.g. evaluation of forest productivity, determination of structure and composition of potential natural vegetation, presentation of more precise forest information in a proper ecological context. Because forest types enable comparison of ecologically similar forests, they are meaningful units for stratification and reporting of NFIs data, especially concerning the assessment of forest biodiversity variables (Barbati et al., 2007).

Four of the five Partners (CH, CZ, DE, IT) have already well defined forest type systems of nomenclature in place within NFIs. Swedish NFI do not have a predefined FT schemes but the plots may be classified depending on different reporting needs.

The adoption of FT for the classification of NFI sampling units is justified by three main reasons (Table 15):

1) stratification within the NFI sampling design (different sampling intensity for different FT);
2) reporting when presenting the results of NFI (forest area or forest volume reported by FT);
3) evaluation of forest naturalness by comparison between actual and potential vegetation.

	COUNTRY				
	CZ	IT	DE	SE	CH
STRATIFICATION, REPORTING		1			
STRATIFICATION, COMPARISON ACTUAL VS. POTENTIAL VEGETATION	1			1	
NOT PRE DEFINED			1		1

Table 15: Main use of FT system of nomenclature in five Country's NFI.

The information used for defining a FT is actual tree species composition for all the investigated Countries, excepted for Switzerland where FT are referred exclusively to the potential natural vegetation (PNV, Figure 14). This classification results from a classification system base on:

- 5 production regions (Jura, Central Plateau, Pre-Alps, Alps, Southern Alps);
- 14 economics regions;
- 6 biogeographical regions;
- 26 Cantons;
- 5 altitudinal vegetation zones (collin/submontane; lower montane; upper montane; lower subalpine; upper subalpine), grouped in 1-2 “lowlands” and 3-5 “mountain regions”;
- 71 potential natural forest communities (grouped in 6 classes, see Figure 14).

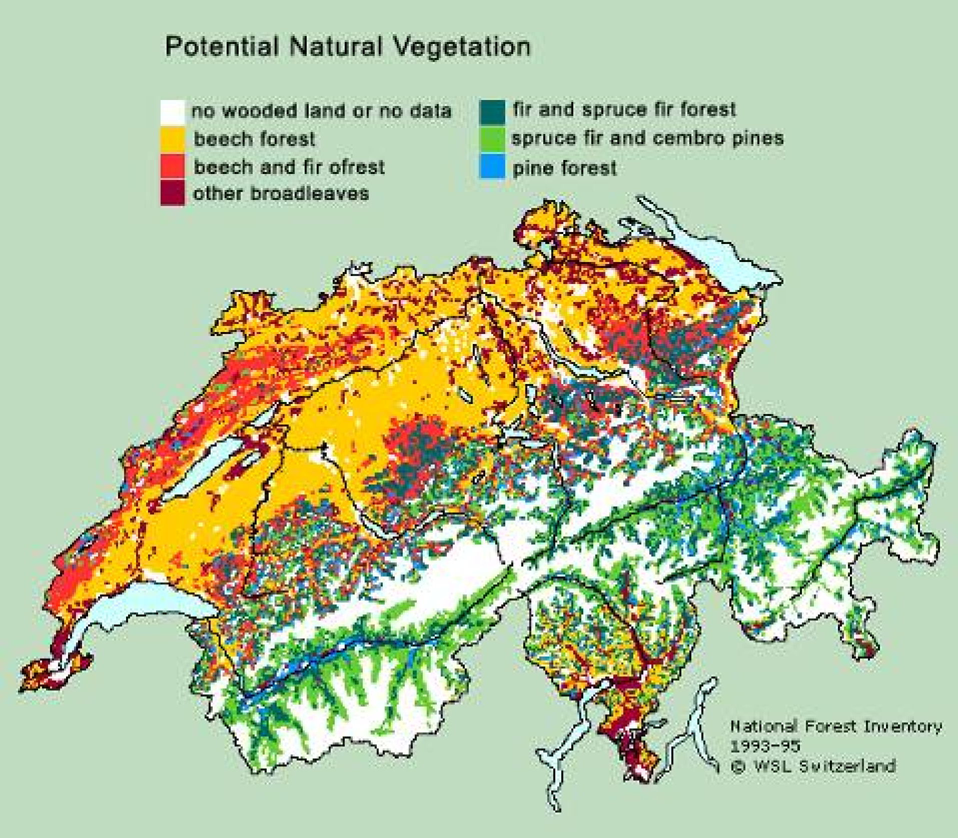

Figure 14: Potential Natural Vegetation of Switzerland.

Also in Czech and German NFI FT are based both considering real and potential vegetation on the basis of ecological conditions (altitude, climatic biogeographical zones) and soil information.

In Italy FT are based just on real vegetation with no direct relationship with potential vegetation. (Table 16).

COUNTRY	REAL	POTENTIAL	REAL AND POTENTIAL
CZ			1
IT	1		
DE			1
CH		1	
SE			

Table 16: Relationship between NFI FT and real or potential vegetation.

5.1.1.1. Data and methods

For all the investigated Countries FT are defined esclusively on the basis of field work, excepted for Switzerland that use also information resulting from GIS layers (Table 17), here FT are based on prefixed GIS based models that enable, given the environmental conditions as gereferenced thematic layers, to derive automatically the PNV.

Although Swedish NFI does not have a pre-defined forest type scheme, the actual tree species composition and field layer vegetation are assessed during fieldwork. Afterwards classification into FT can be performed in post processing.

COUNTRY	FIELD WORK	FIELD WORK AND GIS LAYERS
CZ	1	
IT	1	
DE	1	
CH		1
SE	1	

Table 17: Source of methods used for assessing FT in the five NFI.

The main output of FT classification are are NFI sampling units classification and mapping. In particular, plots classification are used by Italy, Germany and Switzerland while Czech use FT just for mapping purposes. For Sweden does not exist a standard output: they can produce both maps, plots and tables on demands.

Regarding the FT classification of sampling units in the field the minimum forest area for FT characterisation in Italy and Germany is 0.2 ha, in Switzerland it is 0.25 ha, for Czech Republic and Sweden it is not defined.

Minimum mapping unit (MMU) for FT mapping is of 0.25 ha for Czech NFI while for the other NFIs the MMU is not defined.

The length of the time series of FT assessment is different for each Country. In Sweden the NFI data are available since 1923 (8 surveys, intermittent in the period 1923-1952, continuosly since 1952). Long time series are available also for other countries like Switzerland (three NFIs in about 25 years: 1983-85; 1993-95; 2004-06) and Germany (15 years). The other countries (Czech Republic and Italy) do not have time series (just one NFI).

For the possible harmonisation of FT system of nomenclature of the five Countries participating in the project the main problematic difference is related to the different approach followed in considering the relationship between the FT definition and real vs. potential vegetation.

This is particularly truth for Switzerland where the FT concept is related exclusively with PNV, but it is problematic also for Czech Republic and Germany were the FT express itself a relationship between real and natural/potential vegetation.

5.1.1.2. Reference proposal: the European Forest Types

The reference proposed for the harmonisation of the five NFI is the system of nomenclature “European Forest Types” (EUFT) recently released by the European Environmental Agency (EEA, 2006). The EUFT is based on actual real forest vegetation and it is structured into two hierarchical levels (14 Categories and 76 Types).

Forest biodiversity monitoring would be greatly benefit from a forest type based assessment, as forest biodiversity indicators increase their specificity when referenced to a proper ecological background. Accordingly, biodiversity data quality increases allowing an improved data evaluation, understanding and reporting.

The EUFT is proposed not as an indicator itself but mainly for stratification purposes of other indicators. EUFT can be used directly as an indicator when related with potential vegetation, for example for the assessment naturalness.

We identify as forest type a category of forest defined by its composition, and/or site factors (locality), as categorized by each country in a system suitable to its situation.

Forest refers to the adopted definition of forest sensu FAO Forest Resource assessment (at least 0.5 ha, 10% crown coverage, 5 m height at maturity)

Composition refers to species composition of trees, shrubs and other vegetation components

Site factors are environmental parameters such as altitude, aspect, slope, soil parameters, etc.

Here follow the structure of the EEA (2006) system of nomenclature, it is possible that during the project some changes will be done in some specific classes, also following the discussion on going in MCPFE, COST action E43, etc.

1. BOREAL FOREST

1.1 SPRUCE DOMINATED BOREAL FOREST

1.2 PINE DOMINATED BOREAL FOREST

2. HEMIBOREAL FOREST AND NEMORAL CONIFEROUS AND MIXED BROADLEAVED-CONIFEROUS FOREST

2.1 HEMIBOREAL FOREST

2.2 NEMORAL SCOTS PINE FOREST

2.3 NEMORAL SPRUCE FOREST

2.4 NEMORAL BLACK PINE FOREST

2.5 MIXED SCOTS PINE-BIRCH FOREST

2.6 MIXED SCOTS PINE-PEDUNCULATE OAK FOREST

3. ALPINE CONIFEROUS FOREST

3.1 SUBALPINE LARCH (LARIX DECIDUA)-STONE PINE (PINUS CEMBRA) AND DWARF PINE (PINUS UNCINATA) FORESTS

3.2 SUBALPINE AND MONTANE SPRUCE (PICEA ABIES) AND MONTANE MIXED SPRUCE-SILVER FIR (ABIES ALBA)-FORESTS

3.3 SCOTS PINE (PINUS SILVESTRIS) AND BLACK PINE (PINUS NIGRA) FORESTS

4. ACIDOPHILOUS OAK AND OAK-BIRCH FORESTS

4.1 ACIDOPHYLOUS OAKWOODS

4.2 OAK-BIRCH FORESTS

5. MESOPHYTIC DECIDUOUS FOREST

5.1 PEDUNCULATE OAK (QUERCUS ROBUR)–HORNBEAM (CARPINUS BETULUS) FORESTS

5.2 SESSIL OAK (QUERCUS PETRAEA) – HORNBEAM (CARPINUS BETULUS) FORESTS

5.3 ASHWOODS AND OAK-ASH FORESTS

5.4 MAPLE-OAK FOREST

5.5 LIME-OAK FOREST

5.6 MAPLE-LIME FOREST

5.7 LIME FOREST

5.8 RAVINE AND SLOPE FORESTS

5.9 OTHER MESOPHYTIC DECIDUOUS FORESTS

6. BEECH FOREST

6.1 LOWLAND BEECH FORESTS OF S-SCANDINAVIA AND NORTH CENTRAL EUROPE

6.2 ATLANTIC AND SUBATLANTIC LOWLAND BEECH FORESTS

6.3 SUBATLANTIC SUBMOUNTAINOUS BEECH FORESTS

6.4 CENTRAL EUROPEAN SUBMOUNTAINOUS BEECH FORESTS

6.5 CARPATHIAN SUBMOUNTAINOUS BEECH FORESTS

6.6 ILLYRIAN SUBMOUNTAINOUS BEECH FORESTS

6.7 MOESIAN SUBMOUNTAINOUS BEECH FORESTS

7. MOUNTAINOUS BEECH FOREST

7.1 SW-EUROPEAN MOUNTAINOUS BEECH FORESTS (CANTABRIANS – PYRENEES – CENTRAL MASSIF – SW-ALPS)

7.2 CENTRAL EUROPEAN MOUNTAINOUS BEECH FORESTS

7.3 APENNINE-CORSICAN MOUNTAINOUS BEECH FORESTS

7.4 ILLYRIAN MOUNTAINOUS BEECH FORESTS

7.5 CARPATHIAN MOUNTAINOUS BEECH FORESTS

7.6 MOESIAN MOUNTAINOUS BEECH FORESTS

7.7 CRIMEAN MOUNTAINOUS BEECH FORESTS

7.8 ORIENTAL BEECH AND HORNBEAM-ORIENTAL BEECH FORESTS

8. THERMOPHILOUS DECIDUOUS FOREST

8.1 DOWNY OAK (QUERCUS PUBESCENS) FORESTS

8.2 SUPRA-MEDITERRANEAN OAKWOODS

8.3 PYRENEAN OAK (QUERCUS PYRENAICA) FORESTS

8.4 QUERCUS FAGINEA AND QUERCUS CANARIENSIS IBERIAN FORESTS

8.5 TROJAN OAK (QUERCUS TROJANA) FORESTS

8.6 VALONIA OAK (QUERCUS ITHABURENSIS SPP. MACROLEPIS) FORESTS

8.7 CHESTNUT FORESTS (CASTANEA SATIVA)

8.8 OTHER DECIDUOUS WOODS

9. BROADLEAVED EVERGREEN FOREST

9.1 MEDITERRANEAN EVERGREEN OAK FOREST

9.2 OLIVE-CAROB FOREST

9.3 PALM GROVES

9.4 MACARONESIAN LAURISILVA FOREST

9.5 OTHER SCLEROPHLYLLOUS FORESTS

10. CONIFEROUS FOREST OF THE MEDITERRANEAN, ANATOLIAN AND MACARONESIAN REGIONS

10.1 THERMOPHILOUS PINE FOREST

10.2 MEDITERRANEAN AND ANATOLIAN BLACK PINE FOREST

10.3 CANARIAN PINE FOREST

10.4 MEDITERRANEAN AND ANATOLIAN SCOTS PINE FOREST

10.5 ALTI-MEDITERRANEAN PINE FOREST

10.6 MEDITERRANEAN AND ANATOLIAN FIR FOREST

10.7 JUNIPERUS FOREST

10.8 CUPRESSUS SEMPERVIRENS FOREST

10.9 CEDAR FOREST

10.10 TETRACLINIS ARTICULATA STANDS

10.11 MEDITERRANEAN YEW STANDS

11. MIRE AND SWAMP FORESTS

11.1 CONIFER DOMINATED OR MIXED MIRE FORESTS

11.2 ALDER SWAMP FOREST

11.3 BIRCH SWAMP FOREST

11.4 PEDUNCULATE OAK SWAMP FOREST

11.5 ASPEN SWAMP FOREST

12. FLOODPLAIN FOREST

12.1 RIPARIAN FOREST

12.2 FLUVIAL FOREST

12.3 MEDITERRANEAN AND MACARONESIAN RIPARIAN FOREST

13. NON-RIVERINE ALDER, BIRCH OR ASPEN FOREST

13.1 ALDER FOREST

13.2 ITALIAN ALDER FOREST

13.3 MOUNTAIN BIRCH FOREST

13.4 OTHER BIRCH FOREST

13.5 ASPEN FOREST

14. PLANTATIONS AND SELF-SOWN EXOTIC FOREST

14.1 PLANTATIONS OF SITE-NATIVE SPECIES

14.2 PLANTATIONS OF NOT-SITE-NATIVE SPECIES AND SELF-SOWN EXOTIC FOREST

5.1.2. Harmonisation

All the involved Countries reported they can classify their own plots on the basis of EUFT.

Two possible ways to carry out this harmonisation can be followed:

1. using ground plot raw data on tree species composition (DBH) and any other available information relevant to classify site ecological conditions; in this case, the classification keys provided with European Forest Types will be used as decision rules to classify NFIs ground plots according to categories and types;

2. developing 'label to label' bridging functions; this is applicable and convenient in the Countries having already forest types schemes in place within NFIs to stratify ground plots, provided that such classifications are grounded on same diagnostic criteria as the European forest types. In these cases the European forest types nomenclature shall be used to establish 'label to label' bridging functions to cross-link national forest types, and associated ground plots, to European Forest Types.

	NFI AVAL. DATA			
KEY ISSUE (biblio)	yes	no	PROBLEMS	SOLUTIONS
Compositional indicator (Forest types)	CH		PNV	FT derived form re-building of tree level information
	CZ			
	IT			
	DE		PNV	FT derived form re-building of tree level information
	SE			

Table 18: summary table for Forest Type core variable.

5.2. DEADWOOD

At the moment of the analysis presented in this report, in Czech Republic and Italy the first inventory cycle is still on going and the final official deadwood statistics in these Countries are not yet available.

Every Country has its own definition of deadwood differing on the basis of: definition of deadwood (different components of deadwood and/or minimum size of deadwood pieces inventoried), different attributes recorded for each deadwood component (species or group of species, decomposition stage), different inventorying methods.

The harmonisation of deadwood attributes is for these reasons difficult but not impossible, here follow a description of definitions and methods adopted in NFIs and the consequent harmonisation proposal.

5.2.1. Deadwood in NFIs

In Table 19 the definition of the components of deadwood in each of the five considered Countries is presented.

ELEMENTS	COUNTRY				
	CH	CZ	DE	IT	SE
UPROOTED STEMS	1	1	1	1	1
PIECES OF STEMS	1	1	1	1	1
INTACT SNAGS	1	1	1	1	1
BROKEN SNAGS	1	1	1	1	1
BROKEN, LYING STEMS WITHOUT UPROOTING	1	1	1	1	1
PIECES OF BRANCHES	1	1	1	1	
CUT BRANCHES	1	1	1	1	
UPROOTED STAVES	1	1	1	1	
LOGGING RESIDUES	1	1	1	1	
FINE WOODY DEBRIS		1			1
CLEAR-CUT STEMS				1	1
STUMPS			1		

Table 19: Components of dead wood for each of the selected Countries.

To summarize the results, the categories considered in Table 19 were collected into three main deadwood types:

1. **standing deadwood:** standing dead trees, snags, standing uprooted stems and uprooted staves, the minimum height is 1.3 m;

2. **lying deadwood**: clear-cut stems, pieces of stems, pieces of branches, cut branches, logging residues, fine woody debris, broken and lying stems without uprooting.
3. **stump:** a standing snag or the post cut residual, the maximum height is 1.3 m;

The minimum diameter and the minimum length considered by each Country is shown in Table 20 and Table 21.

		DEADWOOD TYPES		
		(1) STANDING DEADWOOD	(2) LYING DEADWOOD	(3) STUMP
MINIMUM DIAMETER	4 cm	SE	SE	
	5 cm		CH	
	7 cm	CZ*	CZ	
	10 cm	IT	IT	
	12 cm	CH		
	20 cm	DE**	DE**	DE

* = but intact snags (considered as stumps) and uprooted staves ("residue after cutting of uprooted stems") are measured from 30 cm in diameter

** = at the ticker end

Table 20: Dimensional thresholds according to the different dead wood types.

The exact place where the diameter is measured for lying dead wood is not always known. It can be in the middle of the woody piece, at the butt end or the thin end or, in some methods, at the point where the bolt intercepts a sampling line. For example, taking into account woody pieces with 7 cm diameter at butt end is completely different than if the diameter is measured at the thin end (first methodology leading to a higher volume).

		DEADWOOD TYPES		
		STANDING DEADWOOD		(2) LYING DEADWOOD
		(1a) snags (DBH)	(1b) uprooted trees and stems	
MINIMUM LENGTH	NO		DE*	DE*
	10 CM		CZ	CZ
	130 CM	CH, CZ, DE, SE		

* = in practice
1 cm

Table 21: Number of countries using the different length thresholds according to the different deadwood types.

Deadwood pieces are classified on the basis of the species (SE, CH) or on the basis of groups of species: conifers, broadleaves (CZ, IT). In Germany a mixed system of nomenclature is used on the basis of three species groups: conifers, broadleaves with the exception of oaks, oaks.

In the case of the advanced state of decay it is impossible to recognize in the field the piece species for these reasons in the resulting NFIs DB frequently the species are “missing” or “unclassifiable”. In Czech NFI the pieces are reported only for standing deadwood, no species are recorded for laying deadwood and stumps.

5.2.1.1. Sampling methods

In Table 22 for each Country the total number of deadwood plots and the sampling area of each plot where deadwood is surveyed is reported.

COUNTRY	NUMBER OF DEADWOOD PLOTS	DEADWOOD PLOT AREA (m²)
CH	6500	LIS
CZ	14500	500
DE	-	-
IT	7000	530
SE	8600 per year	VAR

Table 22: Presentation of number of plots and plot area.

The Swiss NFI uses the line intersect sampling method (LIS with transect of 10 m), while the Swedish NFI uses variable circular area plots (VAR). The transects size and plot radius adopted in this two forest inventories are described in Table 23. Three countries (Italy, Switzerland and Czech Republic) measure only the part of the woody piece (tree, log, branch, …) that is inside the plot, although for Swiss NFI the question regarding plot border concerns only dead trees. In the German and Swedish NFIs, lying dead trees are completely measured if the base of the tree is inside the plot. Conversely, if the base of the tree is outside the plot, the tree is ignored (not measured). In **DE** the pieces are completely measured if their thick end is inside the plot.

	DEADWOOD TYPES		
	(1) STANDING DEADWOOD		(2) LYING DEADWOOD
COUNTRY	(1a) snags (dbh)	(1b) uprooted trees and stems	
CH	radius = 7.98 m radius = 12.62 m	Transects: 3 x 10 m	
SE	In subplots radius = 3.5 m min diam.= 4-10 cm temporary plots: radius = 7m permanent plots: radius = 10m min diam. = 10 cm	temporary plots: radius = 7m permanent plots: radius = 10m min diam. = 10 cm	

Table 23: Description of the criteria used in the case of variable area plots (VAR) and transect plots (LIS).

5.2.1.2. Deadwood volume calculation

Most European NFIs use two different ways to calculate dead wood volume: one for standing dead trees and another one for lying dead wood. Generally, volume function is used to measure standing part whereas cylinder formula is used for volume calculation of lying parts. The Van Wagner's formula (Van Wagner, 1968) is applied for the assessment of lying dead wood volume in Czech Republic.

	STANDING DEADWOOD (snags)	LYING DEADWOOD
VOLUME FUNCTION	CH, DE if DBH >7.5 cm SE	
CYLINDER FORMULA	CZ, IT	CZ, DE, IT, SE
LINE INTERSECT SAMPLING	-	CH

Table 24: Countries using different volume calculation methods according to different dead wood types.

5.2.1.3. Deadwood and forest biodiversity

All Countries collect at least one deadwood variable useful to assess the biodiversity value of deadwood (Italy only decay stage, Table 25). Decay stage can be therefore considered the only information available in all the selected NFIs, although methods for the harmonised definition of dead wood decay stages exist (e.g. Harmon & Sexton, 1996[1]), all NFIs use different methodologies for the classification. To describe the decay status of deadwood German and Czech NFIs adopt four decay classes, while Italian, Swiss and Swedish NFIs adopt five classes (Table 26).

	COUNTRIES				
	CH	CZ	DE	IT	SE
INVERTEBRATES			1		1
MOSSES	1				1
BIRD ACTIVITIES	1		1		1
NESTS		1			1
FUNGI	1	1	1		1
HOLES	1	1	1		1
HOLLOW TREES		1	1		1
DECAY STAGES	1	1	1	1	1

Table 25: List of different countries that inventory the different biodiversity parameters

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[1] HARMON M.E. and SEXTON J., 1996. Electronic document available at: http://intranet.lternet.edu/archives/documents/Publications/woodydetritus/woodydetritus.pdf

COUNTRY	DECAY CLASS
CH	1. FRESH 2. DRY 3. DECAYED 4. FUSTINESS 5. DUFF
CZ	1. HARD WOOD 2. SURFACE LAYER SOFT, HEARTWOOD HARD 3. HEARTWOOD SOFT, SURFACE LAYER HARD 4.SOFTWOOD
DE	1. RECENTLY DEAD 2. STARTING DECOMPOSITION 3. ADVANCED DECOMPOSITION 4. HEAVILY DECOMPOSED
IT	5 CLASSES MAINLY BASED ON THE PRESENCE OF BARK AND TWIGS AND THE WOOD TEXTURE (ACCORDING TO HUNTER, 1990)
SE	0. RAW WOOD. 1. HARD DEADWOOD 2. SLIGHTLY DECOMPOSED DEADWOOD 3. DECOMPOSED DEADWOOD 4. VERY DECOMPOSED DEADWOOD

Table 26: Decay classifications adopted in each investigated Country.

The results of the analysis of the deadwood methods and definition used in the investigated five NFIs highlight a very significant variability. This variability is related to but not limited at: deadwood dimensional thresholds and component definitions, sampling methods in the field, different methods for identifying decay stage, are only some examples among the others.

The choice of the adopted inventorying methodologies frequently depend on practical problems such as limited time availability for the acquisition of information in the field (and/or financial constraints) or on historical contingencies related to the objectives pursued by the NFIs rather than on real scientific basis.

5.2.2. Harmonisation

In the harmonisation of NFI deadwood definition we considered also the main definitions adopted in international projects, here they follow.

For the purposes of the present project and given the different deadwood definitions adopted in the investigated NFIs the deadwood will be defined as all aboveground parts (lying or standing) of dead woody plants, it will not include dead parts attached to living plants, it will not include stumps. Deadwood is divided in two main compartments for harmonisation purposes: standing and lying deadwood.

It is considered as “dead” all stems lacking of photosynthetic activity and presenting obvious signs of mortality (leaves or needles faded or fallen, dryness, loss of bark,…).

It is considered standing a deadwood piece presenting a vertical angle smaller than 45°, it is considered laying when it is not standing.

TBFRA 2005 (FAO)

(ref: FAO 2005 Global Forest Resources Assessment 2005 – Terms and definitions)

“Dead wood includes wood lying on the surface, dead roots and stumps larger than or equal to 10 cm in diameter (or any other diameter used by the country)”.

MCPFE report

(réf : MCPFE 2006 - Relevant definitions used for the improved pan-European indicators for sustainable forest management).

"Any piece(s) of dead woody material, e.g., dead boles, limbs, and large root masses, on the ground in forest stands or in streams."

Forest Biota

(ref : Stand structure assessments including dead wood within the EU/ICP Forests Biodiversity Test-Phase – ForestBiota).

"Standing dead trees (including snags) and downed dead trees are inventoried if the DBH is ≥ 5 cm and if the height is ≥ 1,30 m. A lying dead wood piece is inventoried if its diameter at the thicker end is ≥ 5 cm. Stumps are measured if the diameter at the height of cut is ≥ 10 cm and if the height is < 1.3 m".

Biosoil project

(ref : The BioSoil Forest Biodiversity Field Manual – Version 1.1 – For the Field Assessment 2006-07)

Coarse woody debris (CWD): components with diameter > 10 cm.

Fine woody debris (FWD): diameter ≤ 10 cm.

Snag: a standing deadwood without branches, height > 130 cm and DBH > 10 cm.

5.2.2.1. Standing deadwood

The harmonisation of the definition of standing deadwood can be easily accomplished for the height that is unanimously defined by NFIs as equal to 1.3 m, which corresponds to the "reading height" of DBH.

The harmonisation of standing deadwood definition regarding the minimum DBH is instead more complex. In the further development of the project two main types of harmonisation methods will be tested:

Cut off: the maximum DBH is chosen (20 cm from Germany) and all the other deadwood definitions will reported following this new definition.

Modelling: on the basis of the acquired raw NFI data the relationship between the standing deadwood at 20, 12, 10, 7 and 4 cm at DBH will be modelled. If the modelling tentative will be successful a regression will be applied to original NFI data in order to express the original NFI data to the new selected threshold. A special attention will be dedicated in the tentative to express the original NFI standing deadwood data to DBH_{10} because the 10 cm threshold at international level seems to be the most used standard.

EXISTING DEFINITIONS AT THE INTERNATIONAL LEVEL		
Country	*DBH threshold*	*Height threshold*
TBFRA2005 (FAO)	-	-
ForestBIOTA	5 cm	1.3 m
Biosoil	0 cm	1.3 m
MCPFE (2002)[2]	10 cm	1 m
NFI definitions		
Country	*DBH threshold*	*Height threshold*
Proposition	10 cm	1.3 m
CZ	7 cm	1.3 m
DE	20 cm	1.3 m
IT	10 cm	-
SE	4 cm	1.3 m
CH	12 cm	1.3 m

Table 27: Existing definitions at the international and NFI levels.

5.2.2.2. Lying deadwood

includes all fallen dead trees and individual lying woody pieces. In order to have a consistent definition with the standing deadwood the proposed thresholds for harmonisation are a minimum diameter of 10 cm and a minimum length 1.3 m.

Unfortunately the NFI definitions adopted for lying deadwood made the harmonisation process extremely more complex than for standing deadwood. The main problem is related to Germany and Czech Republic that adopt a diameter threshold not measured at the smaller side of the deadwood piece but at the thicker and median side of the pieces.

In this situation for IT, SE and CH it will be possible to apply both the harmonisation methods proposed for standing deadwood, for DE and CZ only the modelling approach will be possible. In such a case the models won’t be based simply on the experimental relationship as for standing deadwood but they will have to be based on some basic dendrometric and allometric assumptions.

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[2] EFI Proceedings No. 51, 2004

EXISTING DEFINITIONS AT THE INTERNATIONAL LEVEL		
Country	*Diameter*	*Length*
TBFRA2005 (FAO)		
ForestBIOTA	10 cm (diameter thicker end)	1 m
Biosoil	10 cm (minimum diameter)	1 m
MCPFE (2002)	10 cm (mean diameter)	1 m
NFI definitions		
Country	*Diameter*	*Length*
Proposition (biodiversity)	10 cm (minimum diameter)	1.3 m
CZ	7 cm median diameter	0.1 m
DE	20 cm thicker end	0.1 m
IT	10 cm minimum diameter	-
SE	4 cm minimum diameter	1.3 m
CH	5 cm minimum diameter	1 m

Table 28: Existing definitions at the international and NFI levels.

5.2.2.3. Decay classes

The harmonisation of decay classes is merely derived from the Hunter (1990) system of classification derived on the basis of the level of decay based on wood texture and amount of bark. The proposed system can be used both for standing and lying deadwood components.

Here follow the definition of the decay classes proposed and the relationship with the original Hunter (1990) system.

PROPOSED CLASSIFICATION	FEATURES OF BARK AND TEXTURE		*HUNTER (1990) LYING DEADWOOD DECAY CLASSES*
	Amount of bark	*Wood texture*	
A NOT DECAYED	BARK COMPLETELY **INTACT** (≥90%)	TEXTURE COMPLETELY **HARD** (≥90%)	*1*
B SLIGHTLY DECAYED	BARK MOSTLY **INTACT** (60 - 90%)	MOST PART (60-90%) OF TEXTURE STILL **HARD**	*2*
C DECAYED	MOST PART (40-70%) OF BARK **ABSENT**	MOST PART (40-70%) OF TEXTURE **SOFT**	*3-4*
D VERY DECAYED	BARK COMPLETELY **ABSENT** (≥70%)	MOST PART OF TEXTURE (≥70%)**SOFT**	*5*

In the proposed system the term Hard texture is referred to wood that cannot be destroyed pressing with foot and Soft texture for wood that can be destroyed pressing with foot. This definition is derived on the basis of the common NFI field procedures. The "foot" test is considered equivalent to the "knife" test (soft and hard deadwood are differentiated if a knife enter inside the wood or not).

PROPOSED CLASSIFICATION			BARK (PRESENCE)			
			≥ 90	90-60	60-30	≤30
			Completely intact	Most part intact	Most part absent	Completely or most part absent
TEXTURE	≥ 90	Completely hard	**A**	A	A	B
	90-60	Most part still hard	B	**B**	B	C
	60-30	Most part soft	B	B	**C**	C
	≤30	Completely or most part soft	B	C	D	**D**

Table 29 & 30: Description of proposed classification inspired from Hunter (1990).

The proposed decay classes are the following:

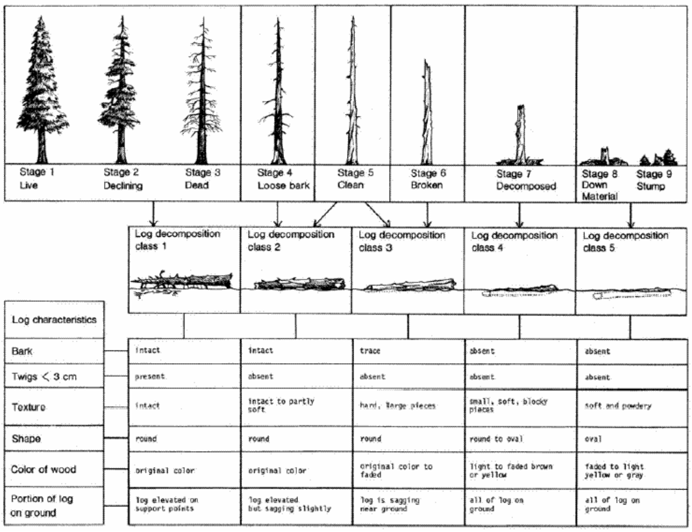
A - Not decayed: bark completely (≥90%) intact and texture completely (≥90%) hard

B - Slightly decayed: bark mostly intact (60 - 90%) and most part (60-90%) of texture still hard

C - Decayed: most part (40-70%) of bark absent and most part (40-70%) of texture soft

D - Very decayed: bark completely (≥70%) absent and most part (≥70%) of texture soft

The harmonisation is carried on the basis of tables of correspondence between NFI deadwood decomposition classes and the proposed reference (Table 31).



Log characteristics	Log decomposition class 1	Log decomposition class 2	Log decomposition class 3	Log decomposition class 4	Log decomposition class 5
Bark	intact	intact	trace	absent	absent
Twigs < 3 cm	present	absent	absent	absent	absent
Texture	intact	intact to partly soft	hard, large pieces	small, soft, blocky pieces	soft and powdery
Shape	round	round	round	round to oval	oval
Color of wood	original color	original color	original color to faded	light to faded brown or yellow	faded to light yellow or gray
Portion of log on ground	log elevated on support points	log elevated but sagging slightly	log is sagging near ground	all of log on ground	all of log on ground

Figure 15: Decay classes according to Hunter (1990).

ADOPTED REFERENCE	A. texture completely **hard** (≥90%) B. 60-90% of texture still **hard** C. 40-70% of texture **soft** D. most part of texture (≥70%)**soft**	A. bark completely **intact** (≥90%) B. bark mostly **intact** (60 - 90%) C. 40-70% of bark **absent** D. bark completely **absent** (≥70%)	**A**	**B**	**C**	**D**
HUNTER, 1990			1	2	3 - 4	5
COUNTRY	NFI CLASS DEFINITION	NFI CLASS NAME	DECAY CLASSES			
CH (5 categories)	1 = cambium wet 2 = cambium dry, knife penetrates hardly in fibre orientation (FO) 3 = knife penetrates easy in and hardly across FO 4 = knife penetrates easy in any FO 5 = very fluffily; hardly connected	1 = fresh 2 = dry 3 = decayed 4 = fustiness 5 = duff	1	2	3 - 4	5
CZ (4 categories)	NA	1. hard wood 2. surface layer soft , heartwood hard 3.heartwood soft , surface layer hard 4. softwood	1	2	3	4
DE (4 categories)	1. bark still on trunk 2. bark loose to missing, wood still sound, in the case of heart rot <1/3 of the diameter 3. sapwood soft, heart only partly sound, in the case of heart rot >1/3 of the diameter 4.wood soft all the way through, crumbly if trodden on, contours disintegrated	1. recently dead, 2. starting composition, 3. advanced decomposition, 4. heavily decomposed	1	2	3	4
IT (5 categories)	5 categories according to Hunter, 1990		1	2	3 - 4	5
SE (5 categories)	0. Newly dead trees where green needles or leaves are present. 1. More than 90 % of the tree volume and the tree surface is hard. The stem has very little impact from decomposing insects or fungi. 2. 10-25 % of the tree volume is soft and the rest is hard. A knife or a soil stick can be pressed through the wood surface but not through the sapwood. 3. 26 - 75 % of the stem volume is soft or very soft. 4. 76 - 100 % of the stem volume is soft or very soft. A knife or a soil stick can be pressed through most of the trunk. However, a hard core can exist.	0. Raw wood. 1. Hard deadwood 2. Slightly decomposed deadwood 3. Decomposed deadwood 4. Very decomposed deadwood	0 -1	2	3	4

Table 31: Proposed classification related to each Country's NFI.

Based on our knowledge, only the Total Amount of Deadwood (TADW, in m³/ha) is used to compare forest ecosystems regarding their "deadwood naturalness". However, as highlighted by Albrecht (1991), this rough indicator "cannot be used for an ecological assessment unless details are given about tree species woody debris come from, size of logs, abiotic factors of decay and decomposition classes".

Indeed, ranging from the hardest standing dead trees to the well-decayed twigs, plenty of diverse habitats are hidden behind the "deadwood pool" (DW). All those habitats differ regarding the woody piece species, size (i.e. tree, limb, small branch, …), stage of decay, way of decay and position (lying or standing) and shelter different living communities (fauna and flora). Those communities are sometimes linked to very specific habitat characteristics (i.e. they have very narrow ecological niches), only met in a small part of the DW pool. In this context, the simple indicator that is TADW doesn't express the global complexity and "interest" (for saproxylic organisms) of a given dead wood stock.

Several studies (Haase et al., 1998; Kirby et al., 1998; Martikainen et al., 2000) concluded that a global DW stock of 40 m³/ha seems to be a threshold compatible with the conservation or restoration of diversified saproxylic communities (i.e. saproxylic communities with a similar diversity of those found in virgin or old-growth forests) in Western Europe deciduous forests.

This value is obviously purely indicative, as most saproxylic species have a "narrow" ecological niche and none of them are capable to exploit the whole CWD stock. Up to 40 m³ DW/ha, a slight increase of the TADW results in a significant increase of saproxylic biodiversity. The likely explanation could be that below this amount (taking into account the natural dynamic of DW: input rates, decay rates, …), not all types of DW are represented in the forest ecosystem. Any increase of the stock could thus reveal the availability of another type of DW.

It should be noted that large diameter DW are particularly lacking in so-called "commercial forests" (Kirby et al., 1991; Green & Peterken, 1997; Kirby et al., 1998). It is why more importance (from a biodiversity point of view) should be given to large diameter DW categories (elements with a diameter>40 cm).

Ideally, the biodiversity indicator calculation should be based both on the volume as well as on the diversity of habitats "offered" to saproxylic organisms : beyond "rough" volumes, the diversity of DW species, sizes, stage of decay, etc., should be considered, giving a higher weight to "more interesting" or rarer elements (such as large diameters and rare tree species).

Setting up a "universal" indicator is however extremely difficult as a consequence of the subjectivity of the interesting character of DW elements. To define objectively the weight of the elements taken into account is thus particularly difficult.

For each plot of the five considered NFIs on the basis of harmonisation rules previously defined a number of standard indicators will be calculated: total (and lying/standing) volume of deadwood (TADW in m³/ha) by forest type, by species or group of species, by decay stages.

From these basic harmonised values more complex biodiversity indicators could be developed such as:

Plots containing at least TADW of 40 m³/ha, which seems to be an amount allowing the conservation of diversified communities of saproxylic organisms (such as Coleoptera : Martikainen et al., 2000, or birds)

Plots containing at least TADW 20 m³/ha with a diameter > 40 cm (for instance), which are substrates particularly important for many invertebrate red list species (Speight, 1989), fungi (Pentilla et al., 2004; Simila et al., 2006) and birds (e.g. Utschick, 1991).

Several studies (Harmon & Franklin, 1986; Baier et al., 2006) also shown the important role played, at least in some type of forests, by DW regarding the geo-chemical cycles and the success of trees natural regeneration (see also Harmon et al., 1986 for synthesis).

Other indicators will be tested on the basis of the relationship between forest growing stock (volume) and TADW, between the species composition of deadwood and growing stock, etc.

This question appears extremely complex if the aim of the indicator is to give an instantaneous "assessment" of the DW stock of a forest. It is easy to understand that if other fundamental elements (for nature conservation) must be taken into account (such as the spatial distribution of deadwood and the permanence of the availability of all types of habitats), the set up of an objective indicator unfortunately appears unsolvable.

KEY ISSUE (biblio)	NFI AVAL. DATA yes	no	PROBLEMS	SOLUTIONS
Structural indicators (deadwood)	CH CZ IT DE SE			

Table 32: summary table for Deadwood core variable (standing, laying deadwood and decay classes).

5.3. NATURALNESS

The concept of naturalness is potentially extremely relevant for biodiversity assessment but its definition is frequently under discussion because of different approaches in its use. The final aim of the harmonisation phase in the present project is not to discuss the ecological meaning of different existing naturalness concepts but to test the possibility to derive from available existing NFI data a comparable value of naturalness.

Naturalness usually refers to the degree of anthropogenic influences on the environment. At one end of the scale with the highest degree of naturalness are undisturbed and unmanaged environments (primary old growth forests) where the existing vegetation is in a climax condition (real vegetation equal to potential vegetation). At the other end of the scale artificial forests intensively managed where planted species are not ecologically consistent with the potential vegetation.

Following this approach forest naturalness is a very complex concept influenced by a number of factors:

- origin of the forest (natural or planted)
- regeneration (natural or artificial)
- intensity of forest management
- ecological distance between the current vegetation from the climax condition (potential vegetation)
- composition, age and structure of the forest (species composition of all the different vegetation age, horizontal and vertical structure)
- influence of other anthropogenic factors (social use, pollution, fires, etc.)
- other ecological factors (animal presence, microhabitats, etc.).

Naturalness is also adopted in several international processes. The Indicator 4.3 of the pan-European indicator for sustainable forest management (MCPFE, 2008) adopt the same nomenclature system of Timber Forest Resource Assessment (FAO, 2000) based on three classes (undisturbed, semi-natural, plantation). The Global Forest Resource Assessment (FAO, 2005) adopt instead three classes (primary, modified natural, semi-natural, productive plantation, protective plantation).

5.3.1. Naturalness in NFIs

Of the five considered Countries participating to the project only in the German NFI the naturalness is not assessed directly.

When assessed, the criteria adopted to quantify the level of naturalness are very different, in Italy they are related to the level of human activities, in Switzerland and in Czech Republic the naturalness is evaluated comparing the potential natural vegetation with the real vegetation, in Sweden a number of different criteria are considered together. In all NFIs existing also data that are clustering in some principal criteria: stand age; deadwood; signs of silvicultural activities; forest stand structure (distribution and number of vertical layers).

Among the four Countries that assessed naturalness directly, three of them use a specific classification to characterize the level of forest naturalness. All of this classification are different and nobody uses an international classification. For Czech NFI naturalness is assessed by comparing current tree species composition on the plot and the potential natural tree vegetation on the plot and a pre-defined system of nomenclature does not exist.

The number of naturalness classes range from three of the Italian (undisturbed/semi-natural/artificial) and Swedish NFIs (old-growth/plantation/normal) to four of the Swiss (near to nature/fairly far from nature/ far from nature/ very far from nature) (Table 34).

Countries characterize the naturalness level of the forest stand in a quantitative or qualitative way or use both quantitative and qualitative criteria (Table 33). Examples of quantitative criteria are current (tree) species composition compared to potential natural vegetation, % of planted trees, stand age. Qualitative criteria are signs of human impact, type of regeneration.

METHOD	COUNTRIES
Quantitative	CZ, CH
Qualitative	IT
Both	SE

Table 33: Characterization of the naturalness level of the forest stand

COUNTRY	NATURALNESS CLASSES	DEFINITIONS
CZ		Naturalness is assessed by comparing current tree species composition on the plot and the potential natural tree vegetation on the plot
IT (1)	Undisturbed	No human disturbance at all or for a long time
	Semi-natural	If forests are or were disturbed
	Artificial	Artificial forest (plantations included)
CH (2)	Near to nature	Broadleaved forest areas only: stands with less than 10% or 25% of coniferous trees (depending on the plant community)
	Fairly far from nature	Broadleaved forest areas only: forests with up to 75% coniferous trees
	Far from nature	Broadleaved forest areas only: forests with over 75% coniferous trees
	Very far from nature	Broadleaved forest areas only: stands where the proportion of spruce alone is over 75%
SE (3)	Old-growth	>150 years, CWD, no forestry measures the last 25 years, uneven-aged, large diameter variation, at least 2 layers
	Plantation forest	Even-aged, small diameter variation, one layer, mono-culture, strict geometric distribution
	Normal forest	Other

(1) in addition, origin of ground vegetation (regeneration and shrubs): natural, artificial, coppice

(2) no judgement on the closeness to nature could be made in the natural area of coniferous forests, though as a whole, they must be considered as fairly near to nature since very often the site conditions dictate the composition of species (e.g. in the Alps at high altitudes)

(3) in addition, continuous tree coverage without species change since 18th century, >100 years, stocking above 30%: no, possibly, yes

Table 34: Naturalness classifications adopted by the five considered NFIs.

The naturalness is assesses in all sample plot in Czech Republic, Italy and Switzerland while in Sweden only in productive forest land. The surface area of sample plot in which naturalness is assesses ranges from 500 m^2 of Czech NFI to 2500 m^2 of Swiss for stand (see below):

- CZ: 500 m^2
- SE: 1300 m^2
- IT: 2000 m^2
- CH: in sample tree information 200 m^2 (measurements); stand information in 2500 m^2 (as estimations).

Beyond these already existing naturalness systems of nomenclature adopted by the NFIs a number of potentially useful raw information are available to assess naturalness:

- tree species composition (% of non native species); recorded in all the five Countries;
- ground flora composition (% of non native species). Assed in the Swedish NFI, not in Germany; only for woody species in the Italian and in the Czech NFIs.
- forest stand structure. It is possible divided this information into six different categories (see Table 35): horizontal structure, vertical structure, age structure, deadwood, regeneration types; see also the next chapter for more detailed information;
- deadwood, see the specific chapter related to this core variable;
- human disturbances.

	Horizontal	*Vertical*	*Age*	*Regeneration*
CZ	▨	▨	▨	n
DE	▨	▨	▨	▨
IT	▨	n	▨	▨
CH	d	d	*	*
SE	▨	▨	▨	▨

▨ Yes   * , d yes partly or detailed explanations   n no

Table 35: Available information related to stand structure.

Information about human disturbances are available for all the five Countries. Two major categories of human disturbances are considered:

- cutting/planting;
- other (forest roads, recreation features, pruning, ground preparation, building, walls, litter, pollution, grazing, tree damage by human activities, soil damage, ...);

DISTURBANCE	COUNTRIES
Cutting (thinning/felling) or planting	IT, CH
Other human disturbances	CZ, DE, SE, CH

Table 36: Human disturbances information by Country.

With the exception of Czech NFI, some other disturbances are also recorded (mainly biotic or climatic):

- biotic disturbances: diseases, fungi, epiphytic plants, wild animals, insects, grazing;
- climatic disturbances: storm, cold, heat, water, snow, fire.

Only one Country (Italy) collects micro-habitat occurrence potentially useful for naturalness assessment such as (small open areas, water, den trees, monumental trees, etc.).

Among the five considered NFIs two approaches used: in Italy and Sweden the naturalness is mainly related to the different level of human induced, in Czech Republic and Switzerland the naturalness is evaluated on the basis of the relationship between natural/potential and real vegetation.

Naturalness is assessed in the field in plots of very different dimension.

The similarities between NFIs concern the data used in the description of naturalness classes which more or less always consider:

- age structure;
- regeneration types;
- origin of trees;
- cuttings.

5.3.2. Harmonisation

For the development of an harmonised naturalness assessment on the basis of the available NFI data in the five considered NFIs we propose two different approaches. The first one is more simple and finalized to address reporting issues, while the second one is more complex and it is specifically developed for the purposes of the project.

The first one is based on the classification of the NFI plots naturalness on the basis of the FAO-TBFRA/MCPFE classes. This will be accomplished partially reclassifying the national system of nomenclature (for Italy and Sweden) and for the other Countries using existing raw information related to nativeness of tree species, origin of the stand (natural/artificial), cutting system (thinning and harvesting), occurrence of human disturbances other than thinning and harvesting (soil working, grazing, fertilising, roads, etc.).

	PROPOSED CLASSES		
FAO TBFRA 2000 MCPFE 2008	Undisturbed	Semi-natural	Plantation
COUNTRY	NFI CLASSES		
IT	Undisturbed	Semi-natural	Artificial
CH	No clear linkage: classes based on the % of coniferous trees in broadleaved forest areas only (near to nature, fairly far from nature, far from nature, very far from nature)		
SE	Old-growth	Normal forest	Plantation

Table 37: Comparison between the proposed classification and the NFI's existing ones.

The second approach will be developed and tested in order to carry out a new harmonised naturalness classification based on a classification tree methodology. The NFI plots will be classified on the basis of a semi-automatic procedure based on a number of different parameters that once aggregated will express the overall naturalness. The procedure is still under development and will be finalized once the NFI raw database of the project will be completed. The parameters considered in the draft classification are:

- occurrence of native and non native tree species
- forest management
- protected forest
- deadwood quantity and quality
- forest type (sensu EEA, 2006)
- regeneration method
- forest layers (vertical structure)
- ages
- diameter class (horizontal structure)

	NFI AVAL. DATA			
KEY ISSUE (biblio)	yes	no	PROBLEMS	SOLUTIONS
Biodiversity indices (Complex indices combining more components of biodiversity)	CH		Naturalness of coniferous trees proportion in stands of broad-leaved forest area	It seems possible to define naturalness mixing other NFI information (human activities degree, forest origin, stand structure,…)
	CZ		Naturalness is assessed by comparing current tree species composition on the plot and the potential natural tree vegetation on the plot	
	IT			
		DE		
	SE			

Table 38: summary table for Naturalness core variable.

5.4. FOREST STAND STRUCTURE

Forest stand structure characteristics are important to evaluate the potential biological diversity of forest stands, it can be described as made by two components: vertical structure and horizontal structure. Vertical structure can be seen as the architecture of a stand including the distribution of tree heights and layering. Horizontal structure means the two-dimensional mosaic of forests and clear areas with different tree densities and edge effects. Forest structure reflects natural disturbances as well as silvicultural management thus is linked to the core variable that describes "naturalness-nativeness". Attributes like development stages, horizontal and vertical structure, diameter distribution are partially overlapping. As the term "naturalness" implies a subjective valuation, the term "forest structure" should describe elements of naturalness in a more objective quantitative way.

5.4.1. Forest stand structure in NFIs

Forest structure can be assessed on the basis of information acquired in NFIs at tree level or at stand level. At tree level useful attributes are:

a. DBH and tree height: the characteristics (shape, range, variability, etc.) of their distribution are a good simple indexes for evaluating the structural complexity of a stand, these information can be merged in different ways with the species composition.

b. Social position of three: it can show the variation in vertical distribution of trees in a stand.

At stand level potential attributes acquired in NFI's are:

a. Number of layers: this attribute characterizes the vertical architecture of the forest.

b. Abundance/dominance of species per layer: this attribute combines structural and compositional aspects, the spatial arrangement of the layering and the richness and abundance of species. Tree species diversity, according to the different requirements on site factors, contributes to ecosystem diversity (Franklin et al., 2002). For nationwide assessments the benefit of woody species is that, in contrast to herbal species, their occurrence is independent of the season. They can be ascertained all over the year.

c. Stage of development: The occurrence of all development stages and phases ensure a high number of natural habitats. Especially, the terminal and decay stages are rare in managed forests but highly necessary for the ecosystem functions as well as for an overall value of natural biodiversity.

d. Area of gaps/patches per ha: Considering that forest structure in primeval forests as well as in economically used forests depends on disturbances (either the biotic or abiotic caused death of trees, either by natural or human influences), number and area of canopy openings are connected to structural diversity. Disturbances create a mosaic of different development stages and habitats.

e. Edge effects per ha: edge effects can occur on the borderline to non forested areas and within the forest area between old forests and openings or between old and young forests. Outer edges can characterize the stage of fragmentation, which is important for interactions between genuine forest inhabitants and species from the outside. Inner forest edges reflect the changing radiation supply of the ground.

	Attributes COUNTRY	CH	CZ	DE	IT	SE
Tree level	min DBH (cm)	12	7	7	4.5	4
	height (m)	YES	YES	YES	YES	YES
	Social position	NO	YES	YES	YES	YES
Stand level	Number of layers	YES	YES	YES	YES	YES

Table 39: Stand structure variables assessed in the five studied NFIs.

5.4.1.1. DBH and tree height

These attributes are typically assessed by all NFIs with similar procedures, thus their harmonisation is relatively easy. Tree heights are often measured of a sub-sample of trees, for the other trees the height is modelled on the basis of the relationship between height and diameter. Different minimum DBH thresholds are adopted in the studied NFIs, ranging from 4.5 cm to 12 cm see Table 39. Some differences exist also in the rules for the selection of trees for which the height is measured.

In the Italian NFI, for instance, the height is measured on ten sampled trees per plot (with height greater than 1.3 m) to derive DBH-height models for each layer and for species groups. In German NFI height is measured for trees: (i) in the main stand, (ii) in the over-wood and (iii) in the under-wood, while Swiss NFI adopted a DBH threshold for height measurements of 12 cm. In the Swedish NFI all trees higher than 10 cm are collected. In the sample plot are counted and callipered all trees with DBH smaller than 4 cm (collected in four classes), trees with DBH greater than 4 cm. In a sub-sample of this second group tree heights are measured.

5.4.1.2. Social position

The social position of trees is defined in different ways (see Table 40). In Italian NFI a social position is collected only for sampled trees.

German NFI uses the 5 social classes of KRAFT while Czech the 9 classes of the IUFRO system. Kraft’s social classes describe the current social position of a tree from “predominant to suppressed” without respect to dynamic development and vitality as the IUFRO system does. IUFRO classification distinguishes 3 layers (100.upper; 200.lower; 300.middle), the vitality of trees (exceedingly, normally and scarcely tough) and the evolutionary trend.

COUNTRY	**CH**	**IT**	**DE**	**SE**	**CZ**
NUMBER OF CLASSES	Not assessed	3 social classes	5 social classes	7 social classes	9 social classes
CLASSES		1. dominant 2. codominant 3. suppressed	KRAFT classification: 1. predominant 2. dominant, 3. codominant, 4. dominated, 5. suppressed	1. free standing 2. dominating, 3. co-dominating, 4. dominated, 5. suppressed 6. undergrowth 7. remnant trees	IUFRO classification that describes vitality of trees in the upper layer (100), the middle (200) and the lowest (300).

Table 40: System of nomenclature of social classes.

5.4.1.3. Number of layers

The partition of one-, two- and multi layered stands seems to be considered as important for forest structure description, vertical forest structure types are closely related to the distribution of development stages.

In each Country exists a method for classifying the vertical forest structure. The information collected in each NFI related to the number of layers are showed in Table 41. Italian NFI detailed only if forest is characterizes by one or two layers.

COUNTRY	LAYER			
	one	two	three	multi, much, mixed
SE	x	x	x	
DE	x	x		x
IT	x	x		x
SE	x	x	x	
CH	x	x	x	x

Table 41: Number of layers assessed in each NFIs.

5.4.2. Harmonisation

The forest structure is the combination of a number of different parameters of the horizontal and/or vertical features of a forest. For these reasons here below the harmonisation process is described separately for the horizontal structure and for the vertical structure (and definition of development phases as a combination of horizontal and vertical structure).

5.4.2.1. Vertical Forest Structure

The height of the trees is the most important parameter of the vertical forest structure. On the basis of the available information acquired in the field in the different NFIs the height of all the inventoried trees will be estimated on the basis of local DBH-height models. This information will be useful to calculate a number of different indexes (dominant height, diversity in height distributions, etc.).

Two other parameters will be harmonised.

a. Number of layers

A layer is a stratum of tree heights of a stand that is clearly distinguishable from another vertical layer by visual estimation in the field. Three categories: one layer, two layers and three or more layers can be adopted as an harmonised system of nomenclature at stand level.

This attribute can be easily harmonised on the basis of a label-to-label approach with original raw data but the results won't give a fully comparable results across different NFIs because different minimum heights for layers are adopted (e.g. SE 0.1 m, CH 0.4 m). This means that a similarly looking stand could be assessed as one layered in SE and as two layered in CH.

KEY ISSUE (biblio)	NFI AVAL. DATA yes	no	PROBLEMS	SOLUTIONS
Biodiversity indices (Indices characterizing vertical structure)	CH CZ IT DE SE			

Table 42: summary table for Forest Structure core variables (Numbers of layers).

b. Social position

The social position of a tree describes the position of the regarded tree in comparison to the trees in the vicinity of that tree. Only the trees, which are influencing the regarded tree, are used by the way of comparison.

COUNTRY	SOCIAL POSITIONS (KRAFT)				
	predominant	dominant	codominant	dominated	suppressed
CZ	See Table 44				
DE	1	2	3	4	5
IT	1		2	3	
SE	1	2	3	4	5-6-7
CH	not assessed				

Table 43: Proposal for classification of social position.

For the countries that using the IUFRO classification (CZ) a conversion is proposed:

	IUFRO	Social positions (Kraft)				
		predominant	dominant	codominant	dominated	suppressed
1 Upper Layer	11X well	X				
	12X normal		X			
	13X meagre			X		
2 Middle Layer	21X well			X		
	22X normal				X	
	23X meagre				X	
3 under Layer	31X well				X	
	32X normal					X
	33X meagre					X

Table 44: Table of correspondences from IUFRO to Kraft classification.

	NFI AVAL. DATA			
KEY ISSUE (biblio)	yes	no	PROBLEMS	SOLUTIONS
Biodiversity indices (Indices characterizing vertical structure)		CH		
	CZ			
	IT			
	DE			
	SE			

Table 45: summary table for Forest Structure core variables (Social position).

5.4.2.2. Horizontal Forest Structure

The distribution and/or occurrence of forest features in the horizontal feature space is *horizontal forest structure*. The most common parameter is related to the DBH and to the distribution of trees in the inventoried area.

All NFIs measure DBHs of trees. Neumann and Starlinger (2001) fount strong correlation between DBH variation and many other biodiversity indices. As the number of –at least- coleoptera and breeding birds increases with the dimension of trees and obviously decreases with the intensity of management activities, DBH variation can be therefore considered an indicator for biological forest diversity. Uniform, one storied stands indicate a strong human influence.

To harmonise DBH data assessed in different NFIs a simple cut-off method using the highest threshold limit used in between the different Countries (Switzerland, 12 cm) was selected. The use of just bigger trees for stand level horizontal forest structure may be sufficient to show results of changing silvicultural conditions. Temporary short time changes reflected in the upcoming and vanishing of small trees will be probably neglected. Such situations could be better characterized by ground vegetation assessments (emphasis on woody species) and forest density (meant is the amount of radiation which can reach the ground).

Standard deviation of diameters assessed per plot and numbers of trees are simple indexes that will be tested on harmonised data. Example of these indexes recently used also in other projects (Neumann, M., Starlinger, F., 2001; ForestBIOTA, 2006; EEA, 2006)are :

1. number of represented trees per DBH classes;
2. arithmetic mean and standard deviation of DBH per plot;
3. frequency distribution of standard deviation classes per plot.

	NFI AVAL. DATA			
KEY ISSUE (biblio)	yes	no	PROBLEMS	SOLUTIONS
Biodiversity indices (Indices characterizing horizontal structure)	CH			
	CZ			
	IT			
	DE			
	SE			

Table 46: Forest Structure core variables (Horizontal Forest Structure).

5.5. STAND AGE

The age of trees or stands is an important component for evaluating the potential biological diversity of forest ecosystems. It can be an indicator for biodiversity because large and old trees are important habitats of typical forest animals (black stork, [e.g. black] woodpeckers, bats, insects, …), lichens, fungi and mosses. Especially epiphytic, saprophytic and saproxylic species that grow or spread slowly or follow each other in a succession (on the same tree) depend on old trees and stands. Woody humus filled cavities on large trees are rare and important habitats of natural forests and correlate with tree and stand age. Rare forest lichens often occupy the trunks of large living trees (Gilg, 2005).

Old forests indicate more natural dynamics. They may represent the ageing and decay phase of natural forests that have a life cycle of e.g. 400 years in a natural spruce-fire-beech mountain forest. So stand age ratios are indicators for human disturbance too. As the ecological impact of old stands is higher than that of single old trees, ecologists postulate creating «ageing islands» in a network . Thus stand age is an important indicator to check sustainable forest management regarding biodiversity. It is proposed as biodiversity-related indicator by different authors (EEA 2003).

5.5.1. Tree age and stand age in NFIs

In the field work carried out in most of NFIs is related to the acquisition or to the estimation of tree age.

Tree age is defined as biological age of trees, i.e. the actual age of individual tree, i.e. the time period starting by germination and ending by date of measurement.

In coppice system, tree age is defined as a biological age of above ground stem of the tree, not the age of the rootstock or the total age from seed. In a plantation forest the date of planting is considered.

The best way of determining a tree’s age is to find out when it was planted. Obviously, this is difficult, but it occasionally works if the tree was planted by humans in a context where historical information can provide us with a date. Otherwise, there are basically two methods that can be accomplished for tree age assessment: (1) tree rings analysis and (2) estimation.

In all the considered NFIs the age of the single trees is assessed with the exception of Switzerland. or of the forest (Table 47).

COUNTRIES	TREE AGE	STAND AGE
CZ	X	can be calculated
DE	X	X
IT	X	X
SE	X	X
CH		X

Table 47: Countries assessing tree age and stand age.

Tree ring analysis for tree age assessment is scarcely used in DE. Drilling with increment borer is used for taking of samples from standing trees. Study and interpretation of annual growth rings of trees is use exclusively for tree age assessment in IT and SE. Because of danger of affecting of sample trees, CZ drill representative trees growing outside of sample plot.

Tree age is difficult to measure in old-growth or virgin stands because of the large size of the trees and the abundance of hollow or rotten boles.

Stand age is also frequently assessed (all the Countries with the exception of Czech Republic, see Table 47).

Since the traditional application of stand age information was for economical or silvicultural purposes (supporting forest management), most of the stand age definitions include only the dominant elements of a stand (dominant tree species, upper/dominant layer, trees making up 80% of growing stock, main stand).

The definitions of stand age show wide varieties in terms of what trees are considered and how tree age is defined (Table 48). CH is the only Country estimating a biological age.

COUNTRY	DEFINITION
CZ	Not assessed, can be calculated on the basis of tree age
DE	The mean of the tree ages ≥7 cm DBH.
IT	The average age of the main stand at 1,3m level.
SE	The average stand age is given as total age; i.e, years from germination to year of estimation. At forest land over-storey trees, seed trees, undergrowth and dead trees are not considered. If the stand height is 7 meters or higher, the age is determined as basal area weighted average age. In less high stands the age is determined as arithmetic average age. In multi-aged stands the average age is estimated for the layer used to decide cutting class.
CH	Average (biological) age of the main stand.

Table 48: Methods and definition of stand age assessed in the considered NFIs.

Stand age assessment is mostly related to the trees within the plot and not to a larger stand. Thus we should refer to «plot age» instead of stand age.

Stand or plot age is surveyed in most countries in even-aged forests and (if existing) coppice forest (Table 49). Coppice with standards are assessed in IT and SE while uneven-aged (high) forests in DE and SE. The age of other wooded land is estimated in SE only.

COUNTRY	Reference area for stand age assessment (plot or stand size)		Forest area with stand age assessment				
	Min.	max	even-aged high forest	coppice forest	coppice with standards	uneven-aged stands	Other wooded land
DE	variable plot size		X	calculation is possible		X	
IT	530 m^2		X	X	X		
SE	1256 m^2		X	X	X	X	X
CH	500 m^2	2500 m^2	X	X			

Table 49: reference area and forest types for which the stand age is evaluated.

Stand age is assessed with a resolution of one single year, with the exception of IT where it is assess by classes (Table 50).

RESOLUTION (single years or classes)	COUNTRIES
number of years	DE, SE, CH
classes (top class)	IT (>120)

Table 50: time resolution of stand age assessment.

Reference area and resolution differ according the main purpose of tree age assessment:

1. Some Countries assessed tree age on the level of individual tree, thus all trees have information about their age available. In this case the NFI dataset allows providing information about tree age composition. Data on tree level may be used for stand age assessment.

2. Some Countries assess tree age only for representative trees and use such information for stand age assessment. Usually the representatives tree are not chosen randomly but they represent dominant species, main layer etc. Such data cannot be easily compared among countries.

5.5.2. Harmonisation

We could not find an official and international harmonised definition of stand age, either for even-aged nor for uneven-aged stands. Proposals of different authors can be found:

a. Stand age = mean age of dominant (and sometimes co-dominant) trees in the stand. The plantation age is generally taken from the year the plantation was begun, without adding the age of the nursery stock. The age of a tree is the time elapsed since the germination of the seed, or the budding of the sprout or cutting from which the tree developed. (Helms 1998)

b. The average age of dominant and codominant trees in the stand. (http://www.srs.fs.usda.gov/sustain/report/appendix/glossary.htm)

c. The mean age of the dominant and co-dominant trees in the stand. (www.campbellgroup.com/forest_mgmt/glossary.htm)

d. Age of the dominant tree layer in classes 0-20, 21-40 years etc. is used in BIOSOIL project.

The average age of the trees comprising a forest, stand or forest type (http://www.pfc.forestry.ca/monitoring/inventory/terms/glossary_e.html).
In general two concepts are practiced in European NFIs:

a) mean age of dominant trees (mostly)

b) mean age of all trees (seldom)

Regarding ecological aspects the concept a) is better related to biodiversity than concept b).

There is no need of harmonisation of tree age definition. Tree age is defined identically in considered NFIs and the methods of biological tree age determination do not differ in general. There are differences in how tree age is processed and used for estimation of stand age. Fo these reasons the harmonisation method proposed in the project is based on the use of tree age to derive stand age. Different approaches for the evaluation of mean age of dominant trees will be tested on the basis of the available different scientific experiences

	NFI AVAL. DATA			
KEY ISSUE (biblio)	yes	no	PROBLEMS	SOLUTIONS
Biodiversity indices (Structural indices)	CH			
		CZ	stand age are not assessed	can be evaluated from tree age
	IT			
	DE			
	SE			

Table 51: summary table for Stand Age core variables

5.6. SPECIES DIVERSITY

Several studies had showed that the relationship between plants diversity and ecosystem process is very close. In particular, diversity in plant species (α-*diversity*) is positively related to many ecosystemic function as well as net primary production, ecological stability and endurance to disturbances (Hector 2001, Tilman et al. 2001).

A great number of different methods can be used for evaluation of species diversity (Krebs, 1989; Ludwing and Reynolds, 1988). All of this are usually methods are usually based on at least one of the following characteristics: *species richness* (the oldest and the simplest understanding of species diversity expressed as a number of species in the community), *species evenness* (a measure of the equality in species composition in a community), *species heterogeneity* (that encompassing both species abundance and evenness).

On the basis of information acquired in NFIs, we can considerer species diversity of a plot as a composition of three different levels:

1. tree level;
2. shrub level;
3. ground vegetation level.

As is showed in Table 52, all 5 NFIs have gathered information about species of tree inside plot.

In cases of shrub and ground vegetation levels, instead, not all Countries have collected data. In particular, shrub species are not acquired from CH and DE NFIs, while only this two Countries collected information for ground vegetation species.

	CH	CZ	DE	IT	SE
TREE LEVEL	yes	yes	yes	yes	yes
SHRUB LEVEL	no	yes	no	yes	yes
GV LEVEL	yes	no	yes	no	no

Table 52: data assessed in each NFIs at tree, shrub and ground vegetation level.

As Table 52 shows, at tree level an harmonisation process is possible, but not the same thing cannot be said for shrub and ground vegetation levels. The reasons are not only that some NFIs not assessed information regarding this two vegetal formations, but also that when assessed they are very different.

At shrub level, for example, CH assessed information only regarding coverage degree of whole shrub species, while IT, contra, assessed only the species founded in each plot, but not the number of the individuals or coverage degree.

So, only at tree level it's possible to try an harmonisation process. All index able to evaluated species diversity use number of species as basic information. In our case harmonisation process needed a solution regarding the different plot size wherein each NFI collected tree species. In fact, if the same number of species (and/or individual) is registered in two different plot with different size

		NFI AVAL. DATA			
	KEY ISSUE (biblio)	yes	no	PROBLEMS	SOLUTIONS
Tree level diversity	**Biodiversity indices (richness; heterogeneity; eveness; complex div. indices)**	CH			
		CZ			
		IT			
		DE			
		SE			

		NFI AVAL. DATA			
	KEY ISSUE (biblio)	yes	no	PROBLEMS	SOLUTIONS
Groundveg. level diversity	**Biodiversity indices (richness; heterogeneity; eveness; complex div. indices)**	CH			
			CZ		
			IT		
		DE			
			SE		

		NFI AVAL. DATA			
	KEY ISSUE (biblio)	yes	no	PROBLEMS	SOLUTIONS
Shrub level diversity	**Biodiversity indices (richness; heterogeneity; eveness; complex div. indices)**		CH		
		CZ			
		IT			
			DE		
		SE			

Table 53: summary table for Species Diversity core variable (at tree, groundvegetation and shrub levels).

6. NFI COMMON DATABASE

6.1. RAW DATA

In order to acquire those NFI information useful for the calculation of harmonised biodiversity indicators a common database was created and populated by each project Partner.

The database structure (Table 54) is structured in five tables: PLOT, TREE, DEADWOOD, SHRUB, GROWNDVEGETATION.

While for PLOT, TREE and DEADWOOD data the tables are structured because NFI data are expected to supply data that will be operatively harmonised and used for index calculations, for SHRUB and GROUNVEGETATION NFI are expected to be able to supply very different data acquired on the basis of definitions and methods for which the harmonisation is extremely complex or impossible. For this reason the relative tables are just partially structured and the project Partners are free to supply, for these variables, their data on the basis of their own DB structure. A tentative harmonisation of these variables will be tested in a later step.

	TABLES NAME				
	PLOT	**TREE**	**DEADWOOD**	**SHRUB**	**GROUNDVEG.**
FIELDS	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY
	PLOT ID	PLOT ID	PLOT ID	PLOT	PLOT
	FOREST TYPE	TREE ID	TRANSECT OR SUBPLOT	SPECIES	GROUPs or SPECIES
	NATURALNESS	GENDER	PIECE ID	COVER	COVER
	ORIGIN	SPECIES	LAYING STANDYING	DATE	DATE
	CUTTING SYSTEM	ICP CODE	INVENTORYING METHOD		
	YEARS FROM LAST TREATMENT	NATIVENESS	PLOT AREA		
	OTHER HUMAN ACTIVITIES	DBH	LIS LENGTH		
	FOREST AGE	SAMPLING UNIT AREA	INTERSECT DIAMETER		
	LAYERS	BASAL AREA FACTOR	DIAMETER1		
	REG COV	MEASURED HEIGHT	DIAMETER2		
	REG NUM	MODELLED HEIGHT	LENGTH		
	AREAFAC	AGE	VOLUME FUNCTION		
		AGE METHOD	DECAY		
		MANAGEMENT SYSTEM	FOREST CATEGORIES		
		SOCIAL POSITION	VOLUME		

Table 54: Fields of the five tables of the NFI common database.

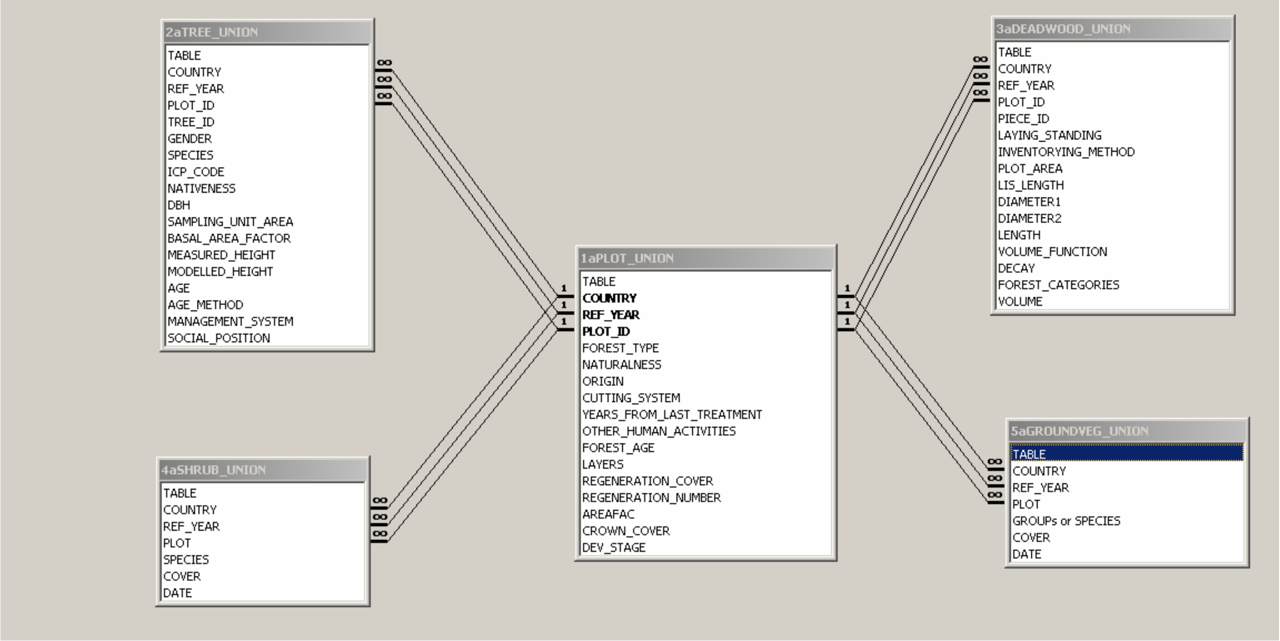


Figure 16: structure of the relationships between the tables of DB.

COUNTRY (test area)	YEAR	PLOT	TREE	DEADWOOD	SHRUB	GROUND VEGET.
CH	2000	723	9365	567	723	723
CZ01	1996	224	5934	1169	29	625
CZ01	2005	224	5757	2962	41	712
CZ02	1996	78	1714	225	125	224
CZ02	2005	78	2151	562	84	232
DE	2002	895	5778	283	0	9690
IT	2006	351	8564	1524	984	22467
SE	1999	494	3741	426	0	0
SE	2003	195	1406	166	111	0
TOTAL		**3262**	**44410**	**7884**	**2097**	**34673**

Table 55: number of records available in the common NFI for test area and year of acquisition.

Regarding the spatial coverage of NFI data the DB here presented is the first release based on one single year (or period) of acquisition. The DB is under completing with multitemporal data for Czech Republic and Sweden.

Name of the table: **PLOT** - One record for each plot.

FIELD NAME	DESCRIPTION
COUNTRY	unique text code of the Country, according to the COST abbreviation
PLOT_ID	number of the plot, unique within a Country, each Country takes track of the selected plots for the population of the DB, in order to make possible that in a further step of the project more information may be asked for a specific plot.
FOREST_TYPE	according to the numeric code of the EUFT (EEA, 2006) the plot is classified on the basis of the European forest type system of nomenclature (type level), one EUFT for each plot.
NATURALNESS	information based on the Country classification acquired in the field and dealing with the naturalness of the dominant plot vegetation.
ORIGIN	information based on the Country system of nomenclature dealing on the prevalent origin of trees within the plot (natural regeneration, seeding, planting, etc.).
CUTTING_SYSTEM	information based on the Country system of nomenclature dealing with the prevalent cutting system adopted within the plot (clear-cutting, thinning, natural evolution, etc).
YEARS_FROM_LAST_TREATMENT	is the number of years elapsed from the last silvicultural treatment.
OTHER_HUMAN_ACTIVITIES	information based on the Country system of nomenclature dealing with the prevalent human activities other than thinning or forest cutting within the plot (grazing, soil preparation, fertilizing, roads, etc.).
FOREST_AGE	information based on the Country system of nomenclature dealing with the prevalent forest age/development stage of the plot as it is assessed in the field.
LAYERS	number of vertical layers (one, two, many, …) based on the Country system of nomenclature as it is assessed in the field.
REGENERATION_COVER	in percentage or in cover classes of the trees based on the Country system of nomenclature as it is assessed in the field.
REGENERATION_NUMBER	in number of individual per hectares (on in classes) based on the Country system of nomenclature as it is assessed in the field.
AREAFAC	This field is useful to obtain an estimate of forest area in Sweden.

Name of the table: **TREE -** One record for each tree of the plot reported in PLOT table

FIELD NAME	DESCRIPTION
COUNTRY	unique text code of the Country, consistent with the same field in the PLOT table.
PLOT_ID	number of the plot, unique within a Country, consistent with the same field in the PLOT table.
TREE_ID	number of the tree, unique within the plot.
GENDER	gender of the tree, according to the Latin system of nomenclature (*Flora Europaea*). ICP codes are also acceptable.
SPECIES	species of the tree, according to the Latin system of nomenclature (Flora Europaea). ICP codes are also acceptable.
ICP_CODE	here the family.gender.species code based on the ICP code system.
NATIVENESS	Answer by "site-native" if this tree species is in its local natural range, by "introduced" if the tree species is out of its natural local range. A tree species could be native in some part of the country but not native in some other part. We are interesting by the site-nativeness, it means the local natural range of the species. The nativeness should be assessed in the field.
DBH	in millimetres, one for each tree, if two diameters are assessed the value is the average. The diameter is measured at 130 cm height from the ground please.
SAMPLING_UNIT_AREA	in square metres, the sampling area dimension the tree is referred to, this value is used to extrapolate from per plot to per hectare values.
BASAL_AREA_FACTOR	in the case of relascopic areas the Bitterlich factor used (m^2 ha^{-1})
MEASURED_HEIGHT	in metres, as it is measured or visually estimated in the field.
MODELLED_HEIGHT	in metres, derived from functions on the basis of diameter. The modelled height is reported for all the trees of the plot.
AGE	age of the tree in year.
AGE_METHOD	method used for calculating or estimating the tree age. On the basis of country methods.
MANAGEMENT SYSTEM	information based on the Country system of nomenclature dealing the prevalent management system adopted (high forest, coppice, etc.).
SOCIAL_POSITION	social position of the tree such as dominat, co-dominant, ecc. Other country system of nomenclature are acceptable.

Name of the table: **DEADWOOD -** One record for each single piece of deadwood

FIELD NAME	**DESCRIPTION**
COUNTRY	unique text code of the Country,
PLOT_ID	number of the plot, unique within a Country
PIECE_ID	number of each single piece of deadwood, unique within each PLOT
LAYING_STANDYING	"L" if the piece is laying deadwood, "S" for standing. The threshold is 45° angle with the vertical position.
DECAY	information based on the Country system of nomenclature dealing the decay stage of the deadwood in the plot.
INVENTORYING_METHOD	**LIS** for lying intersect sampling **PLOT** for plot area sampling.
PLOT_AREA	area in square metres of the plot were the deadwood is assessed, if INVENTORYING_METHOD = PLOT.
LIS_LENGTH	in metres of the length of the line transect, if INVENTORYING_METHOD = LIS
DIAMETER1	in millimetres. For standing deadwood it is the DBH, for lying deadwood it is the first diameter (the smaller one) (or the only one if just one diameter is assessed in the field)
DIAMETER2	in millimetres. Following the concept of DIAMETER1 for lying or standing deadwood if you use the Smalian's method this is the second diameter (larger).
LENGTH	in metres. For standing deadwood this is the height of the tree or the height of the stem. For laying deadwood this is the length of the deadwood piece. In the case of the Smalian's method this is the distance between the points where diameter1 and diameter2 were measured.
VOLUME_FUNCTION	the mathematical model expressing to calculate the volume on the basis of diameter(s) and length. This is a numeric code and referred to a document with the full description of the used formulas.
DECAY	decay stage according to country classification system.
FOREST_CATEGORIES	field for identifying forest species or categories (broadleaves, coniferous). ND if the species or the category cannot be identified in the field. A NA code is used when the attribute is not collected in the NFI.
VOLUME	deadwood piece volume or its contribution to the plot total volume per hectare (in case of LIS). It can be referred to single deadwood pieces or dead trees, lying or standing.

Name of the table: **SHRUB –** One record for each shrub species collected in plot

FIELD NAME	**DESCRIPTION**
COUNTRY	unique text code of the Country.
PLOT_ID	number of the plot, unique within a Country.
SPECIES	numeric code according to the ICP system of nomenclature of the shrub species
COVER	numeric value of the percentage of coverage of the species within the plot. For each plot the sum of the COVER values may be smaller or greater of 1 (100%).
DATE	date (dd/mm/yyyy) of the assessment in the field, if the data is not available information on the month or on the season is used.

Name of the table: **GROUNDVEGETATION –** One record for each group of under-story vegetation

FIELD NAME	**DESCRIPTION**
COUNTRY	unique text code of the Country.
PLOT_ID	number of the plot, unique within a Country.
GROUP	numeric code according to the system of nomenclature as follows 1.0 Moss layer (terricolous bryophytes and lichens) 1.1.Terricolous bryophytes and 1.2.Terricolous lichens 2.0 Herb layer (all non-ligneous, and ligneous < 0.5m height) 2.1.Regeneration/Plantation (trees) 2.2.Herbs 2.3.Shrubs/no perennial 3. Shrub layer (only ligneous, incl. climbers) > 0.5 m height) 3.1.Regeneration/Plantation (trees) 3.2.Herbs 3.3.Shrubs/no perennial 3.4.Climbers
COVER	numeric value of the percentage of the coverage of the species within the plot; within a plot the sum of the COVER values may be smaller or greater of 1 (100%).
DATE	date (dd/mm/yyyy) of the assessment in the field, if the data is not available information on the month or on the season is used.

6.2. HARMONISED FOREST BIODIVERSITY INDICATORS

Here follows the description of the methods and of the results for the harmonisation process carried out on the common DB. The chapters are structured on the basis of the core variables defined in § 5.

The full list of the harmonised forest biodiversity indicators is in the following Table.

Core variable	Indicator		
Forest type	The Forest type is proposed not as an indicator itself but mainly for stratification purposes of other indicators		
Deadwood	Volume of deadwood (m^3/ha) reported by size		Coarse (CWD)
			Fine (FWD)
	Volume of deadwood (m^3/ha) reported by spatial position		Laying
			Standing
	Volume of deadwood (m^3/ha) reported by decay class		Decay class A
			Decay class B
			Decay class C
			Decay class D
	Volume of deadwood (m^3/ha) reported by woody species		Coniferous
			Broadleaves
			Unknown
Naturalness	Naturalness degree (plot level)		Natural
			Semi-natural
			Plantation
Forest structure	Tree species composition	Relative abundance of native tree species	native basal area/total basal area in the plot
			number of native trees/total number of trees in the plot
		Shannon index for native tree species	on basal area
			on number of trees
		Shannon index for tree species	on basal area
			on number of trees
	Horizontal structure	Mean DBH of the 0.1% (1%, 5% and 10%) largest diameter trees	
		Mean of DBH standard deviations of the plots	
		Mean DBH	
	Vertical	standard deviation of the heights	

Core variable	Indicator	
	structure	mean tree height
		number of layers in the plot
Stand age	Dominant age	proportion of "old" trees (older than the half of the natural tree live span)
	Mean age	mean of tree age
	Age diversity	standard deviation of tree ages

Table 56: list of the indicators calculated on the basis of the common NFI DB.

The database with the harmonised indicators calculated for each of the 3262 NFI plots is one of the final products of this project. These indicators are then used for the combined analysis with forest spatial pattern maps presented in § 7 of this report. Please note that due to data availability of raw NFI data not all the indicators here presented have been calculated for each of the 3262 NFI plots.

6.2.1. Forest type

The reference adopted for the classification of the NFI plots of the common DB is the category level of the EU system of nomenclature developed by EEA (2006). One more class (the 15th) was added for other wooded land. Adopted reference definitions of forest and other wooded land are those defined by FAO (1998) and adopted in COST E43 (Vidal et al., 2008).

The harmonisation consists in classifying univocally each NFI plot to one and only one class of the adopted reference system of nomenclature. The rules for the classification are included in the EEA (2006) report and are in general related to the identification of the present dominant tree species in terms of basal area.

Using the information available in the common DB almost all plots (99.42% of the total) were classified (Table 57).

Category	CH (2000)	CZ01 (2005)	CZ02 (2005)	DE (2002)	IT (2006)	SE (2003)	N° plots
1						150	150
2	58	38	6	654			756
3	501				5		506
4			1	48			49
5	34		8	54	2		98
6	23		4	22			49
7	90	1			33		124
8	1				168		169
9					55		55
10					64		64
11	7		1	50			58

Category	CH (2000)	CZ01 (2005)	CZ02 (2005)	DE (2002)	IT (2006)	SE (2003)	N° plots
12	1			10	11		22
13		1		5		8	14
14	1	184	58	40	12		295
15 (OWL)					1	37	38
NA	7			12			19
N° plots	**723**	**224**	**78**	**895**	**351**	**195**	**2466**

Table 57: number of plots of the common NFI DB classified according to the forest categories *sensu* EEA (2006) for each of the NFI dataset used in the project.

6.2.2. Deadwood

The reference adopted for the harmonisation of deadwood indicators is the following:

A ***standing*** deadwood elements is a dead tree (not stumps) taller than 1.3 m and with a DBH higher than 10 cm.

A ***lying*** deadwood piece is a downed (not suspended) piece of deadwood lying on ground, with a median diameter coarser than 7 cm of at least 0.1 m in length.

Lying deadwood is coarse when the minimum diameter (D_m) is larger than 10 cm and its length is more than 1 meter, otherwise is fine.

The harmonisation of deadwood volume consists of 3 steps:

A. harmonisation of volume (m^3/ha) reported by:
    i. position (lying/standing; Table 58);
    ii. decay classes (Table 59);
    iii. category (broadleaves/coniferous/unknown)
B. harmonisation of diameter and length;
C. harmonisation of volume (m^3/ha) reported by size (coarse/fine, defined only for lying deadwood). This kind of harmonisation is more difficult because it is possible to find, in the same piece, a share of fine and coarse deadwood components.

6.2.2.1. Harmonisation of position, decay classes and forest category.

A formal harmonisation of deadwood position (laying/standing) is not possible on the basis of the raw NFI data available. For this reason the harmonised position adopted is identical to that one reported by the countries on the basis of the following table.

Country	**EU lying (L)**	**EU standing (S)**
CH	10	1
CZ	L	S
DE	L	S Stump
IT	L	S
SE	L	S

Table 58: conversion table for laying/standing harmonisation.

The harmonisation of decay classes was based on the basis of a reference system of classification based on four classes adopted in § 5.2.2.3. with a label-to-label bridging function that assigns to each of the decay classes of the national systems of nomenclature one and only one class of the adopted reference. The bridging function is reported in the following Table.

	EU class			
Country	**A**	**B**	**C**	**D**
CH	-	-	-	-
CZ	100	200	300	400
DE	1	2	3	4
IT	1	2	3-4	5
SE	0-1	2	3	4

Table 59: conversion table used as bridging function for the harmonisation of deadwood decay classes. Switzerland did not report any decay class.

The formal harmonisation of forest categories is possible just on the basis of coniferous/broadleaves classification. The unknown class is used when in the field was not possible to identify if the elements belong to coniferous or broadleaves.

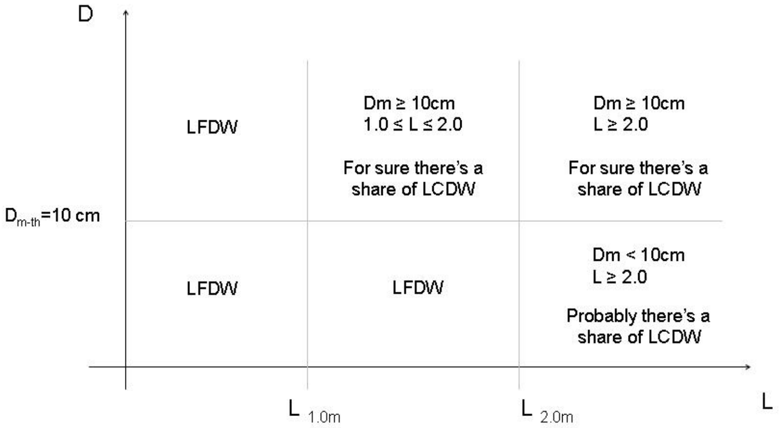
6.2.2.2. Harmonisation of diameter, length, volume

The procedure followed for the harmonisation of deadwood volume of deadwood is different depending of the availability of raw data and on the basis of the relationship between the national definitions and the adopted reference. Finally the procedure are also different for lying and for standing deadwood.

For standing deadwood a formal harmonisation was not needed because the available national definitions are equal to the adopted reference.

For laying deadwood the harmonisation process have the final aim to separate the fine from the coarse components. The procedures are different if raw data available are referred to field measures of one median diameter or two diameters at the smaller and thicker ends of deadwood elements.

If just one median diameter is available a first procedures was adopted in order to select those deadwood elements for which the harmonisation is needed. The procedure is based upon a scheme (Figure 24) that is used to classify each piece as: (*i*) surely and completely fine (*LFDW*) and for which the harmonisation is not needed and (*ii*) with both fine and coarse deadwood (*LFCDW*) for which the harmonisation is needed.



LENGTH	Dm	First classification
L < 1 m	-	LFDW
1 m ≤ L< 2 m	Dm < 100 mm	LFDW
All other cases		LFCDW

Figure 17: scheme for a first classification of deadwood pieces. LFDW**: piece completely fine (lying fine deadwood). The other ones have (for sure) a share of** LCDW **(lying coarse deadwood).**

The estimation of the LFCDW/LCDW components is possible if the position on the length of the element of the 10 cm diameter threshold is available. The relationship between the change of the diameter in terms of change in the position of the diameter along the length of the elements is the tape function that, if considered linear and constant can be expressed as a simple tapering rate (R). It is possible to estimate a mean tapering rate using the raw deadwood data of those Countries in which two diameters are assessed at the end of the lying deadwood elements (equation [7]).

$$R = \frac{\Delta D}{\Delta L} = \frac{D_2 - D_1}{L} \qquad [7]$$

Adopting a constant tapering rate is equivalent to model lying deadwood elements as frustums of cone (Figure 18) where D_1 is the diameter at thicker end, D_2 the one at smaller end, D_3 the median diameter and *L* the total length of the element.

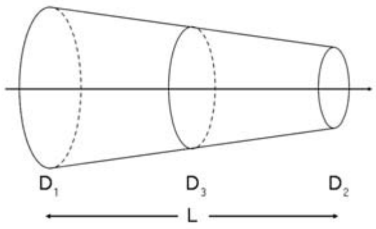


Figure 18: the frustum of cone is the model used for creating the tape function adopted in the harmonisation of lying deadwood elements.

On the basis of the data available R was set equal to 6 mm/m (a change of the diameter of 6 mm every meter of length).

From [7]:

$$l_{th} = L_m + \frac{D_{th} - D_m}{R} \qquad [8]$$

where:

L_m is the half-length of the piece (=L/2);

D_m is the diameter at median section;

D_{th} is the threshold diameter (= 100 mm) between coarse and fine elements;

l_{th} is the length of coarse share;

R is the tapering rate (equal to - 6 mm/m).

and using the adopted values:

$$l_{10} = L_m + \frac{100 - D_m}{-6} \qquad [9]$$

if Lth < 1 m ⇨ all raw deadwood volume is fine (LFDW), the harmonisation is completed;

if Lth ≥ 1m ⇨ all raw deadwood volume is coarse (LCDW), the harmonisation is completed;

if 1 m ≤ Lth < L ⇨ the raw deadwood volume has both fine and coarse components, the harmonisation continues.

The percentage of fine and coarse volumes can be estimated with the equations [7] and [8]. The median diameter of fine portion (D_{mLFDW}) is:

$$D_{mLFDW} = D_{th} - R \cdot (L_{th}/2) \qquad [10]$$

This diameter can be used to estimate the fine volume with Smalian formula [11]:

$$V_{LFDW} = \frac{\pi}{4} \cdot D^2_{m-LFDW} \cdot L_{th} \qquad [11]$$

It is possible to estimate the total volume of the piece ($\hat{V}_{tot}$) using the same formula and with its median diameter (D_m) and its length (L):

$$\hat{V}_{tot} = L \cdot \pi/4 \cdot (D_m)^2 \qquad [12]$$

The percentage of coarse and fine deadwood components can be calculated as::

fine deadwood $$V_{LFDW\%} = \frac{V_{LFDW}}{\hat{V}_{tot}} \qquad [13]$$

coarse deadwood $$V_{LCDW\%} = \hat{V}_{tot} - V_{LFDW} \qquad [14]$$

These percentages are applied to raw deadwood volumes to complete the harmonisation.

The harmonisation of the lying deadwood elements for which two diameters and the ends are available is easier. As a first step all pieces with diameter at thicker end smaller than 10 cm and with length shorter than 1 meter are classified as fine deadwood (LFDW). For the remaining elements the equations [7] and [8] are used to estimate the mean tapering rate and the distance from ticker end (L_{th}) at which the section has a diameter equal to 10 cm. In this case the [8] becomes:

$$L_{th} = -\frac{D_{\max} - D_{th}}{R} \qquad [15]$$

where:

D_{max} is the diameter at thicker end;

D_{th} is the threshold diameter (= 100 mm);

R si the tapering rate (that is different for each piece);

L_{th} is the length of coarse share.

if $L_{th} \geq L$ ⇨ all raw deadwood volume is coarse (LCDW), the harmonisation is completed;

if $L_{th} < L$ ⇨ the raw deadwood volume has both fine and coarse components, the harmonisation continues.

The equations from [10] to [14] are applied to complete the harmonisation.

The last harmonisation step is needed for those Countries adopting a threshold diameter that is smaller than the one defined in the reference (Table 60).

Country	**diameter (mm)**
CH	120 *at smaller end*
CZ	70 *at smaller end*
DE	200 *at thicker end*
IT	100 *at smaller end*
SE	40 *at smaller end*

Table 60: different diametric threshold for the inclusion of piece in the dataset.

The relationship between the deadwood volume with Dm 70 and the deadwood volume with Dm 100 and Dm 120 was calculated on the basis of the information available for CZ and SE. The relationship was then applied to the harmonised volume calculated for CH and IT.

A different approach was followed for the data from the German NFI. In Countries that collected two diameters (e.g. Italy) the harmonised deadwood volume calculated with the German threeshold was calculated and the ratio between this volume and the harmonised deadwood volume calculated with the adopted reference was calculated and finally applied to the German values.

6.2.2.3. Calculation of deadwood indicators

After the harmonisation process the following deadwood indicators were calculated:

- volume of deadwood (m³/ha) reported by spatial position (laying-standing)
- volume of deadwood (m³/ha) reported by harmonised decay classes
- volume of deadwood (m³/ha) reported by woody species (coniferous-broadleaves-unknown)
- volume of deadwood (m³/ha) reported by size (coarse-fine)

6.2.3. Naturalness

The naturalness of a forest stand is defined as the inverse of the distance from the real status to the potential undisturbed condition. The reference adopted is a system of nomenclature based on 4 classes: *natural*, *semi-natural*, *far from natural*, *unknown* The bridging function adopted is the reclassification showed in Table 61. Some of the plots from the original NFI databases are not classified and for this reason this class was also maintained in the reference.

Country	Reference naturalness classes			
	Natural	*Semi-natural*	*Far from natural*	*Unknown*
CH	4-5	2-3	1	0
CZ	400-500	300	100-200-600	0
DE	1	2-3	4-5	/
IT	1	2	3	0
SE	1	/	0	/

Table 61: relationship between naturalness codes adopted by the Countries and the classes of the adopted reference.

The bridging function was applied and the harmonised naturalness was computed for all the NFI plots. In the following Figure an example of the combined result of the harmonisation of naturalness and forest types.

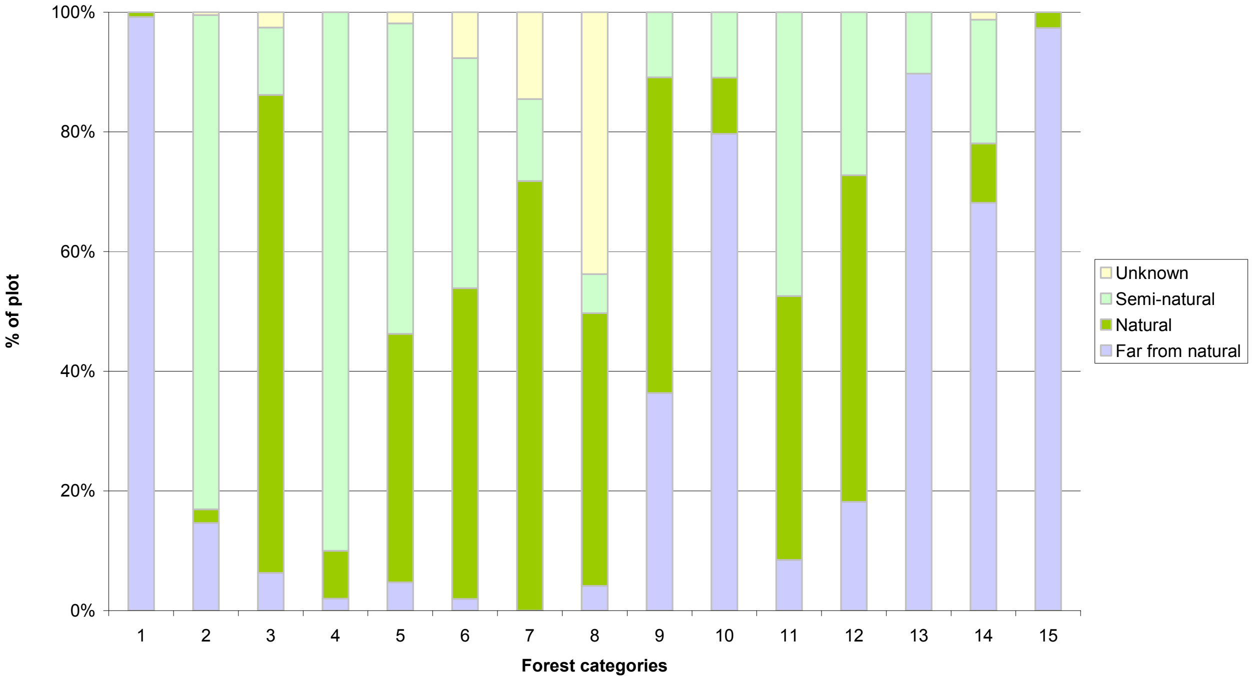


Figure 19: percentage of plot per harmonised naturalness classes and per harmonised forest type categories.

6.2.4. Stand structure

The forest structure indicators can be divided in three classes: (*i*) compositional, (*ii*) horizontal and (*iii*) vertical.

In the next paragraphs the harmonisation methods for all the input parameters needed for the calculation of the indicators are described.

6.2.4.1. Harmonisation of trees and natural trees

Since all the stand structure indicators refer to the arrangements of trees, the reference definition for a tree adopted in this project is:

a tree is a woody perennial of a species typically forming a self-standing main stem and having a definite crown, taller than 1.30 cm from the ground and with a diameter at 1.3 m from the ground (diameter at breast height – DBH) larger than or equal to 10 cm.

All the trees for each NFI plots satisfying this definition were considered for the following harmonisation steps and indicators calculation.

This definition was developed basically on the basis of raw data availability in the NFI databases and considering reference definitions (COST E43, 2008) and the analytical decomposition methods developed in COST action E43 (Vidal et al., 2008).

The adoption of the reference determined the discard of the 11.6% of the total number of trees available in the raw NFI DB (moving from 44383 to 39251 trees) and of the 0.6% of the plots (from 3025 to 3007).

A tree is considered "natural" on the basis of the natural tree species list for available for each of the adopted harmonised forest categories (EEA, 2006).

6.2.4.2. Harmonisation of number of trees per hectare and basal area

To calculate the harmonised values of basal area and number of tree per hectare for each of the NFI plots different methods were used depending of the field methods applied in the different countries.

In Italy and Sweden the area of the NFI plots was available in the raw NFI DB. So the number of trees per hectare in a plot is:

$$N/ha = \frac{N \cdot 10000}{A} \qquad G/ha = \sum_{i=1}^{n} \frac{\pi}{4} DBH_i^2 \cdot \frac{10000}{A}$$

Where: *N* is the number of harmonised trees per plot, A is the plot area in m^2, DBH$_i$ is the diameter in metres measured at 1.3 m height of the *i*-th harmonised trees belonging to the NFI plot.

In Switzerland an *expansion factor* (*ef*) is available for each tree depending of the DBH of the tree. The sum of the *ef* values for each plot is equal to the number of tree per hectare. The basal area is the sum of (g_i**ef*$_i$) for each of the *i*-th harmonised trees belonging to the NFI plot

A similar approach was used for Czech Republic were a number (*RTN-RepreTreeNumber*) that allows to compare the per plot to per hectare data. The total number of trees per hectare per plot (*N/ha*) is:

$$N/ha = RTN \cdot 20 \qquad\qquad G/ha = \sum_{i=1}^{n} \frac{G}{ha}_{i} \cdot RTN_i \cdot 20 \quad [2]$$

In Germany NFI the number of trees is recorded with relascopic approach with area factor equal to 4. So the number of trees per hectare is *4* divided for the basal area and the basal area is the number of harmonised trees per hectare multiplied by *4*.

The calculation of number of trees per hectare and basal area was carried out within the raw NFI DB on the basis of the following query.

```
#QUERY A:

SELECT [2aTREE_UNION_new01].TABLE, [2aTREE_UNION_new01].COUNTRY, [2aTREE_UNION_new01].REF_YEAR,
[2aTREE_UNION_new01].PLOT_ID, [2aTREE_UNION_new01].TREE_ID, [2aTREE_UNION_new01].ICP_CODE_ok,
[2aTREE_UNION_new01].[native or not], [2aTREE_UNION_new01].DBH, Atn(1)*([DBH]^2)/1000000 AS gi_m2,
[2aTREE_UNION_new01].SAMPLING_UNIT_AREA, [2aTREE_UNION_new01].BASAL_AREA_FACTOR,
[2aTREE_UNION_new01].RepreTreeNumber, IIf([COUNTRY]="DE",Round(4/(Atn(1)*([DBH]^2)/1000000),0),0) AS
[DE ni_ha], IIf([COUNTRY]="CH",[SAMPLING_UNIT_AREA]*Atn(1)*([DBH]^2)/1000000,IIf([COUNTRY]="CZ100" Or
[COUNTRY]="CZ200",(Atn(1)*([DBH]^2)/1000000)*[RepreTreeNumber]*20,IIf([COUNTRY]="IT" Or
[COUNTRY]="IT" Or [COUNTRY]="SE",10000*(Atn(1)*([DBH]^2)/1000000)/[SAMPLING_UNIT_AREA],0))) AS
gha_no_DE

FROM 2aTREE_UNION_new01

GROUP BY [2aTREE_UNION_new01].TABLE, [2aTREE_UNION_new01].COUNTRY,
[2aTREE_UNION_new01].REF_YEAR, [2aTREE_UNION_new01].PLOT_ID, [2aTREE_UNION_new01].TREE_ID,
[2aTREE_UNION_new01].ICP_CODE_ok, [2aTREE_UNION_new01].[native or not], [2aTREE_UNION_new01].DBH,
Atn(1)*([DBH]^2)/1000000, [2aTREE_UNION_new01].SAMPLING_UNIT_AREA,
[2aTREE_UNION_new01].BASAL_AREA_FACTOR, [2aTREE_UNION_new01].RepreTreeNumber,
IIf([COUNTRY]="DE",Round(4/(Atn(1)*([DBH]^2)/1000000),0),0),
IIf([COUNTRY]="CH",[SAMPLING_UNIT_AREA]*Atn(1)*([DBH]^2)/1000000,IIf([COUNTRY]="CZ100" Or
[COUNTRY]="CZ200",(Atn(1)*([DBH]^2)/1000000)*[RepreTreeNumber]*20,IIf([COUNTRY]="IT" Or
[COUNTRY]="IT" Or [COUNTRY]="SE",10000*(Atn(1)*([DBH]^2)/1000000)/[SAMPLING_UNIT_AREA],0)))

HAVING ((([2aTREE_UNION_new01].DBH)>=100))

ORDER BY [2aTREE_UNION_new01].COUNTRY, [2aTREE_UNION_new01].REF_YEAR,
[2aTREE_UNION_new01].PLOT_ID, [2aTREE_UNION_new01].TREE_ID;


#QUERY B:

SELECT [Query08: gi per plot].TABLE, [Query08: gi per plot].COUNTRY, [Query08: gi per plot].REF_YEAR, [Query08:
gi per plot].PLOT_ID, Count([Query08: gi per plot].COUNTRY) AS N_plot, Sum([Query08: gi per plot].gi_m2) AS
G_plot, IIf([COUNTRY]="CH",Sum([SAMPLING_UNIT_AREA]),IIf([COUNTRY]="CZ100" Or
[COUNTRY]="CZ200",Round(Sum([RepreTreeNumber])*20,0),IIf([COUNTRY]="DE",Sum([DE
ni_ha]),Round(Sum(10000/[SAMPLING_UNIT_AREA]))))) AS N_ha, IIf([country]="CH" Or [country]="CZ100" Or
[country]="CZ200" Or [country]="IT" Or [country]="IT" Or [country]="SE",Sum([gha_no_DE]),4*Count([DE
ni_ha])) AS G_ha INTO [anagrafica plot TREE TABLE]

FROM [Query08: gi per plot]

GROUP BY [Query08: gi per plot].TABLE, [Query08: gi per plot].COUNTRY, [Query08: gi per plot].REF_YEAR,
[Query08: gi per plot].PLOT_ID

ORDER BY [Query08: gi per plot].COUNTRY, [Query08: gi per plot].REF_YEAR, [Query08: gi per plot].PLOT_ID;
```

Table 62: the two SQL *queries* applied to calculate the harmonised number of trees and the basal area per hectare for each of the NFI plots.

An example of the results of the harmonisation process is the calculation of mean DBH (diameter of the average basal area) by harmonised forest category calculated on the basis of the available NFI plots.

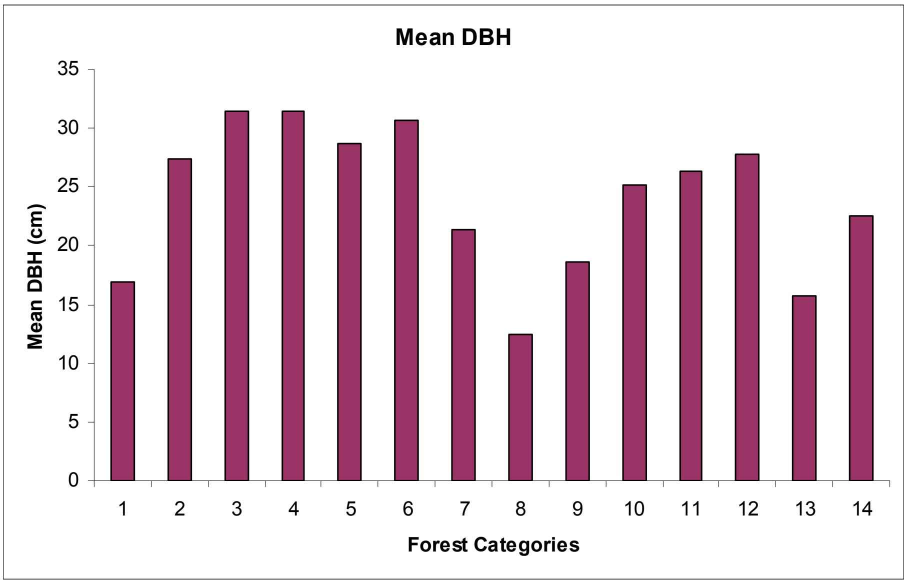


Figure 20: mean DBH per harmonised forest category (EEA, 2006).

6.2.4.3. Harmonisation of trees height and vertical layers

The tree height (measured or estimated) was provided for almost all the test areas with the exception of some plots in IT and Sweden. The following hypsometric functions were built using the available data.

class	hypsometric function
Broadleaves	$y = 4.4397\mathrm{Ln}(DBH) - 1.6227$
Coniferous	$y = 6.8154\mathrm{Ln}(DBH) - 9.4873$
Small trees	$y = 1.1013\mathrm{Ln}(DBH) + 1.825$

Table 63: function used to estimate tree heights on the basis of DBH. The "small trees" category was introduced for a limited number of species typical of the Mediterranean area.

The harmonisation of the number of vertical layers in the plot was based on a reference system of nomenclature with three classes: one layers, two layers, more than two layers. The harmonisation was carried out with a bridging function presented in Table 64 in order to reclassify the systems of nomenclature available in the different countries.

		Common layers code				
COUNTRY	**Country layers code**	**1 LAYER**	**2 LAYERS**	**MORE THAN 2 LAYERS**	**NA**	***total number of records***
CH	0				16	*16*
CH	1	279				*279*
CH	2		367			*367*
CH	3			50		*50*
CH	4			11		*11*
CZ	0	0	0	0	304	*304*
CZ	100	205	0	0	0	*205*
CZ	200	0	92	0	0	*92*
CZ	300	0	0	3	0	*3*
DE	1	242				*242*
DE	-1				1	*1*
DE	2		399			*399*
DE	3		35			*35*
DE	4		70			*70*
DE	5		6			*6*
DE	6			142		*142*
IT	1	122				*122*
IT	2		34			*34*
IT	3			94		*94*
IT	ND				101	*101*
SE	0				501	*501*
SE	1	57				*57*
SE	2		113			*113*
SE	3			17		*17*
SE	4			1		*1*
Total		**905**	**1116**	**318**	**923**	**3262**

Table 64: layers harmonization

6.2.4.1. Calculation of stand structure indicators

Simple indicators such as mean and standard deviations of the above harmonised parameters are not here described and just the methods for the calculation of more complex indicators are presented.

The Shannon index (Shannon & Weaver, 1949) was calculated both on the proportion species by tree numbers and by basal area proportion, both as proportion of the total number of species or as proportion of the total number of native species only.

The Shannon index is:

$$H' = -\sum_{i=1}^{S} p_i * \ln p_i$$

where p_i is the proportion of trees (or propostion of basal area) of *i-th* specie (n_i) divided by the number (N_i) of species (or of natural species) within the plot ($p_i = n_i/N_i$).

The average DBH of the largest trees (in terms of DBH) was calculated for each plot on the basis of the following percentiles classes: 99.9%-100%, 99.0%-100%, 95.0%-100%, 90.0%-100%.

6.2.5. Stand age

Three indicators were foreseen for the stand age core variable unfortunately the limited amount of available information do not led to their calculation.

The only indicator calculated was the average age of the trees in the plots. Also for this simple variable the amount of information was limited. When available we used the "stand age" variable assessed by the NFI at plot level, when not available the available tree ages (not available for all the trees) were averaged.

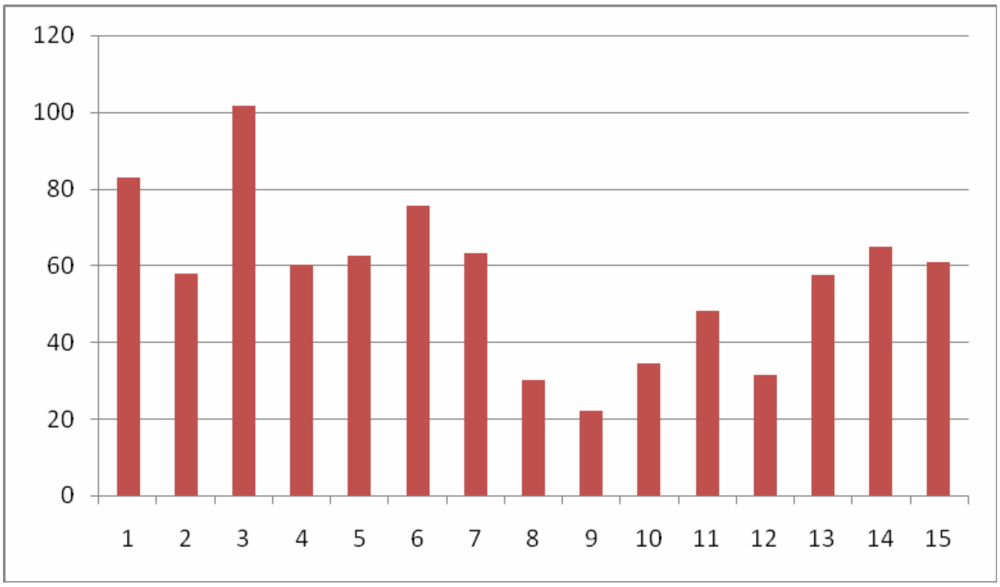


Figure 21: mean age (year) per harmonised forest category (EEA, 2006).

7. DOWNSCALING ANALYSIS

7.1. INTRODUCTION

The downscaling analysis is performed integrating the harmonised biodiversity indicators calculated for the NFI plots in the five test areas and the spatial pattern classes derived by the GUIDOS analysis of the forest maps. The analysis was performed on the basis of two different approaches:

e. pixel approach: for each NFI plot the forest spatial pattern class derived by GUIDOS was extracted from the pixel the plot belong to or from the pixels in the surroundings of the plot. On such a basis the NFI plots database was populated also with spatial pattern information. Finally the combined analysis verified the relationships between biodiversity indicators and spatial pattern classes

f. area approach: the method is similar but instead of extracting spatial pattern classes and NFI biodiversity indicators from one single or a very small number of pixels these information are averaged over larger regions. For this purpose the test areas were divided in sub-areas, for each subarea both NFI biodiversity indicators and pixel level spatial pattern classes are aggregated and then analysed.

The final aims of both the pixel and the area based approaches are:

i. to characterise the forest spatial pattern MSPA classes in terms of the different biodiversity indicators in the different test areas; this activity is done aggregating the forest biodiversity indicators on the basis of the position of the NFI plots in the different MSPA classes derived from the forest maps.

ii. to evaluate if the relationships between MSPA classes and NFI forest biodiversity indicators are similar in all the test areas or not;

iii. to evaluate if the NFI biodiversity indicators have different values depending upon the different MSPA classes they belong to;

iv. to evaluate if the temporal trends in the spatial pattern classes is related with the temporal trends in the forest biodiversity indicators;

v. to evaluate if these relationships are influenced by the resolution of the input forest maps (low: 100 m or high: 25 m) or by the definition of core areas in terms of distance from the outtern border of the forest patch set up with the GUIDOS software.

The analysis is limited to three harmonised plot based forest biodiversity indicators:

- Total volume of deadwood (m^3 ha^{-1})
- Shannon index for tree species (on basal area)
- Standard deviation of DBH (cm)

These three indicators were selected because they are frequently used in international reporting frameworks (MCPFE, FAO, EEA). They cover different components of forest biodiversity: deadwood is an integrated indicator related to the habitat of saproxylic fauna and flora, Shannon is a compositional diversity index while the standard deviation of DBH is a structural index (Winter et al., 2008). Before adopting these indicators in the final phase of the project they were screened in order to ensure that they were well un correlated on the basis of the NFI data available. The test was carried out with a correlation analysis reported in the following Figures that demonstrated the original hypothesis.

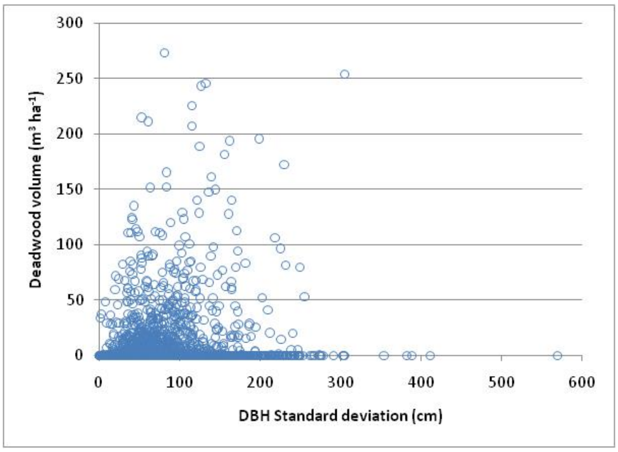


Figure 22: correlation analysis between harmonised values of the indicators (std. dev. of DBH vs. deadwood) based on all the NFI plots available.

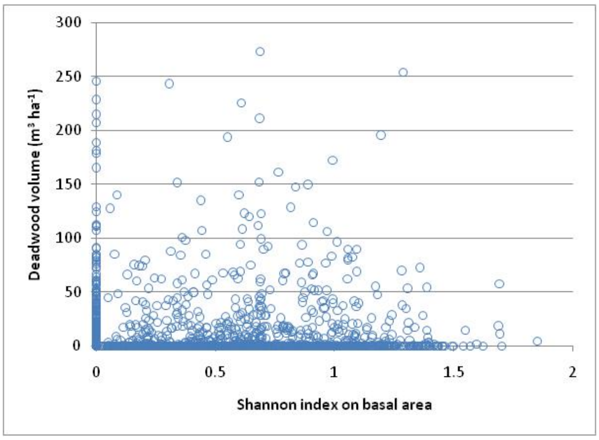


Figure 23: correlation analysis between harmonised values of the indicators (Shannon index vs. deadwood) based on all the NFI plots available.

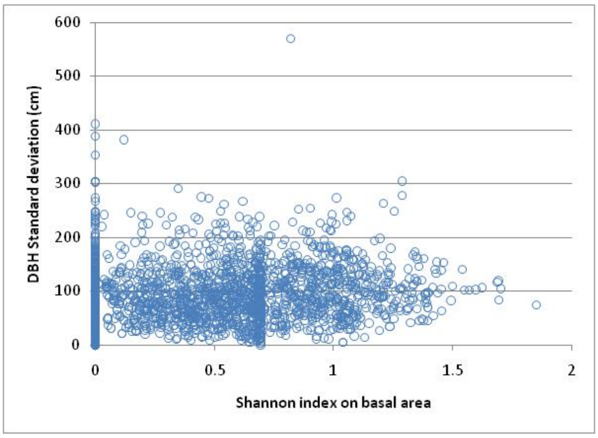


Figure 24: correlation analysis between harmonised values of the indicators (Shannon index vs. std. dev. of DBH) based on all the NFI plots available.

The downscaling analysis required the combination between forest maps and NFIs acquired in similar time frames, for this reason the following data were used in the analysis.

Test areas	Forest maps	NFIs
CZ krivolak	2000HR, 2000LR	NFI2005
CZ krivolak	1990LR	NFI1996
CZ brdy	2000LR	NFI2005
CZ brdy	1990LR	NFI1996

Test areas	Forest maps	NFIs
IT	2005HR, 2000LR	NFI2005
DE	2000HR	NFI2002
CH	2000HR	NFI2000
SE	2005HR	NFI2003
SE	2000HR	NFI1999

Table 65: Relationship between forest maps and NFI's used in the combined analysis in each of the test sites.

Before carrying out the combined analysis the available forest maps classified with the GUIDOS software and the NFI plots classified on the basis of the GUIDOS classes they belong to were analyzed in order to understand if the distribution of GUIDOS classes of forest maps was comparable with the distribution of the NFI plots.

The aim of this test was to understand if the NFI plots in the test areas could be a representative sample of the pixels in the forest maps elaborated with GUIDOS. The representativeness of NFI plots is in fact ensured by their unbiased sampling design optimized for large regions.

7.2. PRE-ANALYSIS

7.2.1. GUIDOS classes in forest maps

In order to get an overview of the GUIDOS classes, the complete maps were analyzed – independently of any NFI plots. As an example here follows the analysis carried out for Czech Republic test sites and a brief comment for all other test areas.

Study area Czech Republic

Abbrevation: CZ01 (Brdy)

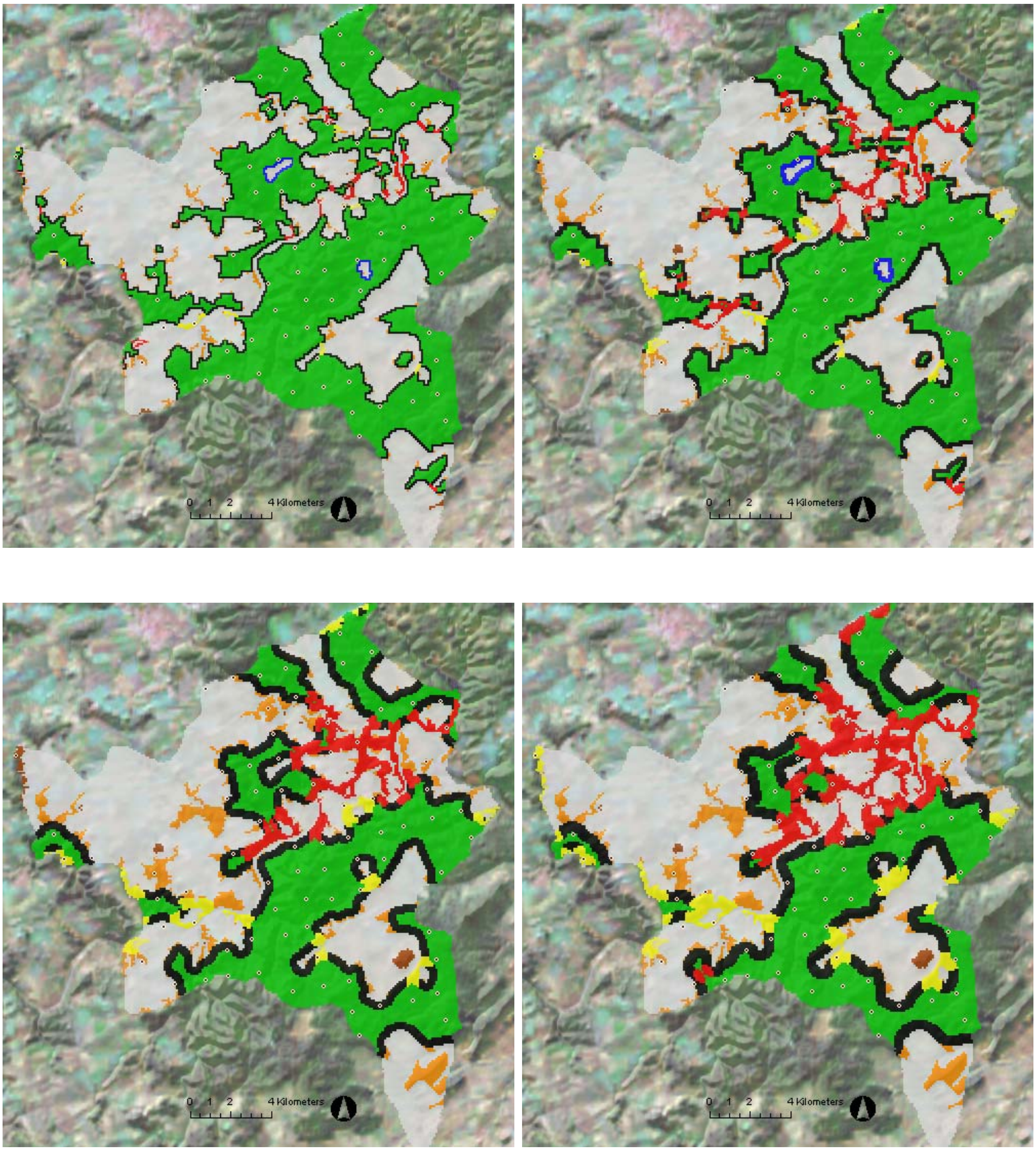


Figure 25: GUIDOS maps based on the forest map 2000: Size/Edge 1 - 4

Year	2000			
Resolution	100m			
Intext	0			
Fraction of GUIDOS Classes				
GUIDOS Class	Edge=1	Edge=2	Edge=3	Edge=4
Branch (1)	3.11%	5.97%	10.30%	10.17%
Edge (3)	15.28%	20.79%	25.33%	26.11%
Core (17)	78.93%	64.21%	49.78%	40.41%
Bridge (33)	0.92%	2.86%	5.24%	8.46%
Bridge in Edge (35)	0.45%	2.97%	3.81%	7.45%
Loop (65)	0.44%	0.99%	1.95%	2.63%
Loop in Edge (67)	0.21%	0.92%	2.65%	4.22%
Perforation (5)	0.50%	1.09%	0.00%	0.00%
Islet (9)	0.17%	0.21%	0.94%	0.55%
Overall result	100.00%	100.00%	100.00%	100.00%

Table 66: Fraction of GUIDOS classes in study area KřIvoklát with GUIDOS parameter Intext = 0 and pixel size 100m.

The GUIDOS analysis was also carried out on the forest management map with a resolution of 25m (Table 67).

Year	2000			
Resolution	25m			
Intext	0			
Fraction of GUIDOS Classes				
GUIDOS Class	Edge=1	Edge=2	Edge=3	Edge=4
Branch (1)	1.53%	2.77%	4.03%	4.52%
Edge (3)	8.82%	12.60%	16.62%	18.58%
Core (17)	85.84%	75.12%	63.66%	55.54%
Bridge (33)	0.42%	1.35%	2.28%	2.95%
Bridge in Edge (35)	0.25%	1.45%	3.48%	6.50%
Loop (65)	0.16%	0.69%	1.45%	2.52%
Loop in Edge (67)	0.18%	1.27%	1.84%	3.05%
Perforation (5)	2.28%	3.17%	3.92%	3.22%
Loop in Perforation (69)	0.08%	0.29%	0.71%	0.81%
Islet (9)	0.43%	1.28%	1.99%	2.20%
Bridge in Perforation (37)	0.00%	0.01%	0.03%	0.12%
Overall result	100.00%	100.00%	100.00%	100.00%

Table 67: Fraction of GUIDOS classes in study area KřIvoklát with GUIDOS parameter Intext = 0 and pixel size 25m.

There is a shift of the fraction of the GUIDOS classes. Class *'Core'* decreased whereas all other classes (except classes *69* and *37*) increased.

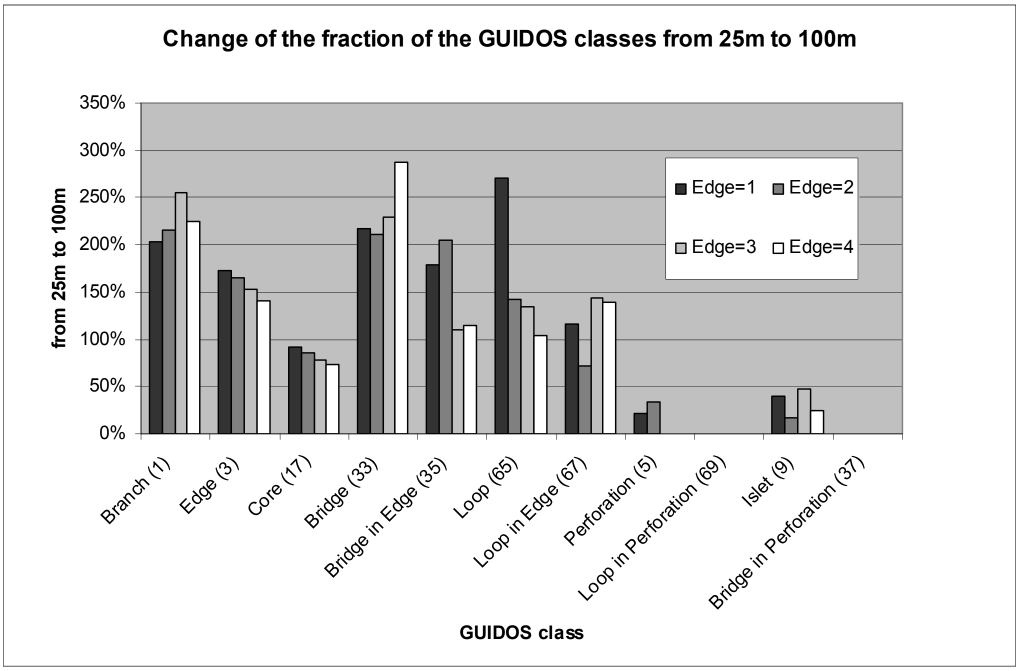


Figure 26: Change of the fraction of the GUIDOS classes in the study area KřIvoklát from pixel size 25m to 100m.

The different fraction can be the result from either the higher resolution or from the different forest map. Although the basis of the forest map 100m (Corine Land Cover) and the forest map 25m (Forest management map) is different, the forest area seem congruent. Thus the effect is because of the different resolution. The higher the resolution, the more pixel of the class *'Core'* occurs.

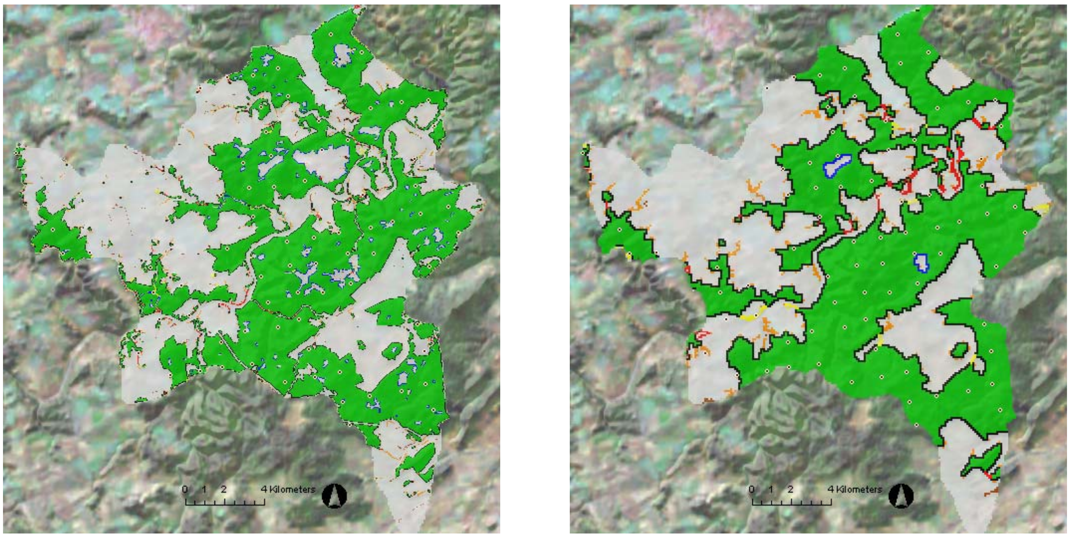


Figure 27: GUIDOS classification of the forest maps from the study area KřIvoklát. Left: Based on the Forest management map (25m). Right: Based on CLC (100m).

Study area Switzerland

Abbrevation: CH

In study area Switzerland the forest map for GUIDOS analysis was the forest layer of the topographic map 1:25’000. The result is very different from the study area KřIvoklát. The forest in the alpine area is with a high proportion of small and narrow patches. Therefore the amount of GUIDOS class *‘Core’* is much smaller than in the study site KřIvoklát. Using the GUIDOS parameter size=4 the class *‘Bridge’* is even the biggest class.

Year	2000			
Resolution	25m			
Intext	0			
Fraction of GUIDOS Classes				
GUIDOS Class	Edge=1	Edge=2	Edge=3	Edge=4
Branch (1)	6.12%	10.02%	10.19%	8.46%
Edge (3)	22.81%	19.87%	13.51%	7.49%
Core (17)	57.00%	34.83%	18.86%	11.88%
Bridge (33)	4.25%	12.65%	24.95%	35.92%
Bridge in Edge (35)	2.40%	10.65%	16.45%	18.34%
Loop (65)	1.57%	2.47%	2.99%	2.85%
Loop in Edge (67)	1.01%	2.32%	2.16%	1.70%
Perforation (5)	1.75%	0.73%	0.33%	0.19%
Loop in Perforation (69)	0.23%	0.27%	0.13%	0.07%
Islet (9)	2.85%	6.17%	10.45%	13.09%
Bridge in Perforation (37)	0.01%	0.02%	0.00%	0.00%
Overall result	100.00%	100.00%	100.00%	100.00%

Table 68: Fraction of GUIDOS classes in study area Switzerland with GUIDOS parameter Intext = 0 and pixel size 25m.

Study area Germany

Abbrevation: DE

Forest pattern in study site Germany are similar to those in study area KřIvoklát. The patches are even larger, resulting in a very high value in GUIDOS class *‘Core’*.

Year	2000
Resolution	25m

Intext	0			
Fraction of GUIDOS Classes				
GUIDOS Class	Edge=1	Edge=2	Edge=3	Edge=4
Branch (1)	0.24%	1.35%	3.70%	5.98%
Edge (3)	8.05%	14.55%	20.51%	23.07%
Core (17)	90.91%	82.39%	72.71%	66.41%
Bridge (33)	0.01%	0.22%	0.67%	1.05%
Bridge in Edge (35)	0.01%	0.38%	1.19%	2.07%
Loop (65)	0.00%	0.01%	0.04%	0.07%
Loop in Edge (67)	0.00%	0.01%	0.05%	0.10%
Perforation (5)	0.77%	1.08%	1.08%	1.00%
Loop in Perforation (69)	0.00%	0.00%	0.01%	0.01%
Islet (9)	0.00%	0.00%	0.03%	0.22%
Bridge in Perforation (37)	0.00%	0.00%	0.00%	0.00%
Overall result	100.00%	100.00%	100.00%	100.00%

Table 69: Fraction of GUIDOS classes in study area Germany with GUIDOS parameter Intext = 0 and pixel size 25m.

Study area Italy

Abbrevation: IT

Table 70 and Table 71 shows the fraction of the GUIDOS classes from the classification of the 25m forest map and the 100m forest map, respectively.

Year	2005			
Resolution	25m			
Intext	0			
Fraction of GUIDOS Classes				
GUIDOS Class	Edge=1	Edge=2	Edge=3	Edge=4
Branch (1)	4.65%	7.30%	8.42%	7.69%
Edge (3)	13.70%	15.45%	14.74%	11.60%
Core (17)	74.94%	61.04%	48.77%	41.93%
Bridge (33)	1.99%	4.92%	10.78%	16.68%
Bridge in Edge (35)	0.91%	4.20%	8.06%	11.75%
Loop (65)	0.64%	1.35%	2.03%	2.48%
Loop in Edge (67)	0.31%	1.30%	2.01%	2.69%

Perforation (5)	1.92%	1.30%	0.91%	0.66%
Loop in Perforation (69)	0.06%	0.12%	0.18%	0.28%
Islet (9)	0.88%	3.01%	4.09%	4.24%
Bridge in Perforation (37)	0.01%	0.00%	0.00%	0.00%
Overall result	100.00%	100.00%	100.00%	100.00%

Table 70: Fraction of GUIDOS classes in study area Italy with GUIDOS parameter Intext = 0 and pixel size 25m.

Year	2000			
Resolution	100m			
Intext	0			
Fraction of GUIDOS Classes				
GUIDOS Class	Edge=1	Edge=2	Edge=3	Edge=4
Branch (1)	6.10%	14.59%	13.41%	15.95%
Edge (3)	23.75%	28.19%	29.55%	26.36%
Core (17)	66.75%	46.70%	29.60%	20.03%
Bridge (33)	1.67%	3.20%	5.39%	11.55%
Bridge in Edge (35)	0.98%	3.51%	5.42%	9.41%
Loop (65)	0.28%	0.98%	1.96%	1.68%
Loop in Edge (67)	0.19%	0.71%	1.76%	2.16%
Islet (9)	0.28%	2.11%	12.91%	12.85%
Overall result	100.00%	100.00%	100.00%	100.00%

Table 71: Fraction of GUIDOS classes in study area Italy with GUIDOS parameter Intext = 0 and pixel size 100m.

The effect of the different pixel size (25m vs. 100m) is different from the study area Brdy. In Italy, the GUIDOS classes *'Branch'*, *'Edges'* and *'Islets'* increased from the GUIDOS classification based on the 25m forest map to the 100m map (Figure 28). All other classes decreased. Especially the class 'Islets' is contradictory to the results from Brdy.

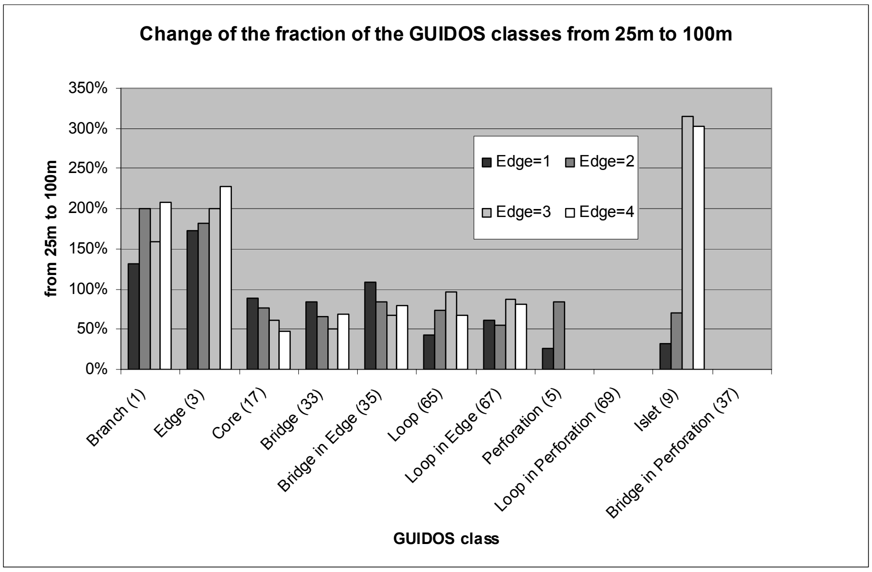


Figure 28: Change of the fraction of the GUIDOS classes in the study area Italy from pixel size 25m to 100m.

Study area Sweden

Abbrevation: SE

Year	2000			
resolution	25m			
intext	0			
Fraction of Guidos Classes				
Guidos_Class	Edge=1	Edge=2	Edge=3	Edge=4
Branch (1)	1.20%	2.96%	4.35%	4.50%
Edge (3)	4.60%	9.91%	14.92%	14.68%
Core (17)	84.42%	71.35%	57.02%	47.76%
Bridge (33)	0.31%	1.47%	4.68%	9.10%
Bridge in Edge (35)	0.19%	1.72%	5.63%	11.25%
Loop (65)	0.27%	0.87%	1.50%	1.68%
Loop in Edge (67)	0.06%	0.62%	1.70%	2.42%
Perforation (5)	8.54%	9.26%	7.25%	5.02%
Loop in Perforation (69)	0.20%	0.98%	1.49%	1.68%
Islet (9)	0.19%	0.65%	1.11%	1.37%
Bridge in Perforation (37)	0.04%	0.21%	0.35%	0.53%
Overall result	100.00%	100.00%	100.00%	100.00%

Table 72: Fraction of GUIDOS classes in study area Sweden with GUIDOS parameter Intext = 0 and pixel size 25m.

For simplification the GUIDOS classes were grouped into CORE and Non-CORE classes:

- Core classes are: 17, 117
- Non-core classes are: the rest, except 0, 100 (Background) and 129 (Missing)

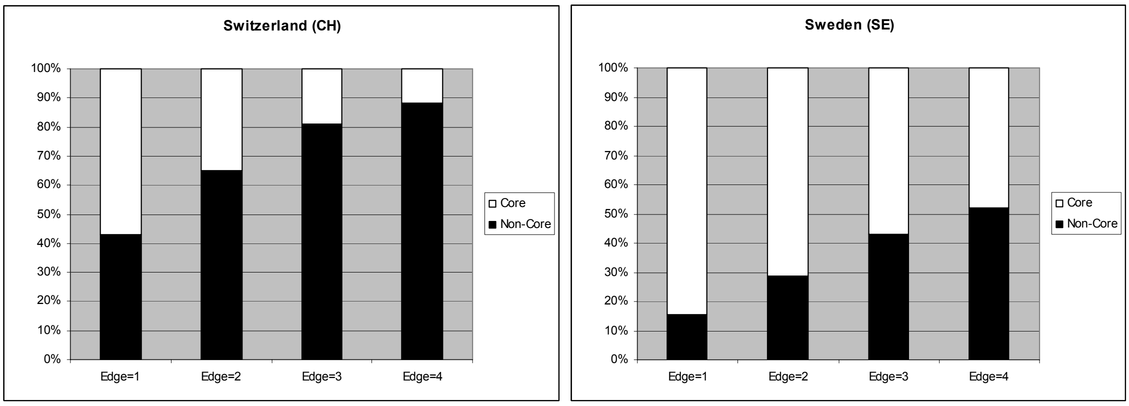


Figure 29: Fraction of Core/Non-Core classes in 2 study sites. The resolution of the input maps was 25m.

In all study areas there is a clear trend in decreasing of the core areas when the size parameter of GUIDOS is increased. This is also independent from the resolution of the tested forest maps. For two study areas (KřIvoklát CZ02 and Italy) both resolutions were classified. In both areas the core area is 20% - 30% higher when the higher resolution maps are classified.

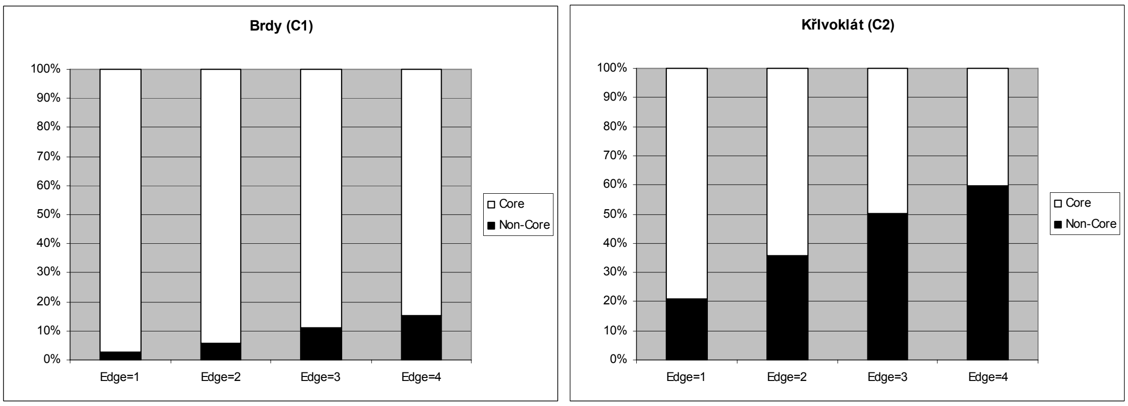


Figure 30: Fraction of Core/Non-Core classes in 2 study sites. The resolution of the input maps was 100m.

7.2.2. GUIDOS classes in NFI plots vs. GUIDOS classes in forest maps

The above analysis of data showed an overview of the situation in the study areas. But for the objective of the project it is decisive, to derive predications at plot level. The GUIDOS maps were therefore been overlaid with the NFI plots. The GUIDOS classes were grouped into *'Core'* and *'Non-Core'* classes as before in Chapter 1.

Study area Brdy (Czech Republic)

Abbrevation: CZ01

In study area Brdy (CZ01) only one NFI plot is outside of the forest mask from the year 2000. Almost all plots are in the *'Core'* area.

Year	2000				
Resolution	100m				
INTEXT	1				
Aggregated Guidos Class	Daten	Edge=1	Edge=2	Edge=3	Edge=4
Core	Number of NFI Plots	215	207	197	192
	Fraction of NFI Plots	96.0%	92.4%	87.9%	85.7%
Non_Core	Number of NFI Plots	8	16	26	31
	Fraction of NFI Plots	3.6%	7.1%	11.6%	13.8%
Background	Number of NFI Plots	1	1	1	1
	Fraction of NFI Plots	0.4%	0.4%	0.4%	0.4%
Sum: Number of NFI Plots		224	224	224	224
Sum: Fraction of NFI Plots		100.0%	100.0%	100.0%	100.0%

Table 73: Fraction of the available NFI – Plots in the classes 'Core', 'Non-Core' and 'Background' of the GUIDOS classification of study area Brdy (CZ01)

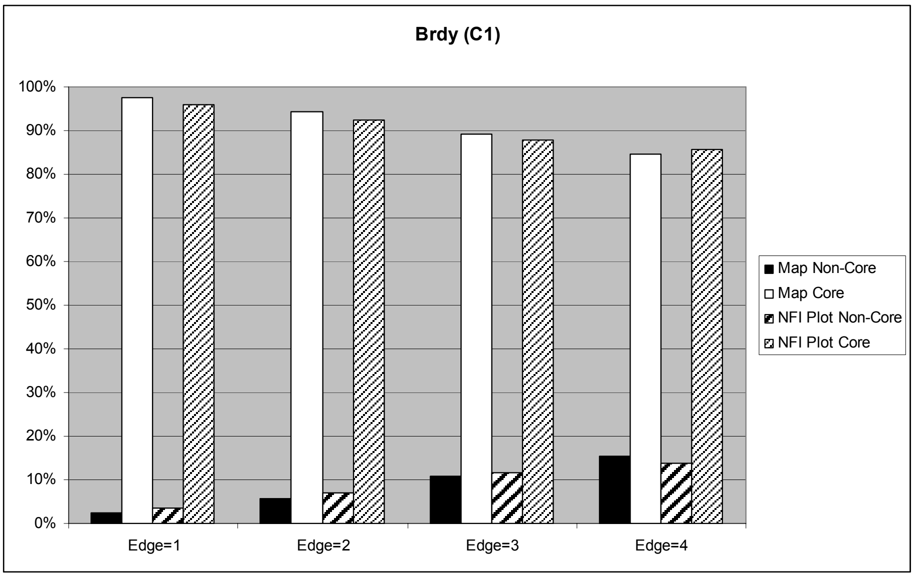


Figure 31: Fraction of NFI plots and forest map per aggregated GUIDOS class

Study area KřIvoklát (Czech Republic)

Abbrevation: CZ02

In study area KřIvoklát 5% of the available NFI plots are outside the forest mask form the year 2000 (Class *'Background'*).

Year	2000				
Resolution	100m				
INTEXT	1				
Aggregated Guidos Class	Daten	Edge=1	Edge=2	Edge=3	Edge=4
Core	Number of NFI Plots	62	50	39	35
	Fraction of NFI Plots	79.5%	64.1%	50.0%	44.9%
Non_Core	Number of NFI Plots	12	24	35	39
	Fraction of NFI Plots	15.4%	30.8%	44.9%	50.0%
Background	Number of NFI Plots	4	4	4	4
	Fraction of NFI Plots	5.1%	5.1%	5.1%	5.1%
Sum: Number of NFI Plots		78	78	78	78
Sum: Fraction of NFI Plots		100.0%	100.0%	100.0%	100.0%

Table 74: Fraction of the available NFI – Plots in the classes 'Core', 'Non-Core' and 'Background' of the GUIDOS classification of study area KřIvoklát (C2)

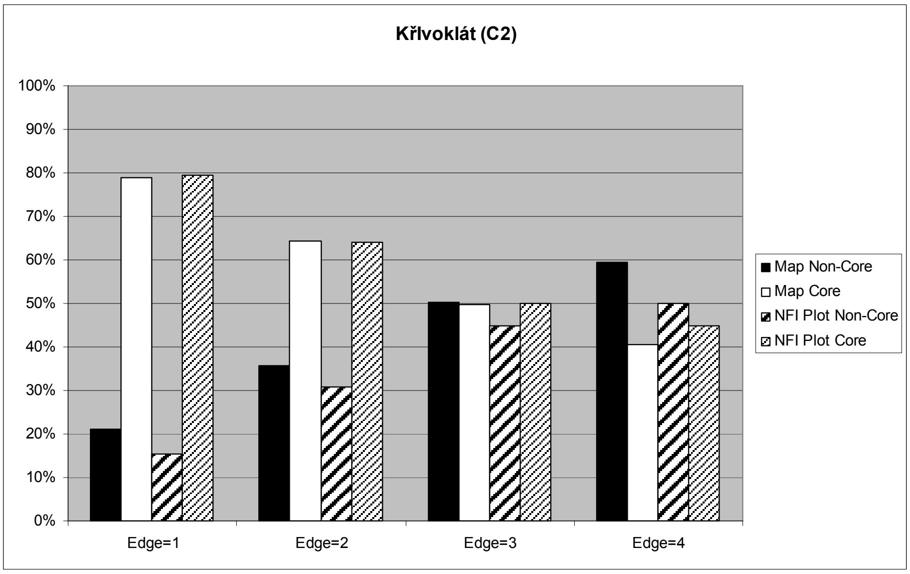


Figure 32: Fraction of NFI plots and forest map per aggregated GUIDOS class

Study area (Switzerland)

Abbrevation: CH

In study area Switzerland only 3.6% of the available NFI plots are outside the forest mask form the year 2000 (Class *'Background'*). The distribution of *'Core'* and *'None-Core'* classes is very similar between the classes in the forest map and at the NFI plots (Figure 33).

Year	2000				
Resolution	25m				
INTEXT	1				
Aggregated Guidos Class	Daten	Edge=1	Edge=2	Edge=3	Edge=4
Core	Number of NFI Plots	436	268	127	87
	Fraction of NFI Plots	60.3%	37.1%	17.6%	12.0%
Non_Core	Number of NFI Plots	261	429	570	610
	Fraction of NFI Plots	36.1%	59.3%	78.8%	84.4%
Background	Number of NFI Plots	26	26	26	26
	Fraction of NFI Plots	3.6%	3.6%	3.6%	3.6%
Sum: Number of NFI Plots		723	723	723	723
Sum: Fraction of NFI Plots		100.0%	100.0%	100.0%	100.0%

Table 75: Fraction of the available NFI – Plots in the classes 'Core', 'Non-Core' and 'Background' of the GUIDOS classification of study area Switzerland (CH)

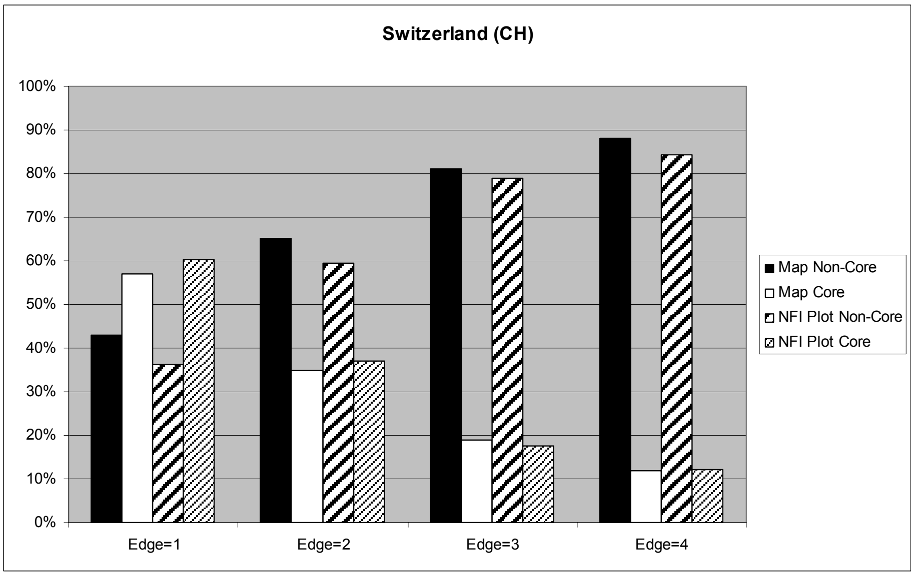


Figure 33: Fraction of NFI plots and forest map per aggregated GUIDOS class

Study area (Germany)

Abbrevation: DE

A very high portion of NFI plots fell outside the forest mask. 22.7% were classified as *'Background'* GUIDOS class. The distribution of *'Core'* and *'None-Core'* classes is similar between the classes in the forest map and at the NFI plots at SIZE parameter is 1 and 2 (Figure 34). With SIZE parameter 3 and 4 the *'Core'* class is reduced.

Year	2000				
Resolution	25m				
INTEXT	1				
Aggregated Guidos Class	Daten	Edge=1	Edge=2	Edge=3	Edge=4
Core	Number of NFI Plots	655	618	576	534
	Fraction of NFI Plots	73.2%	69.1%	64.4%	59.7%
Non_Core	Number of NFI Plots	37	74	116	158
	Fraction of NFI Plots	4.1%	8.3%	13.0%	17.7%
Background	Number of NFI Plots	203	203	203	203
	Fraction of NFI Plots	22.7%	22.7%	22.7%	22.7%
Sum: Number of NFI Plots		895	895	895	895
Sum: Fraction of NFI Plots		100.0%	100.0%	100.0%	100.0%

Table 76: Fraction of the available NFI – Plots in the classes 'Core', 'Non-Core' and 'Background' of the GUIDOS classification of study area Germany (DE)

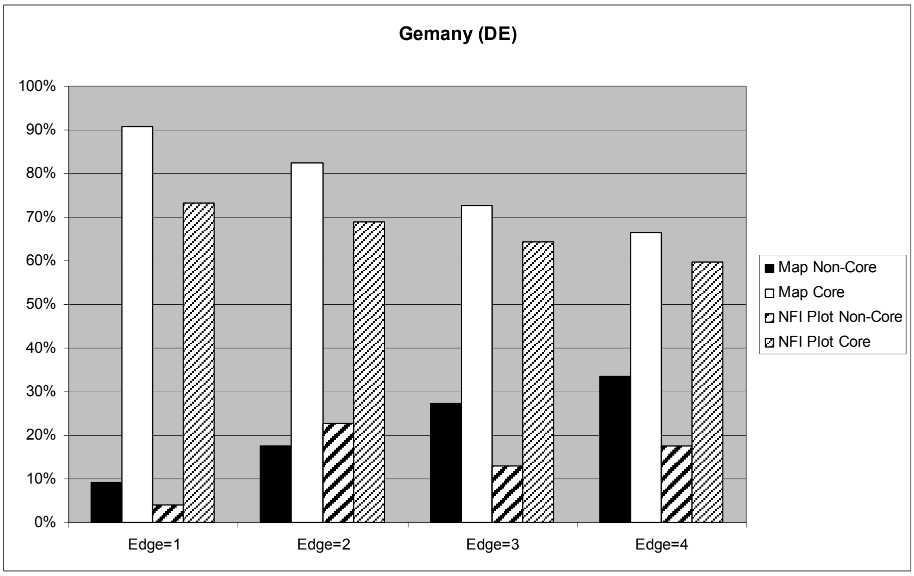


Figure 34: Fraction of NFI plots and forest map per aggregated GUIDOS class

Study area (Italy)

Abbrevation: IT

In Italy a very high amount of available NFI plots are outside the forest mask with resolution 100m: 42.4% (Table 78). Using the forest map with resolution of 25m, these 'outliers' are reduced to 6%. The distribution of *'Core'* and *'None-Core'* classes is similar between the classes in the forest map and at the NFI plots (Figure 35).

Year	2005				
Resolution	25m				
INTEXT	1				
Aggregated Guidos Class	Daten	Edge=1	Edge=2	Edge=3	Edge=4
Core	Number of NFI Plots	70	57	40	34
	Fraction of NFI Plots	70.7%	57.6%	40.4%	34.3%
Non_Core	Number of NFI Plots	23	36	53	59
	Fraction of NFI Plots	23.2%	36.4%	53.5%	59.6%
Background	Number of NFI Plots	6	6	6	6
	Fraction of NFI Plots	6.1%	6.1%	6.1%	6.1%
Sum: Number of NFI Plots		99	99	99	99
Sum: Fraction of NFI Plots		100.0%	100.0%	100.0%	100.0%

Table 77: Fraction of the available NFI – Plots in the classes 'Core', 'Non-Core' and 'Background' of the GUIDOS classification of study area Italy, Map resolution 25m

Year	2000				
Resolution	100m				
INTEXT	1				
Aggregated Guidos Class	Daten	Edge=1	Edge=2	Edge=3	Edge=4
Core	Number of NFI Plots	39	29	16	11
	Fraction of NFI Plots	39.4%	29.3%	16.2%	11.1%
Non_Core	Number of NFI Plots	18	28	41	46
	Fraction of NFI Plots	18.2%	28.3%	41.4%	46.5%
Background	Number of NFI Plots	42	42	42	42
	Fraction of NFI Plots	42.4%	42.4%	42.4%	42.4%
Sum: Number of NFI Plots		99	99	99	99
Sum: Fraction of NFI Plots		100.0%	100.0%	100.0%	100.0%

Table 78: Fraction of the available NFI – Plots in the classes 'Core', 'Non-Core' and 'Background' of the GUIDOS classification of study area Italy, Map resolution 100m

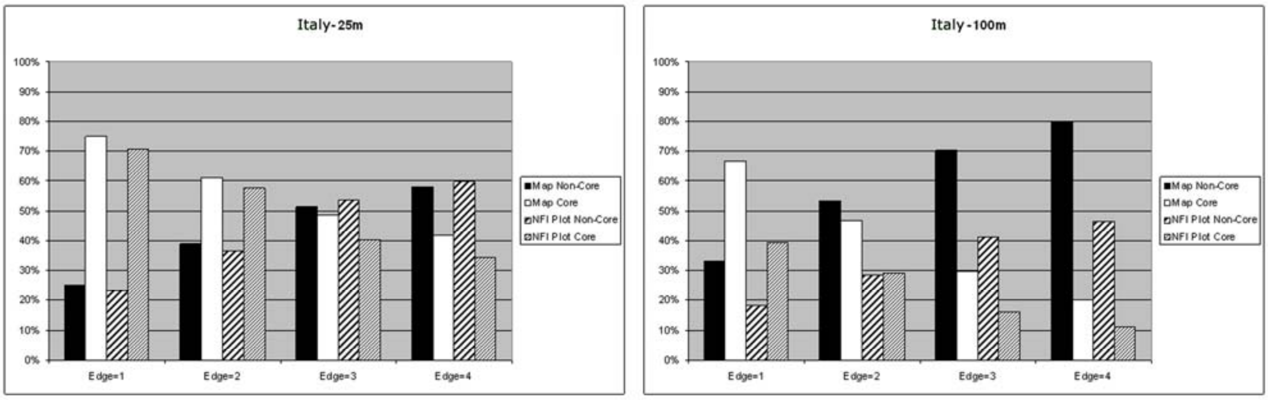


Figure 35: Fraction of NFI plots and forest map per aggregated GUIDOS class (resolution 25m and 100m)

Study area (Sweden)

Abbrevation: SE

28% of the available NFI plots fell outside the forest map. The distribution of *'Core'* and *'None-Core'* classes is similar between the classes in the forest map and at the NFI plots (Figure 36).

Year	2005				
Resolution	25m				
INTEXT	1				
Aggregated Guidos Class	Daten	Edge=1	Edge=2	Edge=3	Edge=4
Core	Number of NFI Plots	121	102	79	68
	Fraction of NFI Plots	65.4%	55.1%	42.7%	36.8%
Non_Core	Number of NFI Plots	12	31	54	65
	Fraction of NFI Plots	6.5%	16.8%	29.2%	35.1%
Background	Number of NFI Plots	52	52	52	52
	Fraction of NFI Plots	28.1%	28.1%	28.1%	28.1%
Sum: Number of NFI Plots		185	185	185	185
Sum: Fraction of NFI Plots		100.0%	100.0%	100.0%	100.0%

Table 79: Fraction of the available NFI – Plots in the classes 'Core', 'Non-Core' and 'Background' of the GUIDOS classification of study area Sweden (SE)

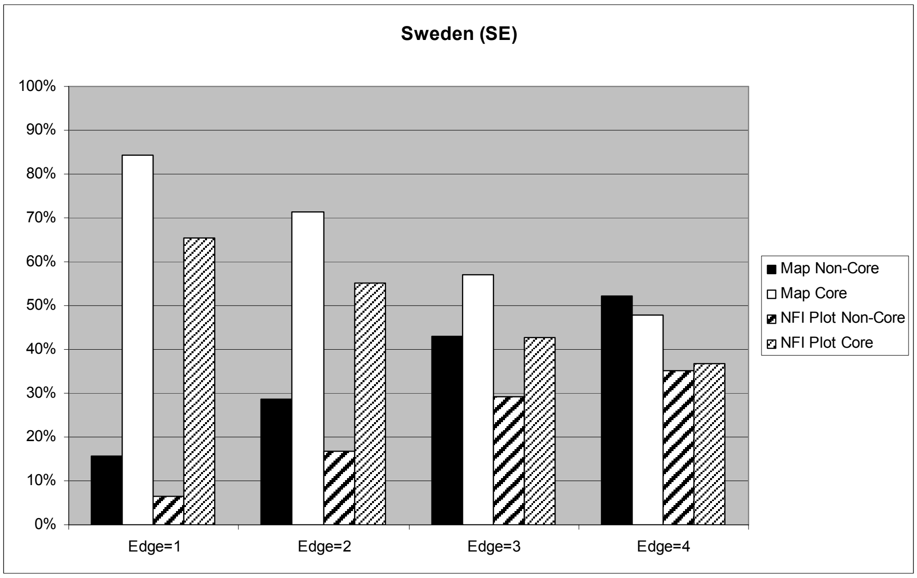


Figure 36: Fraction of NFI plots and forest map per aggregated GUIDOS class

7.3. PIXEL APPROACH

The objectives of the project are focused to downscaling and the derivation of biodiversity indices. In this part of the project it was tested, if it is possible to combine biodiversity indicators with maps, different in scale and time as well as in ecological aspects.

Two methods were adopted for the pixel bases approach:

(i) The GUIDOS class at each NFI plot location was extracted (Figure 37). The GUIDOS classes were afterwards classified into two classes – 'Core' (17,117) and 'Non-Core' (remaining classes). The full results for all study areas are presented in Appendix 3.

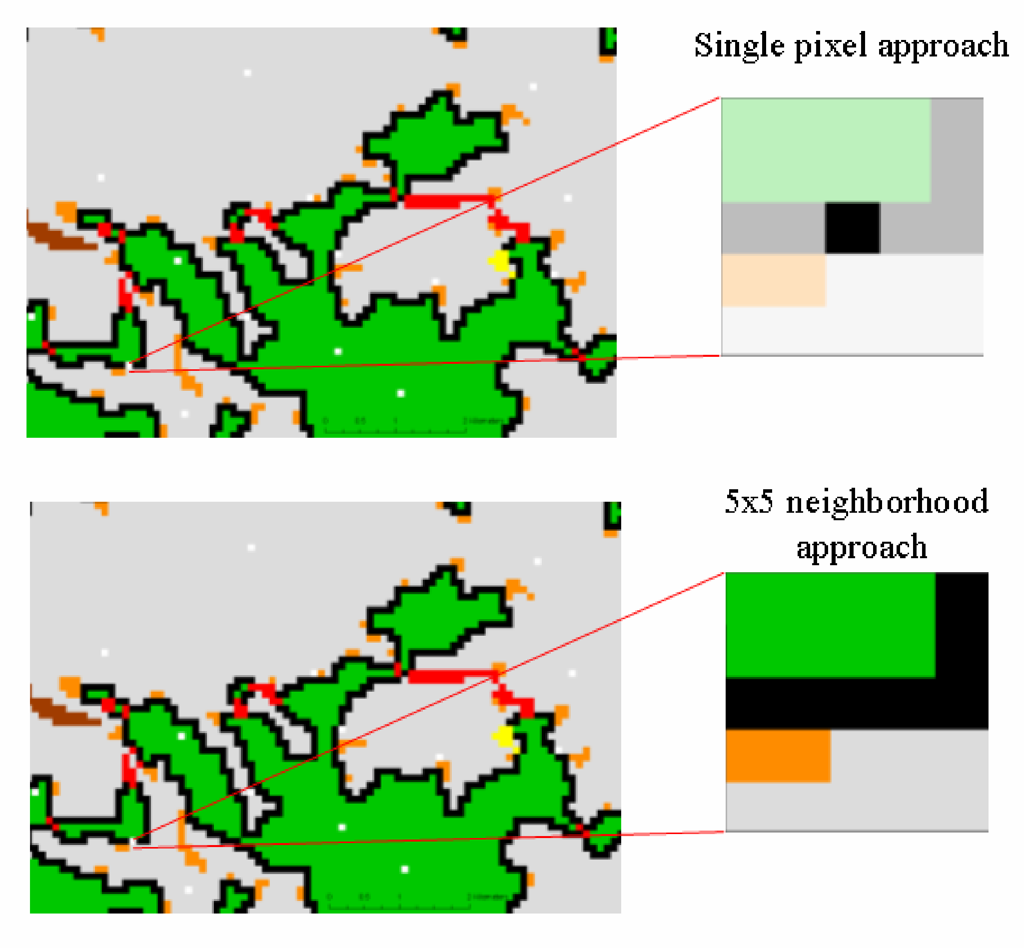
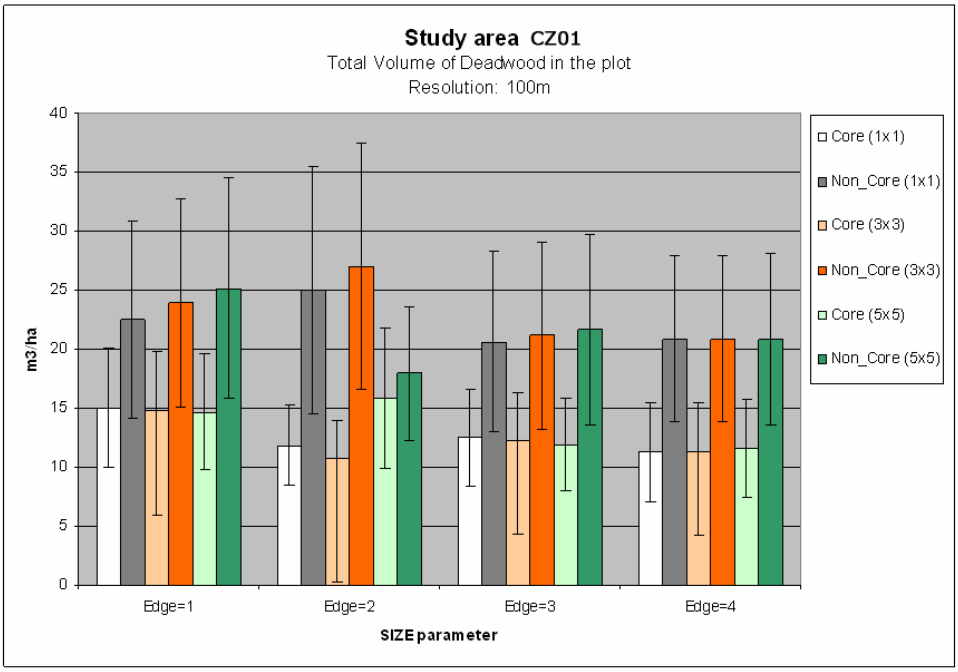


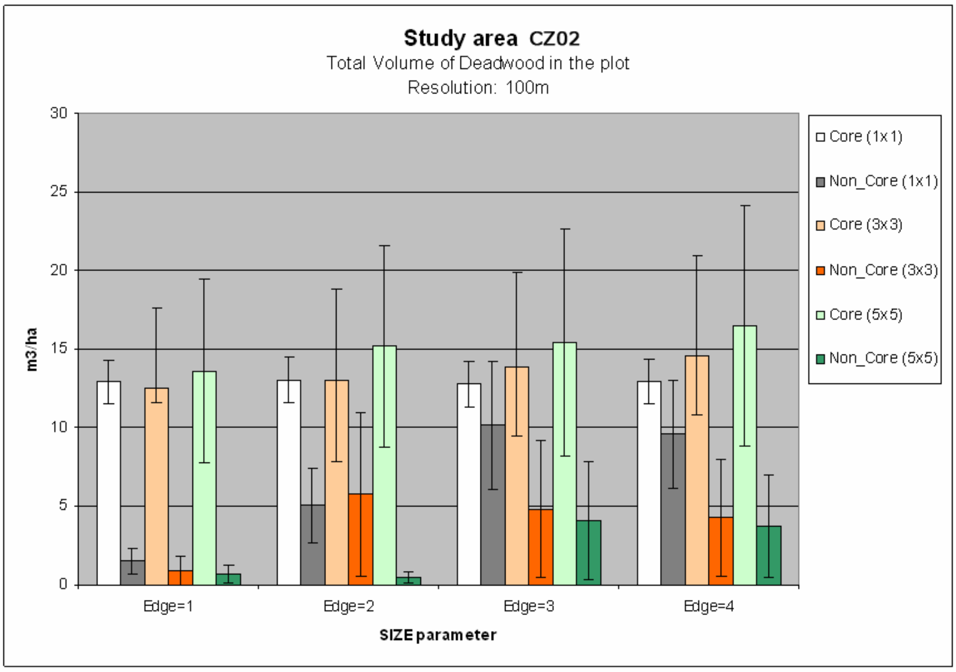
Figure 37: Single pixel approach (above) vs. neighbor pixel approach (below) combining the GUIDOS classification and the diversity indicators from the harmonized database.

(ii) In order to examine if the inclusion of neighboring pixels could allow a differentiation of the biodiversity indicators for each plot in the dataset, the neighboring pixels were examined – thus a 3 x 3 filter and a 5 x 5 filter over the plot pixel itself (Figure 37). Subsequently it was calculated, which GUIDOS class forms the majority in this area. For the same area also the variety of values is calculated. The GUIDOS classes already include the neighborhood for each pixel in the forest maps. But here, only the direct vicinity of the terrestrial plots is included, since the discrete values (pixels) of the maps may not perfectly overlap with the data plots. The main objective of these tests was to check, if there might be a relation between the indicators and the variety – speaking, the higher the variety, the better the

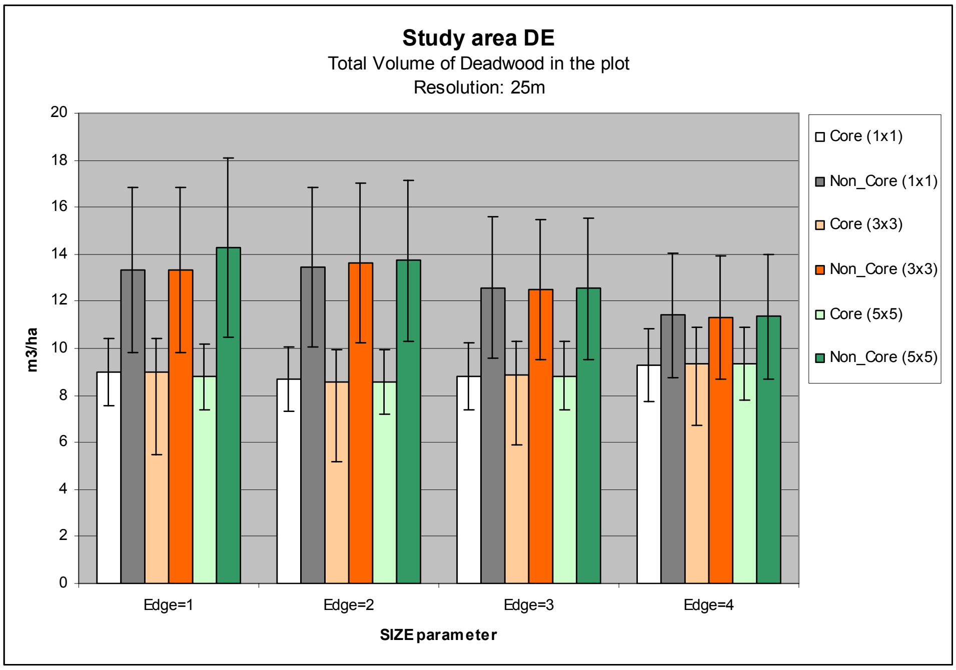
biodiversity. The results are similar to the single pixel based approach. Some examples are given. The results using the 5x5 window are correspondent to the results using the 3x3 window. Subsequent the results of the 3x3 window approach are shown. The GUIDOS classes were grouped into 'Core' and 'Non-Core' classes.

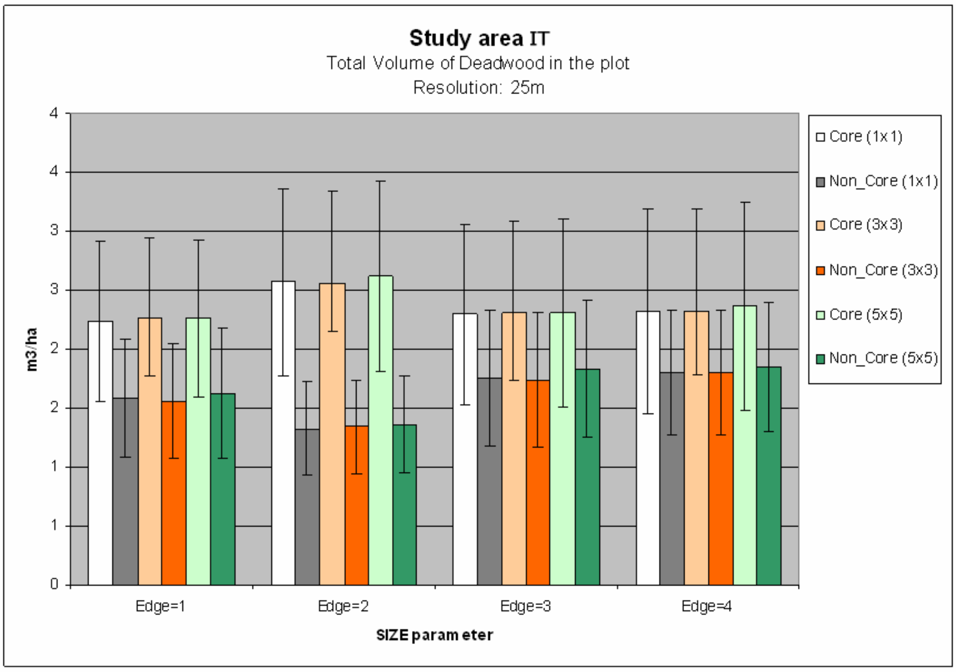
7.3.1. Total volume of deadwood

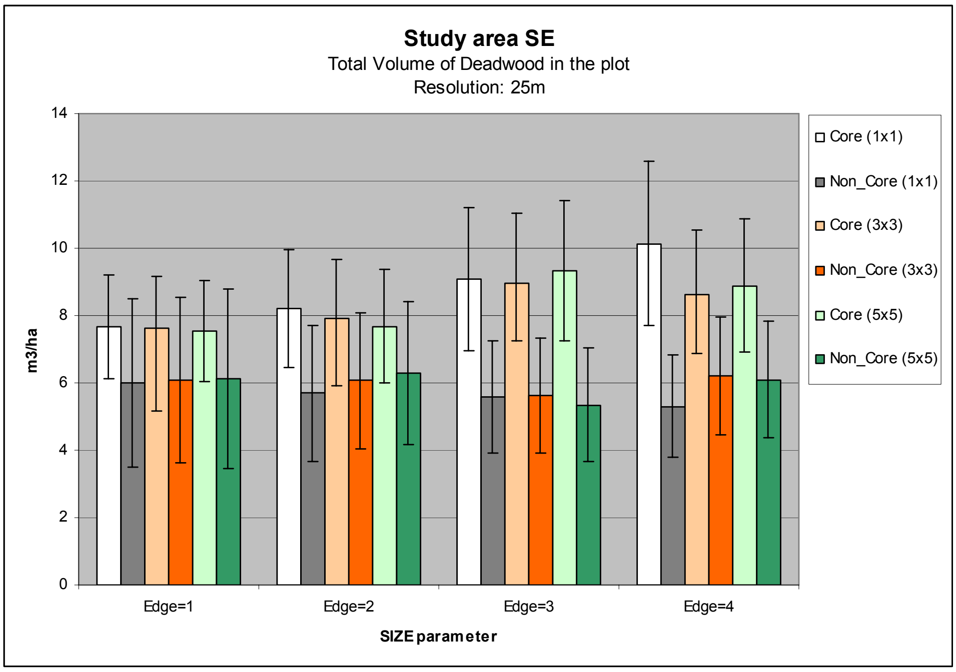




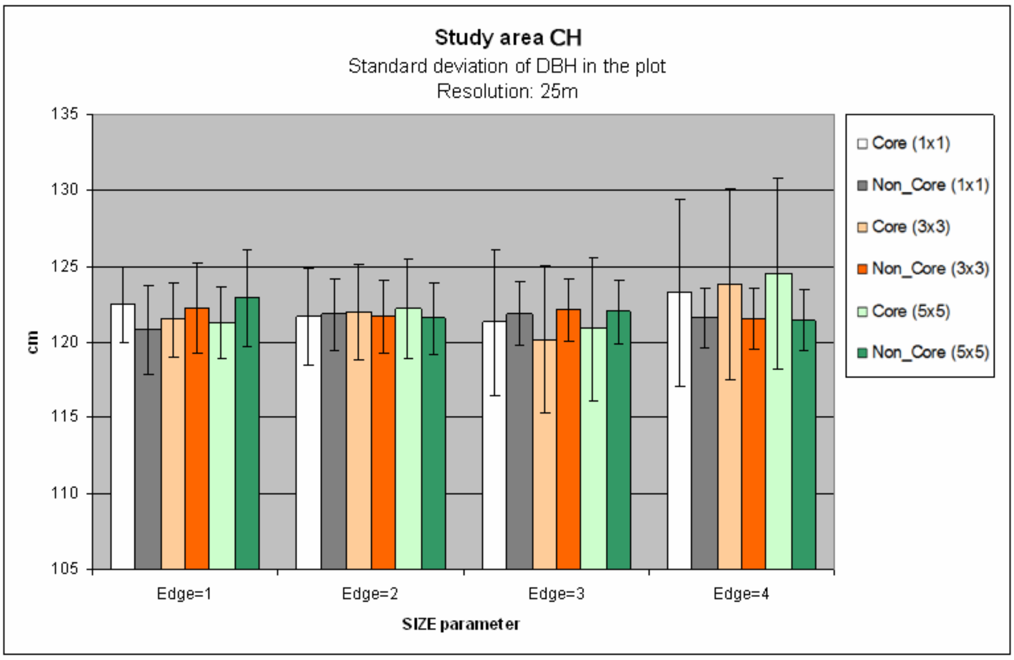
c

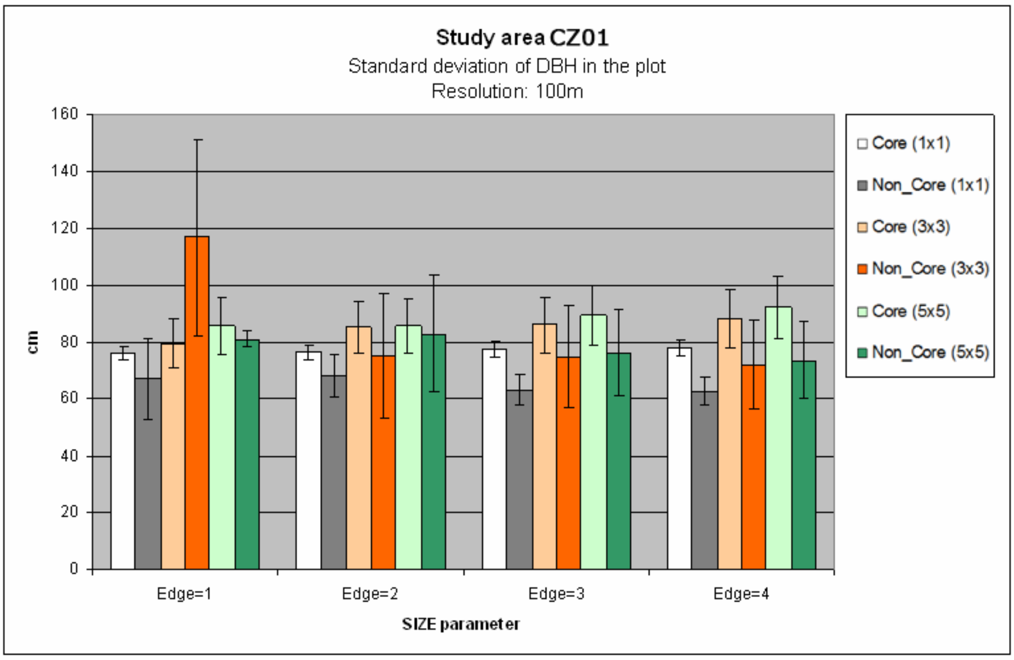

Study area DE
Total Volume of Deadwood in the plot
Resolution: 25m
20
18
16
14
12
10
8
6
4
2
0
m3/ha
Edge=1
Edge=2
Edge=3
Edge=4
SIZE parameter
Core (1x1)
Non_Core (1x1)
Core (3x3)
Non_Core (3x3)
Core (5x5)
Non_Core (5x5)

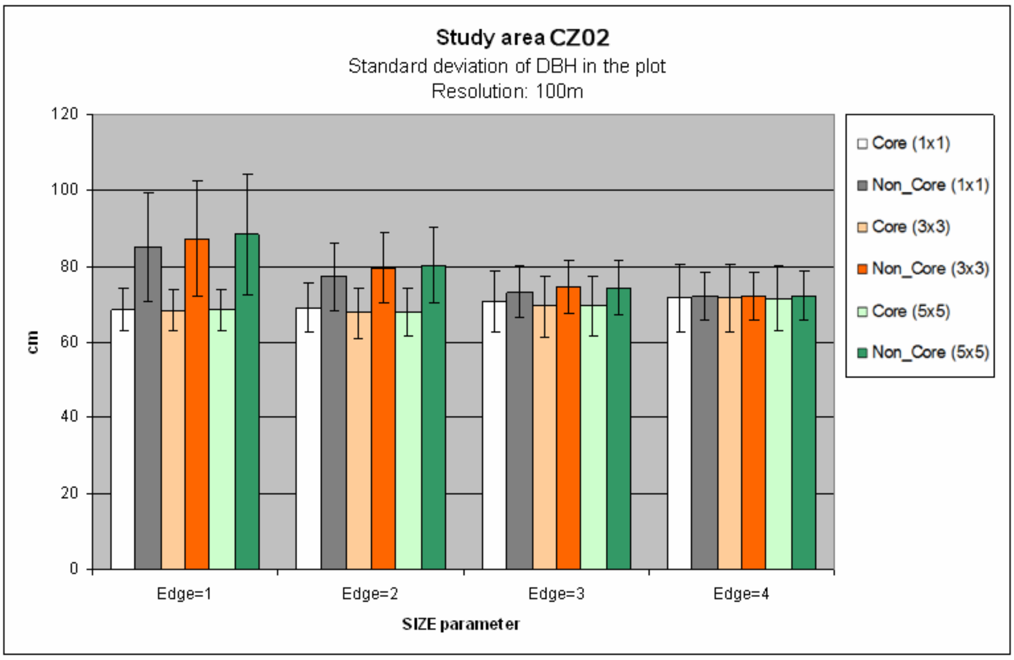

Study area IT
Total Volume of Deadwood in the plot
Resolution: 25m
4
4
3
3
2
2
1
1
0
m3/ha
Edge=1
Edge=2
Edge=3
Edge=4
SIZE parameter
Core (1x1)
Non_Core (1x1)
Core (3x3)
Non_Core (3x3)
Core (5x5)
Non_Core (5x5)

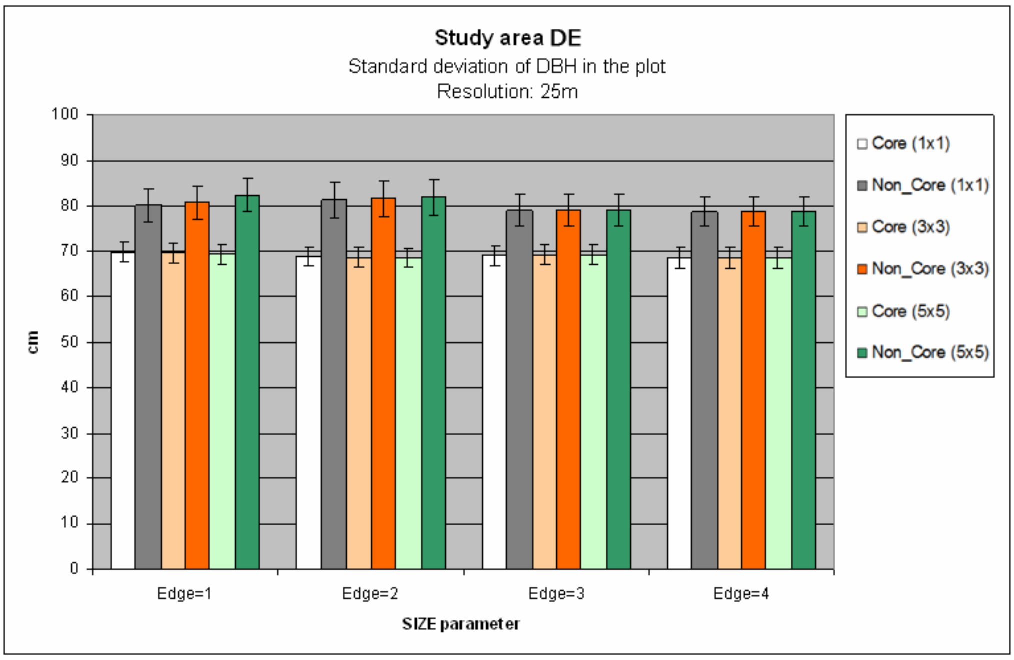


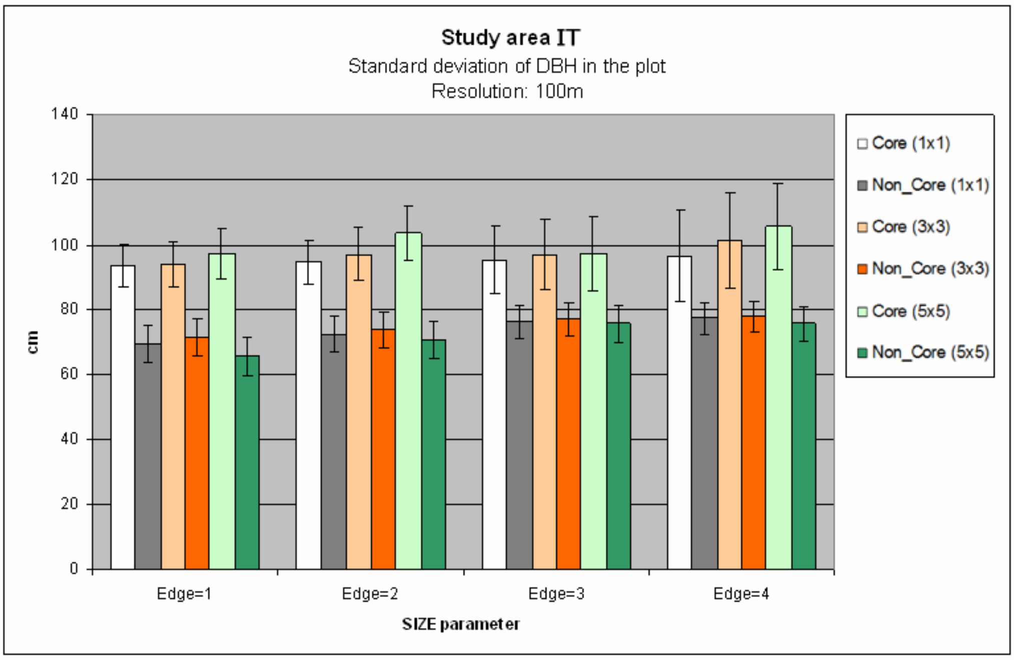
7.3.2. Standard deviation of DBH

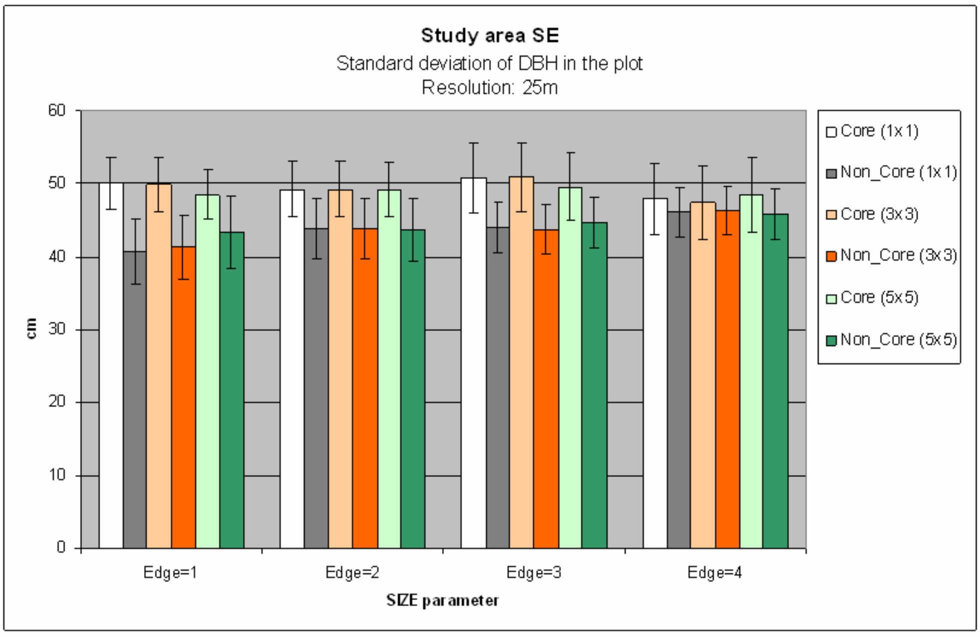



Study area CZ01
Standard deviation of DBH in the plot
Resolution: 100m
cm
160
140
120
100
80
60
40
20
0
Edge=1
Edge=2
Edge=3
Edge=4
SIZE parameter
Core (1x1)
Non_Core (1x1)
Core (3x3)
Non_Core (3x3)
Core (5x5)
Non_Core (5x5)


Study area CZ02
Standard deviation of DBH in the plot
Resolution: 100m
cm
120
100
80
60
40
20
0
Edge=1
Edge=2
Edge=3
Edge=4
SIZE parameter
Core (1x1)
Non_Core (1x1)
Core (3x3)
Non_Core (3x3)
Core (5x5)
Non_Core (5x5)

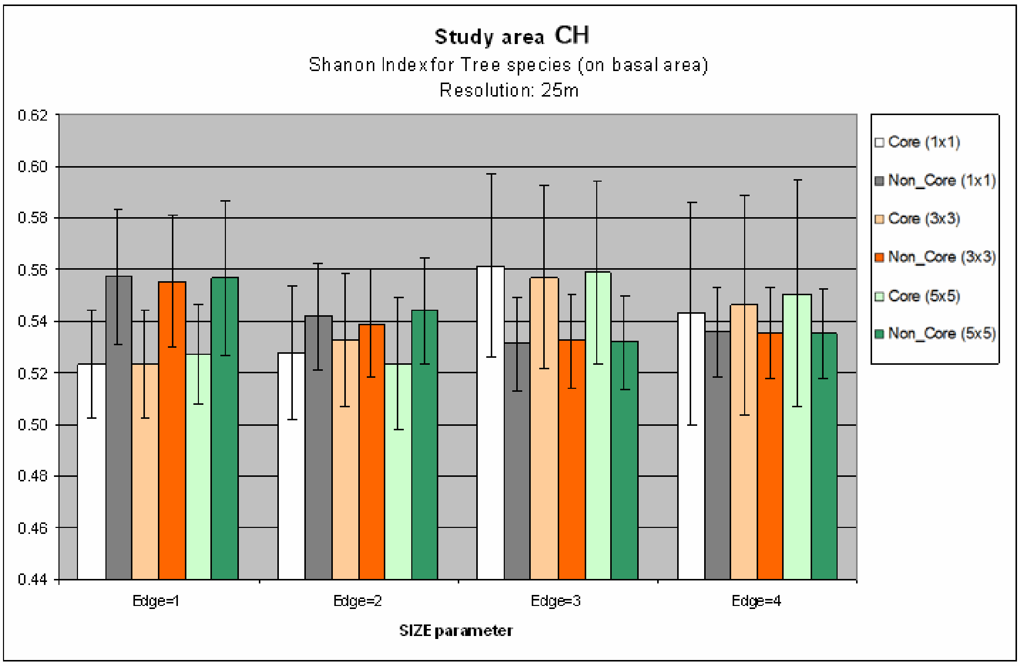

Study area DE
Standard deviation of DBH in the plot
Resolution: 25m
cm
0
10
20
30
40
50
60
70
80
90
100
Edge=1
Edge=2
Edge=3
Edge=4
SIZE parameter
Core (1x1)
Non_Core (1x1)
Core (3x3)
Non_Core (3x3)
Core (5x5)
Non_Core (5x5)

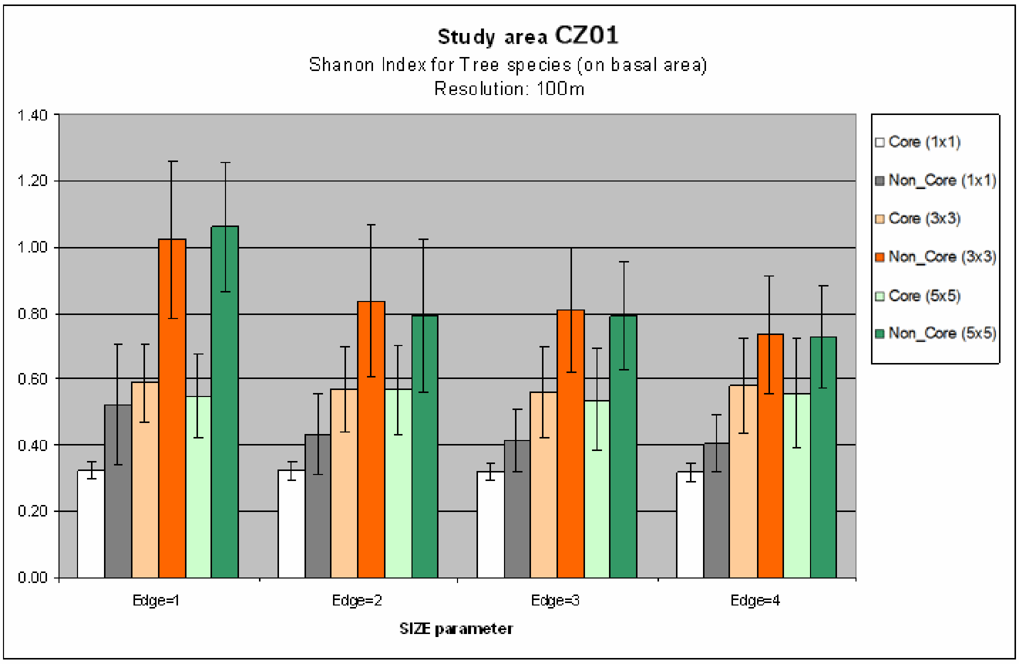

Study area IT
Standard deviation of DBH in the plot
Resolution: 100m
cm
0
20
40
60
80
100
120
140
Edge=1
Edge=2
Edge=3
Edge=4
SIZE parameter
Core (1x1)
Non_Core (1x1)
Core (3x3)
Non_Core (3x3)
Core (5x5)
Non_Core (5x5)

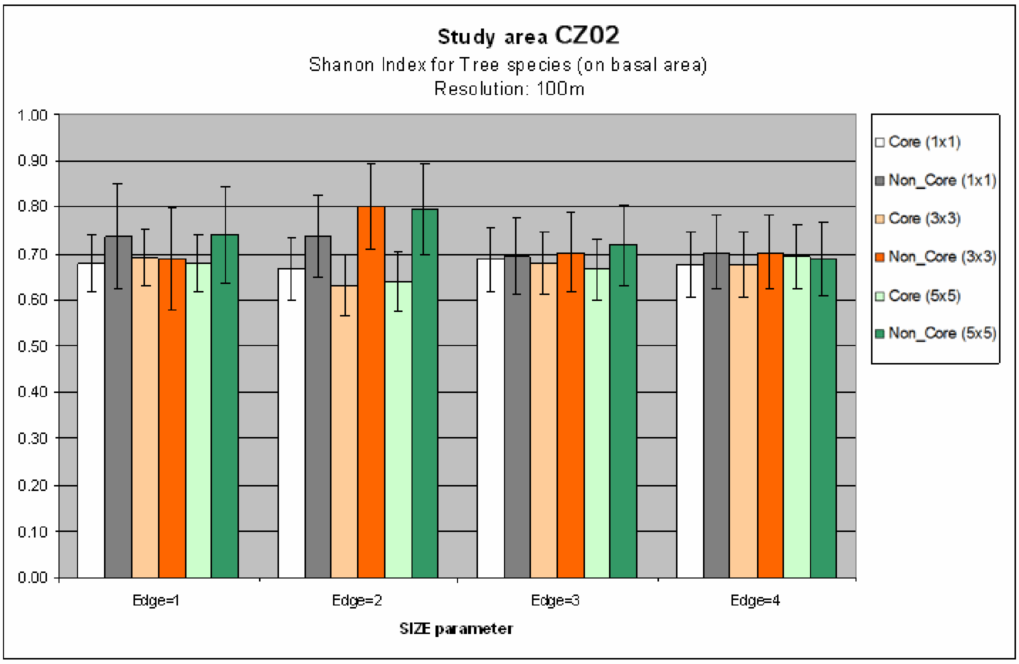


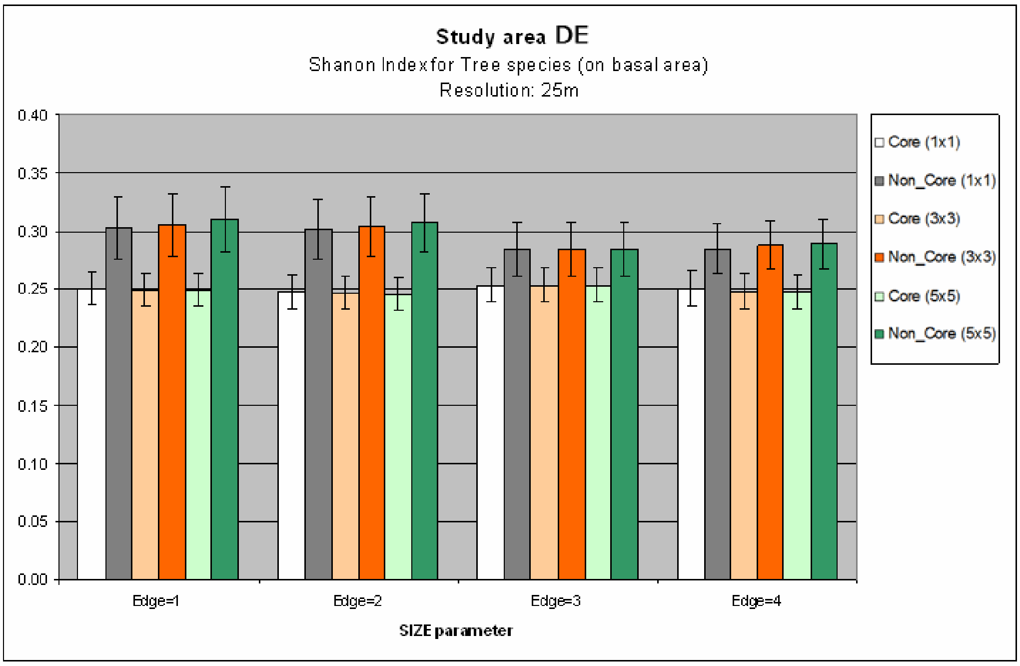
7.3.3. Shannon Index of tree species on the basis of the basal area

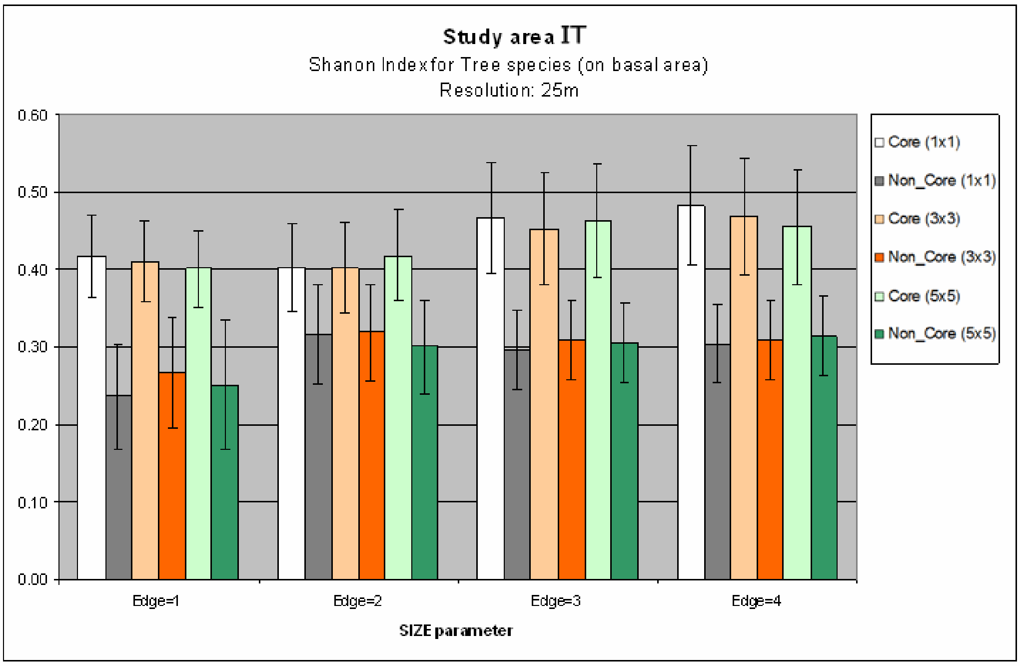
Here follow the graphic representation of the results of the comparison of the average values of the indicator for core and non-core NFI plots, for the four types of edge definitions used in the setup of GUIDOS and for the three methods used in the extraction of GUIDOS maps (single pixel 1x1, 3x3, 5x5).

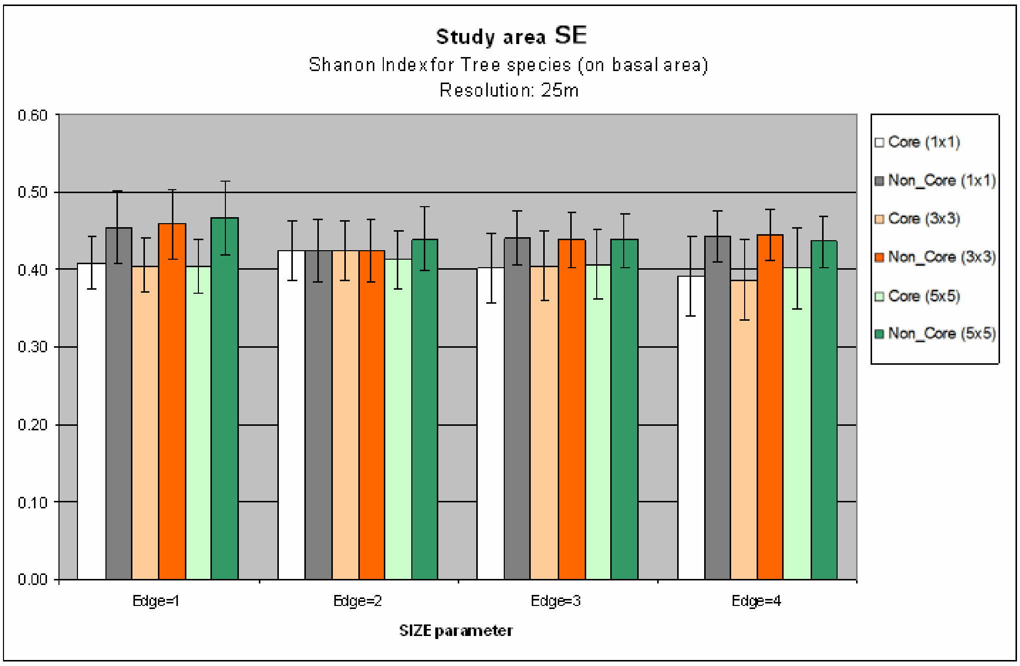



Study area CZ01
Shanon Index for Tree species (on basal area)
Resolution: 100m
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Edge=1
Edge=2
Edge=3
Edge=4
SIZE parameter
Core (1x1)
Non_Core (1x1)
Core (3x3)
Non_Core (3x3)
Core (5x5)
Non_Core (5x5)


Study area CZ02
Shanon Index for Tree species (on basal area)
Resolution: 100m
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Edge=1
Edge=2
Edge=3
Edge=4
SIZE parameter
Core (1x1)
Non_Core (1x1)
Core (3x3)
Non_Core (3x3)
Core (5x5)
Non_Core (5x5)


Study area DE
Shanon Index for Tree species (on basal area)
Resolution: 25m
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Edge=1
Edge=2
Edge=3
Edge=4
SIZE parameter
Core (1x1)
Non_Core (1x1)
Core (3x3)
Non_Core (3x3)
Core (5x5)
Non_Core (5x5)


Study area IT
Shanon Index for Tree species (on basal area)
Resolution: 25m
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Edge=1
Edge=2
Edge=3
Edge=4
SIZE parameter
Core (1x1)
Non_Core (1x1)
Core (3x3)
Non_Core (3x3)
Core (5x5)
Non_Core (5x5)



The results obtained are not easy to be summarized and can be described under different points of view.

The first result is that in many of the test cases the biodiversity indicators show to be sensible to their spatial location in the GUIDOS classes (core, non-core). On the other side none of the three indicators show a unique direction of this differences.

The total volume of deadwood is higher in core areas in CZ1, IT2 and SE but lower in CZ2, CH and DE.

The standard deviation of tree DBH is higher in IT1 IT2 and SE but lower in CZ2 and DE.

The Shannon index (calculated on the basal area of trees) is higher in core areas IT1 and IT2 but lower in CZ1, CH, DE and SE.

In nearly all the cases the method for the extraction of GUIDOS classes from the maps (1x1, 3x3, 5x5) do not have any impact on the results. In general we consider preferable the method 5x5 because it is also able to partially limit the problem of the possible incorrect geographic location of NFI plots.

The results are frequently insensible to the width of the border adopted for the GUIDOS classification. When some differences occur they have different behavior depending of the test area and of the indicator adopted.

On the basis of the test carried out the results are always not sensible to the resolution of the map (25 and 100 meters in IT2).

7.4. AREA APPROACH

The test area approach was used to investigate relationships between spatial pattern maps derived using the GUIDOS software and estimates of harmonized forest variables from the NFI's at a test area level. Initially the intention was to use test areas with a size in the order of 10,000 km^2 to get statistically reliable NFI estimates. This has not been possible due to the relatively small test areas available within the project. Instead the test areas have been divided into subareas ranging from 21 km^2 to 17,000 km^2 (Table 81). If possible, according to the amount of plots available, two set of sub-areas has been created for each test area. The first set was created by overlaying each test area with a grid to create 4-5 sub-areas. A second set were created by splitting each sub-area in the first set into two new sub-areas. The second set was adjusted so that a minimum of 15 - 20 NFI plots were available within each sub-area. For the Italy test area, only one set of areas could be created due to the low number of available NFI plots (Figure 50). The reason for using two different sizes of subareas was to investigate if the scale or the size of the forest landscape had any impact on the relationship between classes in the spatial pattern maps and harmonized NFI estimates.

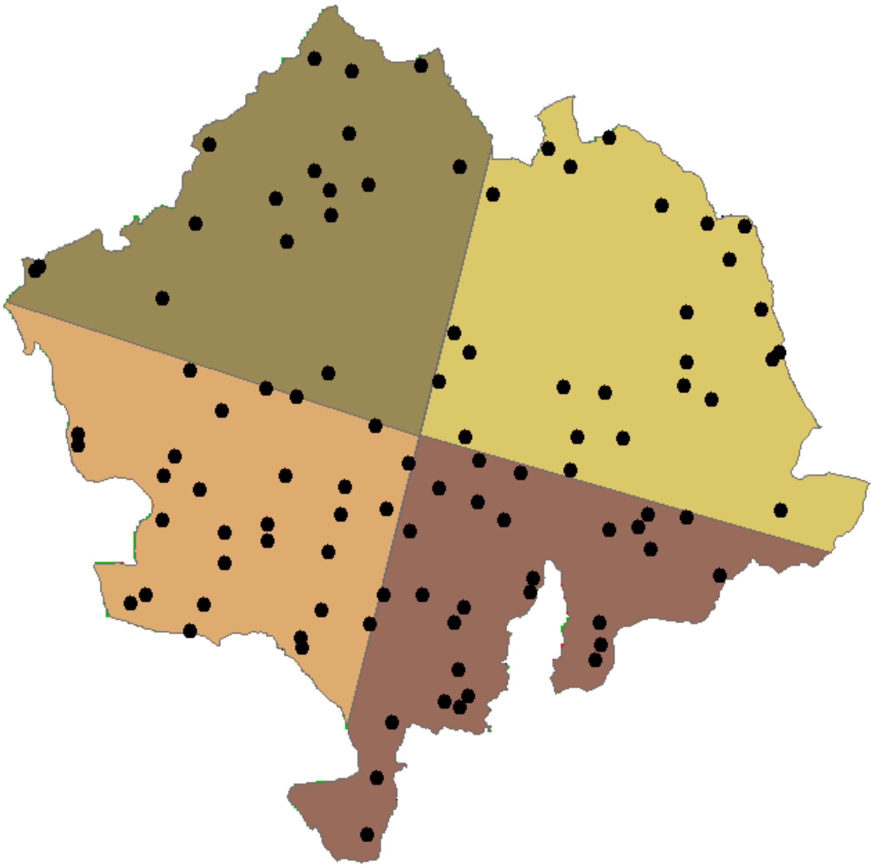


Figure 38: Example of subareas used in a test area.

Test area	*No. of sub-areas*	*Year*	*Average size (km^2)*	*Number of NFI plots within the sub-areas*		
				mean	*min*	*max*
Sweden	5	1999	12000	95	51	123
	10	1999	6000	48	23	66
	5	2003	12000	38	14	58
	10	2003	6000	19	9	35
Switzerland	5	2000	660	145	106	174
	10	2000	330	72	52	94
Italy	4	2006	100	25	17	29
	8	2006	3300	31	16	69
Germany	4	2002	2400	224	177	265
	8	2002	1200	112	59	162
Czech Republic, CZ01	4	1996	75	20	15	23
	4	2005	75	20	15	23
Czech Republic, CZ02	4	1996	65	56	44	73
	8	1996	32	28	20	46
	4	2005	65	56	44	73
	8	2005	32	28	20	46

Table 80: The number of subareas used in each test area, their sizes and the number of NFI plots available within each subarea.

The relation between harmonized NFI indicators and the ecologically based GUIDOS classes has been investigated for the same set of indicators (total volume of dead wood, Standard deviation of DBH and Shannon Index based on basal area) as used in the pixel based approach.

As mentioned previously, the aim is to investigate the relationship between forest spatial pattern classes and harmonized indicators from NFI's, and to document if this relationship and the value of such forest pattern maps changes across test areas. It has also been important to investigate if the scale of the forest pattern maps affects the relationship between, for example GUIDOS classes and harmonized NFI indicators. Another essential issue has been to investigate how temporal changes or trends that are observed using spatial pattern maps derived from remote sensing data are related to trends in forest biodiversity indicators according to the NFI's.

Italy

For the test area Italy, it was found that both Std of DBH and Shannon index in core areas increases with increased edge width for both the HR and LR based spatial pattern maps (Table 81 and Table 82). It should also be noted that the highest values for the two indicators were obtained for core areas as compared to the other GUIDOS classes. The trend of having higher Std of DBH and higher Shannon index values with increased edge width was not that evident in non-core areas. The internal versus external classes were not possible to evaluate due to lack of field data.

COUNTRY	Italy
DATE OF MAP DATA	2005
MAP RESOLUTION	25m
DATE OF NFI DATA	2005

		Estimated mean value for NFI plots			
		4 sub-areas			
		Edge size (No. Pixels)			
GUIDOS Class	Indicator	1 pix	2 pix	3 pix	4 pix
Core	Dead wood	-	-	-	-
	Std. of DBH	79.7	83.1	90.0	92.9
	Shannon Index	0.43	0.42	0.48	0.48
Non-core	Dead wood	-	-	-	-
	Std. of DBH	65.1	66.1	67.0	66.9
	Shannon Index	0.15	0.33	0.32	0.32
Internal*	Dead wood	-	-	-	-
	Std. of DBH	-	-	-	-
	Shannon Index	-	-	-	-
External	Dead wood	-	-	-	-
	Std. of DBH	78.2	78.7	77.5	77.2
	Shannon Index	0.30	0.40	0.39	0.38

*) No results are presented since only two NFI plots were located within the class

Table 81: Estimated NFI indicators from 2003 for different GUIDOS classes derived from the ItalyHR forest/non-forest map from 2005.

COUNTRY	Italy
DATE OF MAP DATA	2000
MAP RESOLUTION	100 m
DATE OF NFI DATA	2005

		Estimated mean value for NFI plots			
		4 sub-areas			
		Edge size (No. Pixels)			
GUIDOS Class	Indicator	1 pix	2 pix	3 pix	4 pix
Core	Dead wood	-	-	-	-
	Std. of DBH	94.0	94.3	97.0	97.6

	Shannon Index	0.51	0.52	0.50	0.52
Non-core	Dead wood	-	-	-	-
	Std. of DBH	64.9	68.1	72.6	72.9
	Shannon Index	0.35	0.34	0.37	0.38
Internal	Dead wood	-	-	-	-
	Std. of DBH	-	-	-	-
	Shannon Index	-	-	-	-
External	Dead wood	-	-	-	-
	Std. of DBH	77.2	77.2	77.2	77.2
	Shannon Index	0.38	0.38	0.38	0.38

*) No results are presented since only two NFI plots were located within the class

Table 82: Estimated NFI indicators from 2003 for different GUIDOS classes derived from the Italy LR forest/non-forest map from 2000

Sweden

The results from the Swedish test area show smaller differences for the selected harmonized NFI indicators between core and non-core areas, as well as between internal or external areas (Table 83 and Table 84) compared to the differences obtained for the Italy test area. However, the volume of dead wood in Table 84 seems to be higher for the Internal class as compared to the External class. This is most probably explained by the fact that there are relatively few plots located in the Internal class and that some of them have very high volumes of dead wood. It can be noted that there is no trend of having higher values for dead wood in the Internal class than in the External class according to the NFI estimates from 1999 (Table 84).

COUNTRY	Sweden
DATE OF MAP DATA	2005
MAP RESOLUTION	25m
DATE OF NFI DATA	2003

		Estimated mean value for NFI plots							
		5 sub-areas				10 sub-areas			
		Edge size (No. Pixels)				Edge size (No. Pixels)			
GUIDOS Class	Indicator	1 pix	2 pix	3 pix	4 pix	1 pix	2 pix	3 pix	4 pix
Core	Dead wood	6.3	6.6	5.6	5.0	6.8	7.3	6.6	7.6
	Std. of DBH	37.4	37.2	39.3	36.4	41.5	40.4	41.2	39.0
	Shannon Index	0.32	0.34	0.32	0.31	0.36	0.38	0.35	0.34
Non-core	Dead wood	5.4	5.3	5.7	5.3	9.6	6.4	7.0	6.5
	Std. of DBH	35.2	35.2	33.6	34.8	30.6	33.4	32.8	34.3
	Shannon Index	0.43	0.37	0.36	0.36	0.36	0.33	0.34	0.34
Internal*	Dead wood	15.3	12.9	15.9	13.6	26.5	23.0	21.9	18.2
	Std. of DBH	40.8	36.0	38.0	31.8	41.6	45.2	46.7	37.2
	Shannon Index	0.35	0.35	0.27	0.22	0.34	0.29	0.24	0.20

External	Dead wood	4.0	5.2	5.2	5.0	5.3	5.6	4.5	5.0
	Std. of DBH	36.3	36.6	36.6	36.9	38.7	37.5	35.4	36.7
	Shannon Index	0.33	0.36	0.36	0.36	0.37	0.40	0.36	0.37

Table 83: Estimated NFI indicators from 2003 for different GUIDOS classes derived from the Swedish HR forest/non-forest map from 2005

COUNTRY	Sweden
DATE OF MAP DATA	2000
MAP RESOLUTION	25m
DATE OF NFI DATA	1999

		Estimated mean value for NFI plots							
		5 sub-areas				10 sub-areas			
		Edge size (No. Pixels)				Edge size (No. Pixels)			
GUIDOS Class	Indicator	1 pix	2 pix	3 pix	4 pix	1 pix	2 pix	3 pix	4 pix
Core	Dead wood	2.8	3.0	3.1	3.4	2.6	2.7	3.0	3.1
	Std. of DBH	34.6	34.5	36.5	37.1	33.9	33.8	35.6	36.2
	Shannon Index	0.30	0.30	0.32	0.31	0.29	0.29	0.30	0.30
Non-core	Dead wood	3.2	2.6	2.5	2.5	3.0	2.4	2.3	2.3
	Std. of DBH	36.7	35.1	33.0	33.1	34.9	33.9	32.0	32.0
	Shannon Index	0.30	0.31	0.30	0.31	0.30	0.31	0.30	0.30
Internal*	Dead wood	2.3	2.3	2.7	4.2	2.5	2.2	3.0	6.5
	Std. of DBH	31.1	29.8	23.2	28.0	32.6	28.7	23.6	31.0
	Shannon Index	0.29	0.34	0.20	0.26	0.28	0.33	0.22	0.23
External	Dead wood	3.0	3.0	2.7	2.7	2.7	2.7	2.5	2.5
	Std. of DBH	35.6	35.4	35.5	35.5	34.7	34.6	34.5	34.3
	Shannon Index	0.31	0.30	0.31	0.31	0.29	0.30	0.30	0.30

*) The results are based on a small number of NFI plots due to the low area coverage of the class.

Table 84: Estimated NFI indicators from 1999 for different GUIDOS classes derived from the Swedish HR forest/non-forest map from 2000

How temporal changes in the spatial pattern maps are linked to the ecological indicators used in this study has been investigated for the Swedish test area. Table 86 shows that the percentage of area coverage in each GUIDOS class is almost constant between 2000 and 2005. The major difference between estimate indicators from 1999 and 2003 is that the volume of dead wood has increased substantially during the time period. The increase in dead wood obtained in this study is higher than the increase reported by the official Swedish NFI, the differences could be the result of the harmonisation process or to the different time frame (five years for the official NFI).

COUNTRY	Sweden
DATE OF MAP DATA	2000, 2005
MAP RESOLUTION	25m

DATE OF NFI DATA	1999, 2003

		Mean values for 5 sub-aeras							
		2000				2005			
		Edge size (No. Pixels)				Edge size (No. Pixels)			
GUIDOS Class	Indicator	1 pix	2 pix	3 pix	4 pix	1 pix	2 pix	3 pix	4 pix
Core	Area (%)	84,46	71,41	57,10	47,83	84,40	71,30	56,95	47,67
	Dead wood	2,8	3,0	3,1	3,4	6,3	6,6	5,6	5,0
	Std. of DBH	34,6	34,5	36,5	37,1	37,4	37,2	39,3	36,4
	Shannon Index	0,3	0,30	0,32	0,31	0,32	0,34	0,32	0,31
Non-core	Area (%)	15,54	28,59	42,90	52,17	15,60	28,70	43,05	52,33
	Dead wood	3,2	2,6	2,5	2,5	5,4	5,3	5,7	5,3
	Std. of DBH	36,7	35,1	33,0	33,1	35,2	35,2	33,6	34,8
	Shannon Index	0,3	0,31	0,30	0,31	0,43	0,37	0,36	0,36
Internal*	Area (%)	13,25	14,37	11,45	8,85	12,43	13,67	11,18	8,54
	Dead wood	2,3	2,3	2,7	4,2	15,3	12,9	15,9	13,6
	Std. of DBH	31,1	29,8	23,2	28,0	40,8	36,0	38,0	31,8
	Shannon Index	0,3	0,34	0,20	0,26	0,35	0,35	0,27	0,22
External	Area (%)	86,75	85,63	88,55	91,15	87,57	86,33	88,82	91,46
	Dead wood	3,0	3,0	2,7	2,7	4,0	5,2	5,2	5,0
	Std. of DBH	35,6	35,4	35,5	35,5	36,3	36,6	36,6	36,9
	Shannon Index	0,31	0,30	0,31	0,31	0,33	0,36	0,36	0,36
Core	Area (%)	84,46	71,41	57,10	47,83	84,40	71,30	56,95	47,67
	Dead wood	2,6	2,7	3,0	3,1	6,8	7,3	6,6	7,6
	Std. of DBH	33,9	33,8	35,6	36,2	41,5	40,4	41,2	39,0
	Shannon Index	0,30	0,29	0,30	0,30	0,36	0,38	0,35	0,34
Non-core	Area (%)	15,54	28,59	42,90	52,17	15,60	28,70	43,05	52,33
	Dead wood	3,0	2,4	2,3	2,3	9,6	6,4	7,0	6,5
	Std. of DBH	34,9	33,9	32,0	32,0	30,6	33,4	32,8	34,3
	Shannon Index	0,30	0,31	0,30	0,30	0,36	0,33	0,34	0,34
Internal*	Area (%)	13,25	14,37	11,45	8,85	12,43	13,67	11,18	8,54
	Dead wood	2,5	2,2	3,0	6,5	26,5	23,0	21,9	18,2
	Std. of DBH	32,6	28,7	23,6	31,0	41,6	45,2	46,7	37,2
	Shannon Index	0,30	0,33	0,22	0,23	0,34	0,29	0,24	0,20
External	Area (%)	86,75	85,63	88,55	91,15	87,57	86,33	88,82	91,46
	Dead wood	2,7	2,7	2,5	2,5	5,3	5,6	4,5	5,0
	Std. of DBH	34,7	34,6	34,5	34,3	38,7	37,5	35,4	36,7
	Shannon Index	0,29	0,30	0,30	0,30	0,37	0,40	0,36	0,37

*) The results are based on a small number of NFI plots due to the low area coverage of the class.

Table 85: Temporal changes in area coverage of GUIDOS classes derived from the Swedish HR forest/non-forest maps from 2000 and 2005 and changes in estimated NFI indicators within GUIDOS classes.

8. DISCUSSION AND CONCLUSIONS

A large part of the project was devoted for the acquisition and the development of a large number of bridging functions for the harmonisation of forest inventory data. For this reason the first results presented in this final report are just a part of the possible analysis that be carried out on the basis of the combination between harmonised NFI biodiversity indicators and forest spatial pattern maps implemented with the GUIDOS software. The analysis of the data will continue also after the official end of the project.

The study was carried out on seven study areas. Two different forest map resolutions were used: with pixels of 25 and 100 metres. From the GUIDOS software the SIZE parameter 1 - 4 were used to classify the maps into spatial pattern classes. For simplification the GUIDOS classes were grouped into two classes: *'Core'* / *'None Core'* and 'Internal' 'External'. Two approaches to combine the plot data from the harmonised database and the spatial pattern classes were carried out: pixel based and area based. The pixel level was based on three methods: single pixel and moving window with sizes of 3x3 and 5x5 pixels. The majority of the GUIDOS class in each window was calculated and used for the analyses.

The results from the test area and the pixel area approach for the three indicators analysed until now show no or little relationship between the harmonized biodiversity indicators and the forest spatial pattern maps derived using GUIDOS. The use of different sized sub-areas (landscapes) in the area approach or of different window sizes for the pixel approach did not affect the relationship between GUIDOS classes and indicators significantly, nor did the use of different resolution in the input forest pattern maps (25m/100m). There was also little influence of the definition of Core areas, except for a few cases.

In the pixel approach, aggregating all the NFI plots available, the relative differences between core and non-core values of the three indicators on the basis of the size of the extraction window (1, 3, 5 pixels) were: -14% (mowing from 1 to 3 pixels) and 2% (moving from 3 to 5 pixels) for deadwood in core areas, and -7% and -2% respectively in non-core areas. For standard deviation of DBH it was 1% and 1% in core areas and 1% and -1% in non-core areas. For Shannon index it was 4% and 0% in core areas and 1% and -2% in non-core areas.

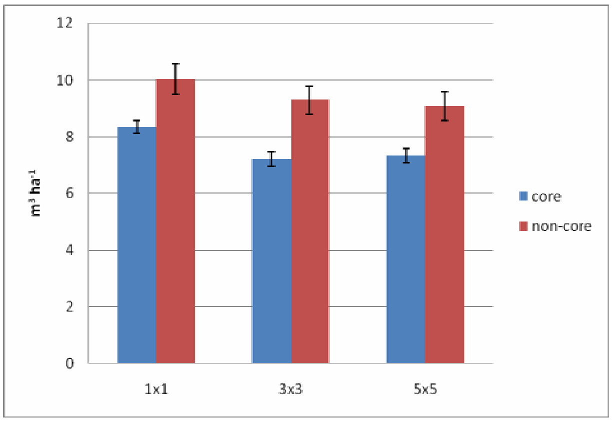


Figure 39: impact on core/non-core relative values of the total deadwood indicator of the size of the extraction window (1 pixel, 3x3 pixels, 5x5 pixels) used in the pixel approach. Based on all the NFI plots available.

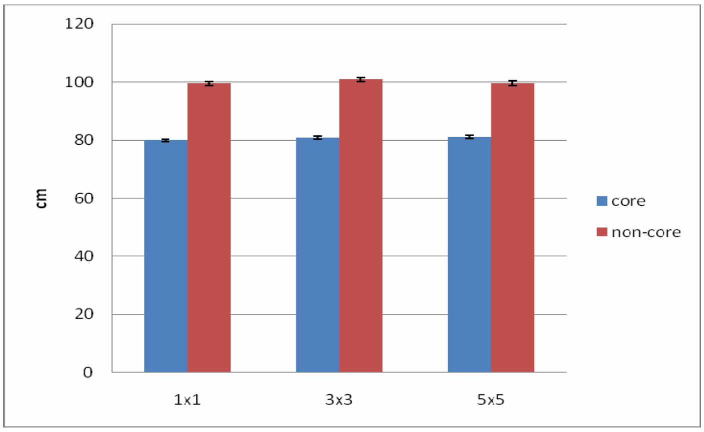


Figure 40: impact on core/non-core relative values of the DBH standard deviation indicator of the size of the extraction window (1 pixel, 3x3 pixels, 5x5 pixels) used in the pixel approach. Based on all the NFI plots available.

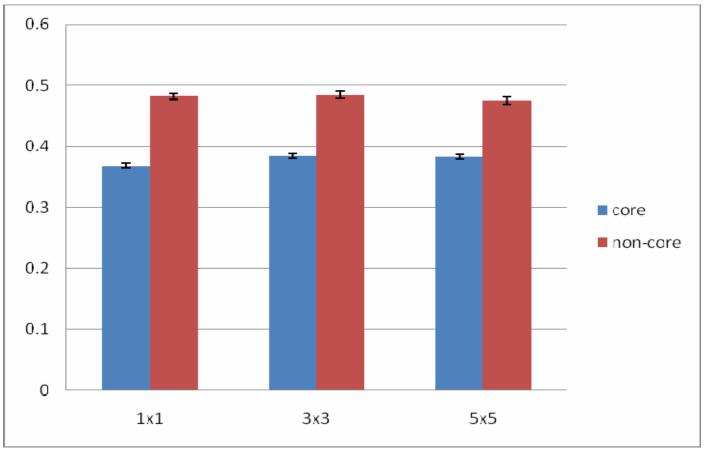


Figure 41: impact on core/non-core relative values of the Shannon index indicator of the size of the extraction window (1 pixel, 3x3 pixels, 5x5 pixels) used in the pixel approach. Based on all the NFI plots available.

These trends show that the distribution in core/non-core pixels of the pixels selected with the single pixel approach or with the 3x3 and 5x5 windows is very similar, at least on the basis of the information available in the test areas. For this reason in the following discussion part the single pixel approach was adopted as a reference.

A similar sensibility analysis was performed on the basis of the dimension of the forest border considered in the MSPA landscape classification of forest area. Four widths of forest border where considered based on 1, 2, 3 and 4 pixels at 100 m resolution. The relative presence of non-core NFI plots augmented, the average values of the three indicators decreased and their standard errors (in non-core areas) decreased accordingly. The same decreasing trends was noticed also in core areas at least for DBH standard deviation and for the Shannon index.

Differences in the values of the three indicators in the four tested forest border width were comprised between 12% and 1%. For this reason in the following discussion part the 1 pixel border was adopted as a reference.

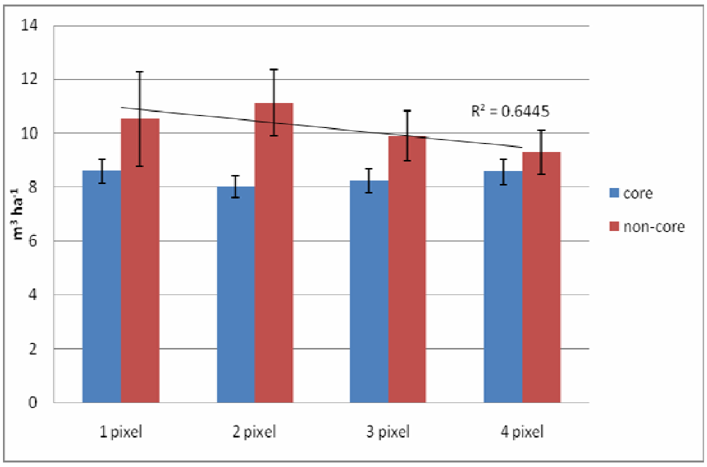


Figure 42: impact on core/non-core relative values of the total deadwood indicator of the width of the forest border in the MSPA analysis (100 m resolution pixels). Statistics based on all the NFI plots available.

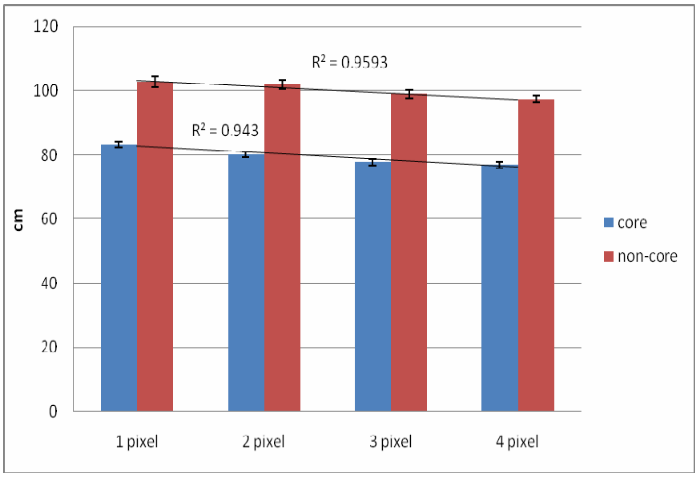


Figure 43: impact on core/non-core relative values of the DBH standard deviation indicator of the width of the forest border in the MSPA analysis (100 m resolution pixels). Statistics based on all the NFI plots available.

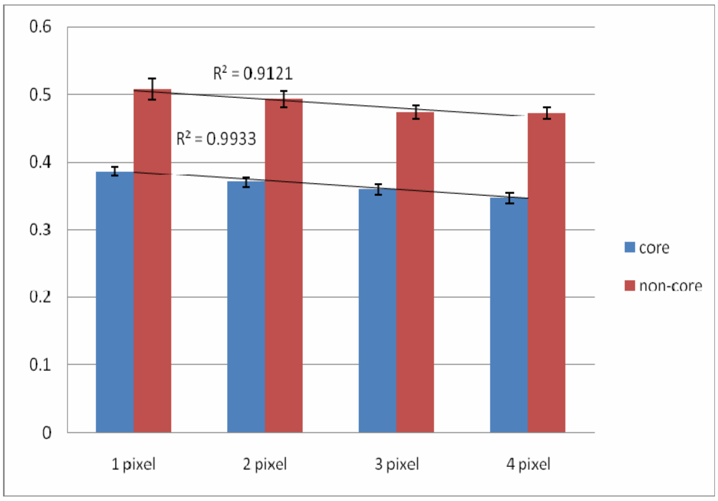


Figure 44: impact on core/non-core relative values of the tree Shannon index of the width of the forest border in the MSPA analysis (100 m resolution pixels). Statistics based on all the NFI plots available.

On the basis of the single pixel extraction method and on a forest border width of 1 pixel (at 100 m resolution) the results in terms of differences between core and non-core forest areas of the three investigated indicators where very different depending of the test areas.

For deadwood in Switzerland, Germany, Italy and Sweden deadwood volume was higher in non-core areas while in both the test areas in Czech Republic the trend was different with higher deadwood volume in core areas.

The limited number of plots in non-core areas frequently determined very high values of standard error (see Germany for example where just 68 plots where in non-core areas).

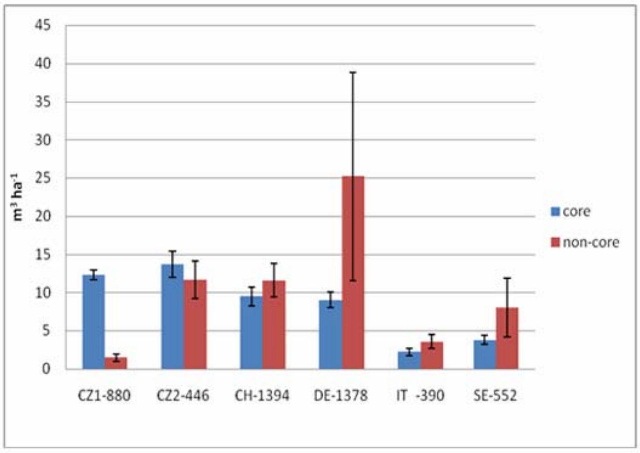


Figure 45: average values of deadwood in the investigated test sites in core and non-core areas. Statistics based on all the NFI plots available. Together with the name of the country the total number of plots available.

For the standard deviation of DBH the trend was the opposite, in most of the test sites (Switzerland, Germany and both the Italian sites) the diversity of tree DBH was higher in core areas than in non-core areas while in both the test sites in Czech Republic and in Sweden the values were higher in non-core areas.

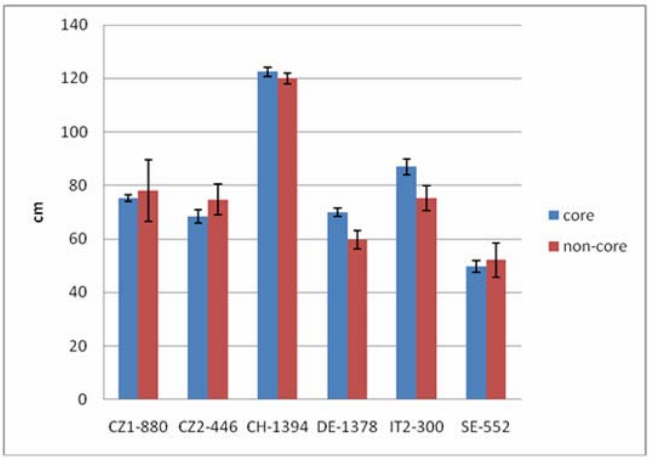


Figure 46: average values of standard deviation of DBH in the investigated test sites in core and non-core areas. Statistics based on all the NFI plots available. Together with the name of the country the total number of plots available.

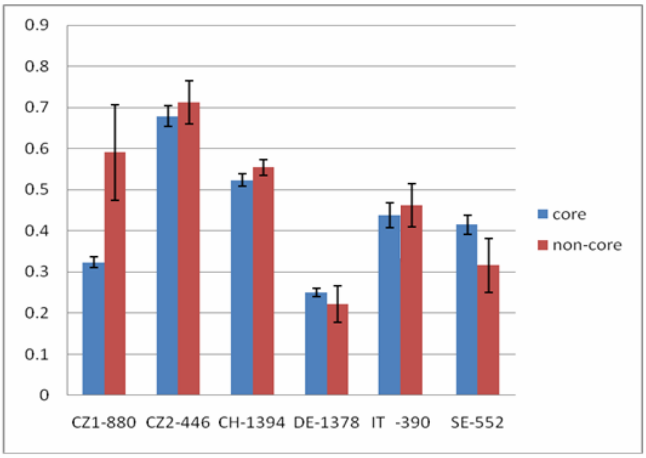


Figure 47: average values of the Shannon index (on basal area) in the investigated test sites in core and non-core areas. Statistics based on all the NFI plots available. Together with the name of the country the total number of plots available.

Finally regarding the Shannon index in four test sites (both test sites in Czech Republic, Switzerland and in Italy) the values were higher in non-core areas than in core areas, the opposite relationships was instead observed in Germany, in Italy and in Sweden.

The last test was carried out aggregating all the plots from all the test sites (forest border with of 1 pixel and extraction of statistics based on a single pixel approach).

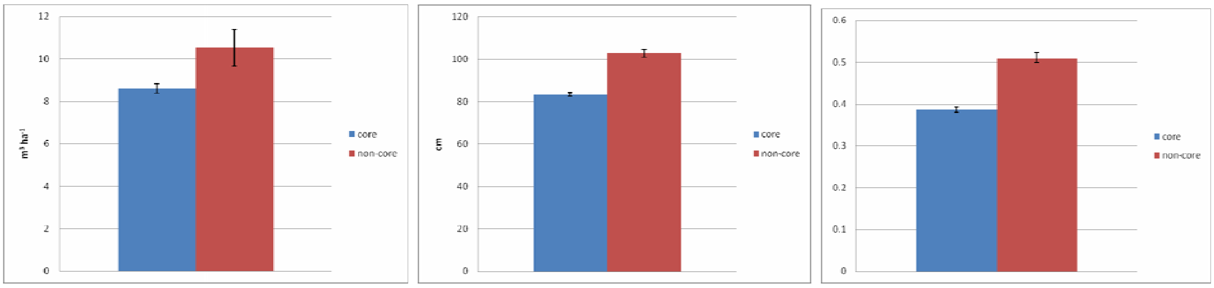


Figure 48: average values of the selected indicators (from the left: deadwood volume, standard deviation of DBH and Shannon index on basal area) in core and non-core areas. Statistics based on all the NFI plots available.

All the investigated forest diversity indicators demonstrated statistically meaningful higher values in non-core areas than in core areas.

These results seems to be related to the relationship between field and landscape scales. Non-core forest areas at landscape level are in more diverse environments since they have a mutual relationship between forest and non-forest habitats. These results seem to suggest the possible downscaling approach between different levels of forest biodiversity acquired at different scales and on the basis of different data sources and assessment methodologies.

For the moment just in Sweden and in Italy test areas the analysis were completed for both the pixel based and area based approaches.

On the basis of the data elaborated until this moment it is interesting to notice that in the Italian test area the values of all the three indicators analysed have similar relationship with core/non-core classes for both the pixel and the area approach. The NFI plots located in core area have higher values in all the three indicators and for all the tested approaches.

The time trend analysis, that is possible just for the area approach and for the test areas in Sweden and Czech Republic, was completed just in Sweden. The trends in the biodiversity indicators is positive with an increase in all the considered biodiversity indicators. For the same area the GUIDOS classes did not show similar trends.

Even if the analysis still have to be completed the first results seems to highlight the fact that the forest maps available, and the relative spatial pattern maps, are in general to coarse to be related with forest biodiversity information acquired in very small field areas such as those ones used in NFIs. The complete and exhaustive statistical analysis of the data acquired in this project will led to a complete evaluation of these relationships.

9. REFERENCES

Aguirre O., Kramer H., Jiménez J., 1998: Strukturuntersuchungen in einem Kiefern-Durchforstungsversuch Nordmexikos. Allgemeine Forst und Jagdzeitung, 169, 213-219.

Alatalo R.V., 1981: Problems in the measurement of evenness in ecology. Dikos, 37, s. 199 – 204

Albrecht L., 1991: Die Bedeutung des toten Holzes im Wald. Forstw. Cbl. 110 : 106-113.

Allen R.B, Bellingham P.J., Wiser S.K., 2003: Forest biodiversity assessment for reporting conservation performance. Science-for-Conservation. (216): 49 pp.

Angelstam P., Breuss M., Gossow H., 2000: Visions and tools for biodiversity restoration in coniferous forest. Forest-ecosystem-restoration:-ecological-and-economical-impacts-of-restoration-processes-in-secondary-coniferous-forests-Proceedings-of-the-International-Conference,-Vienna,-Austria,-10-12-April,-2000. 2000; 19-28

Arnell N.W., Livermore M.J.L., Kovats S., Levy P.E., Nicholls R., Parry M.L., Gaffin S.R., 2004: Climate and socio-economic scenarios for global-scale climate change impacts assessments: characterising the SRES storylines. Global-Environmental-Change 14(1): 3-20

Azman H.N., 2001: Using small-mammal population as an indicator group for assessing impact of logging. Tropical forestry research in the new millennium: meeting demands and challenges Proceedings of The International Conference on Forestry and Forest Products Research CFFPR 2001 held in Kuala Lumpar, Malaysia on 1-3 October 2001. 2001; 47-56

Baier R., Ettl R., Hahn C., Gottlein A., 2006: Early development and nutrition of Norway spruce (Picea abies (L.) Karst.) seedlings on different seedbeds in the Bavarian limestone Alps - a bioassay. Annals of Forest Science 63 : 339-348.

Bailey S., 2007: Increasing connectivity in fragmented landscapes: An investigation of evidence for biodiversity gain in woodlands. For. Ecol.Manage. 238: 7-23.

Barbati,A., Corona, P., Marchetti,M. 2007: A forest typology for monitoring sustainable forest management: The case of European Forest Types. Plant Biosystems, 141(1):93-103.

Barbati A., Corona P., Marchetti M., 2006: European forest types. Categories and types for sustainable forest management and reporting. EEA Technical report No 9/2006.

Barbati A., Marchetti M. 2004: Forest Types for Biodiversity Assessment (FTBAs) in Europe: the Revised Classification Scheme. Efi Proceedings 51: 105-126.

Barthlott W., Kier G, Mutke J., 1998: Biodiversity - the uneven distribution of a treasure. Forests-in-focus:-Proceedings-Forum,-Biodiversity-Treasures-in-the-World'-s-Forests,-3-7-July-1998. 1999; 18-28

BEAR Newsletter 3, http://www.algonet.se/~bear/

BEF (Baltic Environmental Forum), 2000: 2nd Baltic State of the Environment Report based on environmental indicators, Baltic Environmental Forum, Riga.

Behera M.D, Kushwaha S.P.S., Roy P.S., 2005: Rapid assessment of biological richness in a part of Eastern Himalaya: an integrated three-tier approach. Forest-Ecology-and-Management. 207(3): 363-384

Belaoussoff S., Kevan,P.G., Murphy S., Swanton C.E., 2003: Assessing tillage disturbance on assemblages of ground beetles (Coleoptera: Carabidae) by using a range of ecological indices. Biodiversity and Conservation 12: 851–882.

Berglund H., Jonsson B.G., 2001: Predictability of plant and fungal species richness of old-growth boreal forest islands. Journal-of-Vegetation-Science. 2001; 12(6): 857-866

Bollmann K., Graf R.F., Debrunner R., Suter,W., 2004: The capercaillie as indicator of high species richness: potential and limitations of the umbrella species concept. Landscape-ecology-of-trees-and-forests-Proceedings-of-the-twelfth-annual-IALE-UK-conference,-Cirencester,-UK,-21-24-June-2004. 2004; 200-207

Bosch P. and Söderbäck E. ,1997: European environmental state indicators. Project report, European Environment Agency, Copenhagen and Swedish Environmental Protection Agency, Stockholm.

Bougadis J., Adamowski K., 2006: Scaling model of a rainfall intensity-duration-frequency relationship. Hydrological-Processes 20(17): 3747-3757

Bouwer L.M., Aerts J.C.J.H., Coterlet G.M. van de, Giesen N. van de, Gieske A, Mannaerts C, 2004: Evaluating downscaling methods for preparing global circulation model (GCM) data for hydrological impact modelling. Climate-change-in-contrasting-river-basins:-adaptation-strategies-for-water,-food-and-environment. pp. 25-47

Bradshaw R.H.W., Møller P.F., 2004: European Forest Types for Biodiversity Assessment — A Qualitative Approach. EFI Proceedings 51: 127-134.

Brillouin L., 1956: Science and Information Theory. Academic Press, New York

Bruciamacchie M., 1996: Comparison between indices of species diversity. Munich, 3/96, 14s.

Buddenbaum H., Schlerf M., Hill J., 2005: Tree Species and Age Class Mapping using Hyperspectral Data and Geostatistics. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. (138): 25-34

Buehler D. A., Welton M. J., Beachy T. A., 2006: Predicting Cerulean Warbler Habitat Use In the Cumberland Mountains of Tennessee. Journal of Wildlife Management 70(6): 1763-1769

Bugmann H., Lindner M., Lasch P., Flechsig M., Ebert B., Cramer W., 2000: Scaling issues in forest succession modelling. Climatic-Change 44(3): 265-289

Bundeswaldinventur2, 2001-2004: http://www.bundeswaldinventur.de, (2.3.2006).

Burger G, Chen Y, 2005: Regression-based downscaling of spatial variability for hydrologic applications. Journal-of-Hydrology-Amsterdam 311(1/4): 299-317

Butler R., Schlaepfer R., 2004: Dead wood in managed forests: how much is enough? Schweizerische-Zeitschrift-fur-Forstwesen. 155(2): 31-37

Butler R., Schlaepfer R., 2004: Spruce snag quantification by coupling colour infrared aerial photos and a GIS. Forest-Ecology-and-Management. 195(3): 325-339

Campbell J., Fredeen A.L., 2004: Lobaria pulmonaria abundance as an indicator of macrolichen diversity in Interior Cedar-Hemlock forests of east-central British Columbia. Canadian-Journal-of-Botany. 2004; 82(7): 970-982

Casanova P., Memoli A., 2004: Birds and mammals as indicators of changes in biodiversity in Italy. EFI-Proceedings. 2004; (51): 369-378

Cassagne N., Gauquelin T., Bal-Serin M.C., Gers,C., 2006: Endemic Collembola, privileged bioindicators of forest management. Pedobiologia-. 2006; 50(2): 127-134

CBD (1992) Convention on Biological Diversity. Secretariat of the Convention on Biological Diversity, United Nations Environment Programme

Chirici G., Winter S., Bastrup-Birk A., Bertini R., Marchetti M. (submitted): Monitoring biodiversity using data from National Forest Inventories. European Journal of Forest Research.

Christensen M., Heilmann-Clausen J., Walleyn R., Adamcik S., 2004: Wood-inhabiting Fungi as Indicators of Nature Value in European Beech Forests. EFI Proceedings 51: 229-238.

Ciancio O., Nocentini S., 2004: Biodiversity Conservation in Mediterranean Forest Ecosystems: from Theory to Operationality. EFI Proceedings 51: 163-170.

Clark P. J, Evans F. C, 1954: Distance to the nearest neighbour as a measure of spatial relationships in populations, Ecology, 35; 445-453.

Cohen W.B. and Spies T.A., 1992. Estimating structural attributes of Douglasfir/ western hemlock forest stands from LANDSAT and SPOT imagery, Remote Sensing of Environment, 41:1-17.

Collins B.S., Dunne K.P., Pickett S. T. A., 1985: Responses of Forest Herbs to Canopy Gaps

Cooley W.W., Lohnes P.R., 1971: Multivariate data analysis. Wiley, New York

Corona P., Marchetti M., 2007: Outlining multi-purpose forest inventories to assess the ecosystem approach in forestry. Plant Biosystems 141(2): 243-251

Corona P., Chirici G., Travaglini D., 2004: Forest ecotone survey by line intersect sampling. Can. J. For. Res. 34: 1776-1783

Corona P., Delfavero R., Marchetti M., 2004: Stand-level Forest Type Approach in Italy: Experiences from the Last Twenty Years. EFI Proceedings 51: 143-152

Corona P., Chirici G. and Marchetti M., 2002: Forest ecosystem inventory and monitoring as a framework for terrestrial natural renewable resource survey programmes. Plant Biosystems 136: 69-82.

Corona P. and Marchetti M., 2000: Towards an effective integration of forest inventories and natural resources surveys: the Italian perspective. In: Hansen, M. and Burk, T. (eds.). Integrated Tools for Natural Resources Inventories in the 21st Century. USDA, Forest Service, North Central Research Station GTR, NC-212. Pp. 28-34.

COST E43, 2008: Harmonising national forest inventories in Europe. Draft reference definitions. Version: 1st June 2008. Available on line at http://www.metla.fi/eu/cost/e43.

Cox F., 1971: Dichtebestimung und Strukturanalyse von Pflanzenpopulationen mit Hilfe von Abstandsmessungen. Mitt. Bundesforschungsanstalt Forst- und Holzwirtschaft Reinbeck, No. 87, 161 pp.

Curran P.J., Dungan J., Gholz H.L., 1992: Seasonal LAI measurements in slash pine using Landsat TM. Remote Sensing of Environment, 39: 3-13.

Dahm S., 2001: Investigation of forest edge lengths on data of the first forest inventory. Allgemeine Forst- und Jagdzeitung 172 (5-6): 81-86 2001.

De Heer M., Kapos V., Miles L. and Ten Brink B., 2004: Biodiversity Trends and Threats in Europe – Can We Aplly a Generic Biodiversity Indicator to Forests?. In Marchetti M., 2004 (ed.). Monitoring and Indicators of Forest Biodiversity in Europe – From Ideas to Operationality. EFI Proceedings No. 51, 2004, 15-26.

Diaz-Nieto J., Wilby R.L., 2005: A comparison of statistical downscaling and climate change factor methods: impacts on low flows in the River Thames, United Kingdom. Climatic-Change 69(2/3): 245-268.

Dierschke H., 1994: Pflanzensoziologie, Verlag Ulmer, Stuttgart.

DIVERSITAS. 2007. DIVERSITAS Annual Report 2006: Integrating biodiversity science for human well-being. 32 pp.

Drößler L., Von Lüpke B., 2005: Canopy gaps in two virgin beech forest reserves in Slovakia. Journal of Forest Science 51 (10): 446-457.

Duelli P., 1995: Biodiversität erhalten und fördern: Was sagt die ökologische Forschung dazu? Forum für Wissen.

Eckmüllner O., 1998: Einfluß der Probeflächengröße auf Maßzahlen der Biodiversität. Tagung der Sektion Biometrie des FVDFA 30. September - 1. Oktober, Freiburg.

EEA (European Environmental Agency), 2006: Progress towards halting the loss of biodiversity by 2010. EEA report 5, pp 100.

EEA (European Environmental Agency), 2003: An inventory of biodiversity indicators in Europe, 2002. European Enviroment Agency, Copenhagen. Technical report no 92. 42 p.

Estreguil C., Vogt P., Cerruti M. and Maggi M., 2004: JRC Contribution to Reporting Needs of EC Nature and Forest Policies. EFI Proceedings 51: 91-104.

Estreguil, C., Vogt, P., Ostapowicz K. 2007. Implementation of the MCPFE Indicator on landscape level forest spatial pattern for Europe. In Proceedings of the ForestSAT conference held in Montpellier, France on the 5th-7th November 2007 (abstract p 30, proceedings p163.pdf on DVD) http://forestsat.teledetection.fr/

Estreguil C. and Mouton, C. 2009. Measuring and reporting on forest landscape pattern, fragmentation and connectivity in Europe: methodology and indicator layers. Joint Research Centre of the European Commission, EUR23841EN

European Commission, 2001a: A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development. COM(2001)264 final – Brussels. (http://www.europa.eu.int/eur-lex/en/com/cnc/2001/com2001_0264en01.pdf)

European Commission, 2001b: Communication for the Commission to the Council and the European Parliament – Biodiversity Action Plans in the areas of Conservation of Natural Resources, Agriculture, Fisheries, and Development and Economic Cooperation.–Brussels. (http://biodiversitychm.eea.eu.int/convention/cbd_ec/strategy/BAP_html)

European Commission, 2001c: Environment 2010: Our future, Our choice – the Sixth Environment Action Programme. COM(2001) 31 final.

European Commission, 1998: Communication of the European Commission to the Council and to the Parliament on a European Community Biodiversity Strategy. Brussels. (http://europa.eu.int/comm/environment/docum/9842en.pdf)

European Commission, 1992: Council Directive 92/43/EEC of 21 May1992 on the conservation of natural habitats and of wild fauna and flora. Brussels. http://europa.eu.int/comm/environment/nature/habdir.htm)

European Commission, 1979: Council Directive 79/409/EC of 2 April 1979 on the conservation of the wild birds. Luxembourg. (http://europa.eu.int/comm/environment/nature/en.pdf)

Fager E.W., 1972: Diversity: a sampling study. Am. Natur., 106: 293–310

Failing L., Gregory R., 2003: Ten common mistakes in designing biodiversity indicators for forest policy. Journal-of-Environmental-Management. 68(2): 121-132

FAO (1998): FRA 2000 – Terms and definitions. Forest resources assessment programme, working paper 1, Food and Agriculture Organization of the United Nations, Rome, Italy. 59

Ferris R., Humphrey J.W., 1999: A review of potential biodiversity indicators for application in British forests. Forestry-Oxford. 1999; 72(4): 313-328

Ferris-Kaan R., Peace A.J., Humphrey J.W., 1998: Assessing structural diversity in managed forests. In: Bachmann, P., KoÈ hl, M., PaÈivinen, R. (Eds.), Assessment of Biodiversity for

Fisher R.A., Corbet A.S., Williams C.B., 1943: The relation between the number of species and the number of individuals in a random sample of an animal population. J. Anim. Ecol. 12, s.42-58

Foody G.M, Cutler M.E.J., 2003: Tree biodiversity in protected and logged Bornean tropical rain forests and its measurement by satellite remote sensing. Journal-of-Biogeography. 30(7): 1053-1066

Franklin J. F., Spies T. A., Van Pelt R., Carey A. B., Thornburgh D. A., Berg D. R., Lindenmayer D. B., Harmon M. E, Keeton W. S., Shaw D. C., 2002: Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas fir forests as an example. Forest ecology and management 155: 399-423.

Franklin J.F., Cromack Jr. K., Denison W., McKee A., Maser C., Sedell J., Swanson F., Juday G., 1981: Ecological characteristics of old-growth Douglas-fir forests. USDA For. Serv. Gen. Tech. Rep. PNW-118 48.

Franklin S.E, 2001: Remote Sensing for Sustainable forest management. CRC Press, Boca Raton, USA.

Füldner K, 1995: Zur Strukturbeschreibung in Mischbeständen. Forstarchiv 66: 235-240.

Fuller R.M., Groom G.B., Mugisha S., Ipulet P., Pomeroy D., Katende A., Bailey R., Ogutu-Ohwayo R., 1998: The integration of field survey and remote sensing for biodiversity assessment: a case study in the tropical forests and wetlands of Sango Bay, Uganda. Biological Conservation 86: 379-391

Gadow K., 1993: Zur Bestandesbeschreibung in der Forsteinrichtung. Forst und Holz, 21, p. 602-606.

Gadow K., 1999: Waldstruktur und Diverzität. AFJZ, 170, 7, p.117-121

Gadow, K., Hui G., 1999: Modelling forest development. Kluwer Academic Publishers, Dordrecht, 213 pp.

Gadow K., Hui G.Y., Albert M., 1998: Das Winkelmaß – ein Strukturparameter zur Beschreibung der Individualverteilung in Waldbeständen. Centralblatt für das gesamte Forstwesen, 115, p. 1-10.

Gallego-Castillo B., Finegan B., 2004: An evaluation of approaches to the definition of indicator tree species for biodiversity monitoring in a fragmented landscape of the Mesoamerican Biological Corridor. Recursos-Naturales-y-Ambiente. 2004; (41): 49-61

Gallego F.J., Escribano P., Christensen S., 2000: Comparability of landscape diversity indicators in the European Union. From Land cover to landscape diversity in the European Union. pp 84-97.

Gangopadhyay S., Clark M., Werner K., Brandon D., Rajagopalan B., 2005: Statistical downscaling using K-nearest neighbors. Water-Resources-Research. 2005; 41(2): W02024.

Gaston K.J., 1996. What is biodiversity? In Gaston K.J. (ed.). Biodiversity: a biology of numbers and difference. Blackwell Science Ltd., Oxford, U.K.

Ghayyas-Ahmad, 2001: Identifying priority forest areas in the Salt Range of Pakistan for biodiversity conservation planning using remote sensing and GIS. Pakistan-Journal-of-Forestry. 51(1): 21-40.

Ghazoul J., 2001: A framework for monitoring indicators of ecological sustainability in tropical forestry. EFI-Proceedings. (38): 135-149.

Gilg. O., 2005: Old-growth forests: characteristics, conservation and monitoring. Technical report no 74 bis. ATEN, Montpellier. 96 p.

Giorgi F., 2001: Modelling regional climate change. http://www.scidev.net/dossiers/index.cfm?fuseaction=printarticle&dossier=4&policy=30&section=96

Gleichmar W., Gerold D., 1998: Indizes zur Charakterisierung der horizontalen Baumverteilung. Forstw. Cbl. 117, p. 69-80.

Gon H.A.C.D. van der, Bodegom P.M. van, Houweling S., Verburg P.H., Breemen N. van, 2000: Combining upscaling and downscaling of methane emissions from rice fields: methodologies and preliminary results. Nutrient-Cycling-in-Agroecosystems 58(1/3): 285-301

Green P., Peterken G.F., 1997: Variation in the amount of dead wood in the woodlands of the Lower Wye Valley, UK in relation to the intensity of management. For. Ecol. Manage. 98 : 229-238.

Griffiths G. H., Lee J., Eversham B.C., 2002: Landscape pattern and species richness; regional scale analysis from remote sensing. Int. J. Remote Sensing 21(13&14): 2685–2704

Groom G, Mücher C.A., Ihse M., Wrbka T., 2006: Remote sensing in landscape ecology:experiences and perspectives in a European context. Landscape Ecology (21): 391 –408.

Haase V., Topp W., Zach P., 1998: Eichen-Totholz im Wirtschaftswald als Lebensraum fur xylobionte Insekten. . Z. Ökologie u. Naturschutz 7 : 137-153.

Hahn K., Christensen M., 2004: Dead wood in European forest reserves - a reference for forest management. EFI-Proceedings. (51): 181-191

Harmon M.E., Franklin J.F., 1986: Tree seedlings on logs in Picea-Tsuga forests of Oregon and Washington. Ecology, 70 : 48-59.

Harmon M.E., Franklin J.F., Swanson F.J., Sollins P., Gregory S.V., Lattin J.D., Anderson N.H., Cline S.P., Aumen N.G., Sedell J.R., Lienkaemper G.W., Cromack K. Jr., Cummins K.W., 1986: Ecology of coarse woody debris in temperate ecosystems. Adv. Ecol. Res., 15 : 133-302

Harpham C., Wilby R.L., 2005: Multi-site downscaling of heavy daily precipitation occurrence and amounts. Journal-of-Hydrology-Amsterdam. 2005; 312(1/4): 235-255

Harpham C, Wilby R.L., 2004: Multi-site simulation of daily precipitation amounts using Artificial Neural Networks (ANNs). Hydrology:-science-and-practice-for-the-21st-century,-Volume-1-Proceedings-of-the-British-Hydrological-Society-International-Conference,-Imperial-College,-London,-July-2004. 2004; 128-138

Haußmann T, Fischer R., 2004: The Forest Monitoring Programme of ICP Forests – A Contribution to biodiversity monitoring. EFI Proceedings 51:415-419.

Hector A., 2001: Biodiversity and the Functioning of Grassland Ecosystems: Multi-Site Comparison. Pages 71-95, in The Functional Consequences of Biodiversity. Eds

Heer M., De Kapos, V. Miles L., Brink B.T., 2004: Biodiversity Trends and Threats in Europe – Can we apply a generic biodiversity indicator to forests? EFI Proceedings 51: 15-26

Heip C., 1974: A new index measuring evenness. Journal of Marine Biological Association, 54, s. 555 - 57

Helm J.A., 1998: The Dictionary of Forestry, USA, 1998, ISBN 0-939970-73-2

Helms, J. A., 1998, The Dictionary of Forestry. Society of American Foresters. 224pp and Smith, D.M. 1986 The Practice of Silviculture. 8th ed. John Wiley and Sons. New York. ISBN 0-939970-73-2. 527 pp.

Hill J.K., Hamer K.C., Lace L.A., Banham W.M.T., 1995: Effects of selective logging on tropical forest butterflies on Buru, Indonesia. Journal-of-Applied-Ecology. 32(4): 754-760

Hill M.O., 1973: Diversity and Evenness: a unifying notation and its consequences. Ecology 54/2, s. 427-432.

Hočevar M., Kovač M., 2004: A short description of the Slovenian NFI, updated 27.10.2004. http://www.gozdis.si/departments/geomatics/nfi_si.pdf

Hoeven C. vander, Iongh H. H. de, 1999: The use of fauna indicators for monitoring the impact of disturbance; a review. Workshop Proceedings 'The balance between biodiversity conservation and sustainable use of tropical rain forests' , 6-8 December 1999. 2001; 179-189

Holdridge L.R., 1967: Life zone ecology. Tropical Science Center, San JoseÂ, Costa Rica.

Holopainen M., Talvitie M., Leino O., 2005: Forest biodiversity inventory by means of digital aerial photographs and laser scanner data. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. (138): 340-348

Hopmans J.W., Nielsen D.R., Bristow K.L., 2002: How useful are small-scale soil hydraulic property measurements for large-scale vadose zone modeling? Environmental-mechanics:-water,-mass-and-energy-transfer-in-the-biosphere: 247-258

Hubálek Z., 2000: Measures of species diversity in ecology: an evaluation. Folia Zool., 49(4), 241–260.

Huberty C.J., 1994: Applied discriminant analysis. Wiley and Sons, New York

Humphrey J.W., Watts K., 2004: Biodiversity indicators for UK managed forests: development and implementation at different spatial scales. EFI-Proceedings. (51): 79-89

Hurlbert S.H., 1971: The nonconcept of species diversity: a critique and alternative parameters. Ecology 52, s. 577-586

Hutcheson K., 1970: A test for comparing diversities based on the Shannon formula. J. Theor. Biol., 29: 151–154

Hyyppa J., Hyyppa H., Inkinen M., Engdahl M., Linko S., Zhu-Yihong, 2000: Accuracy comparison of various remote sensing data sources in the retrieval of forest stand attributes. Forest-Ecology-and-Management. 128(1/2): 109-120. In: S. T.A., Pickett P. S. White: The ecology of natural disturbance and patch dynamics, 218-234 , Academic Press, San Diego.

Ingram J.C., Dawson ,T.P., Whittaker R.J., 2005: Mapping tropical forest structure in southeastern Madagascar using remote sensing and artificial neural networks. Remote-Sensing-of-Environment. 94(4): 491-507.

Innes J.L, Koch B., 1998: Forest biodiversity and its assessment by remote sensing. Global-Ecology-and-Biogeography-Letters. 7(6): 397-419.

Jaehne S., Dohrenbusch A., 1997: Ein Verfahren zur Beurteilung der Bestandesdiversität. Forstw. Cbl. 116, s. 333-345.

Jha C.S., Udayalakshmi V., Dutt C.B.S., 1997: Pattern diversity assessment using remotely sensed data in the Western Ghats of India. Tropical-Ecology. 38(2): 273-283

Jongman R H.G., Bunce R.G.H., Metzger M.J., Mücher C.A., Howard D.C., Mateus V.L., 2006: Objectives and applications of a statistical environmental stratification of Europe. Landscape Ecology21:409 –419.

Jonsson B. G. and Jonsell M., 1999: Exploring potential biodiversity indicators in boreal forests. - Biodiversity and Conservation 8: 1417-1433.

Juutinen A., Monkkonen M., 2004: Testing alternative indicators for biodiversity conservation in old-growth boreal forests: ecology and economics. Ecological-Economics. 2004; 50(1/2): 35-48.

Kaennel M., 1998: BIODIVERSITY: a Diversity in Definition. (In Bachmann,P.,Köhl,M.,Päivinen,R.,: Assessment of Biodiversity for Improved Forest Planning. Proceedings of the Conference on Assessment of Biodiversity for Improved Forest Planning, 7 - 11 October 1996, held in Monte Verita, Switzerland, Kluwer Academic Publishers, Dordrecht), s. 71 – 82.

Kaennel M., Schweingruber F.H., 1995: Multilingual Glossary of Dendrochronology, Terms and definitions in English, German, French, Spanish, Italian, Portuguese and Russian, , Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf / Paul Haupt Publishers, Berne, 1995. 467 pages, ISBN 3-258-05259-X.

Kati V., Devillers P., Dufrene M., Legakis A., Vokou D., Lebrun P., 2004: Testing the value of six taxonomic groups as biodiversity indicators at a local scale. Conservation-Biology. 2004; 18(3): 667-675.

Kati V.I., Papaioannou H.I., 2001: Identifying biodiversity indicators in a forest ecosystem. Proceedings-International-Conference-Forest-Research:-a-challenge-for-an-integrated-European-approach,-Thessaloniki,-Greece,-27-August-1-September-2001,-Volume-II. 2001; 501-506.

Katila M., 2005: Error variations at the pixel level in the k-nearest neighbor predictions of the Finnish multi-source National Forest Inventory. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. (138): 265-274.

Kempton R.A., Taylor L.R., 1976: Models and statistics for species diversity. Nature, 262: 818–820.

Kerr J.T., Ostrovsky M., 2003: From space to species: ecological applications for remote sensing. TRENDS in Ecology and Evolution 18(6): 299-305.

Khan M.S., Coulibaly P., Dibike Y., 2006: Uncertainty analysis of statistical downscaling methods using Canadian Global Climate model predictors. Hydrological-Processes 20(14): 3085-3104.

Kint V., Lust N., Ferris R., Olsthoorn A.F.M., 2000: Quantification of Forest Stand Structure Applied to Scots Pine (Pinus sylvestris L.) Forests. Invest. Agr.: Sist. Recur. For.: Fuera de Serie n.º 1, 17 pp.

Kirby K.J., Reid C.M., Thomas R.C., Goldsmith F.B., 1998. Preliminary estimates of fallen dead wood and standing dead trees in managed and unmanaged forests in Britain. J. Appl. Ecol. 35 : 148-155.

Kirby K.J., Webster S.D., Antczak A., 1991. Effects of forest management on stand structure and the quantity of fallen dead wood : some British and Polish examples. For. Ecol. Manage. 43 : 167-174

Kirsch M.M.N., Bradshaw R.H.W., 2004: European forest types for biodiversity assessment - quantitative approaches. EFI-Proceedings. (51): 135-142

Koch B. and Ivits E., 2004: Results from the Project BioAssess – Relation Between Remote Sensing and Terrestrial Derived Biodiversity Indicators. In Marchetti M., 2004 (ed.). Monitoring and Indicators of Forest Biodiversity in Europe – From Ideas to Operationality. EFI Proceedings No. 51, 2004, 315-332.

Köhl M. and Päivinen R., 1996: Definition of a System of Nomenclature for Mapping of European Forests and for Compiling a Pan-european Forest Information System Office for Official Publication of the European Communities.

Köhl, M., Traub, B., & Päivinen, R. (2000). Harmonisation and Standardisation in Multi-National Environmental Statistics – Mission Impossible? Environmental Monitoring and Assessment, 63: 361-380.

Koistinen P., Holmstrom L., Tomppo E., 2005: Using local linear smoothing for predicting regional averages in multi-source forest inventory. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. (138): 275-283

Kotar M., 1993: Bestimmung des Verteilungsmusters von Bäumen im Wald. Deutscher Verband forstlicher Forschungsanstalten, Sektion forstliche Biometrie und Informatik, 6. Tagung, Freising, 8. – 10. September 1993.

Kotze D.J., Samways M.J., 1999: Support for the multi-taxa approach in biodiversity assessment, as shown by epigaeic invertebrates in an Afromontane forest archipelago. Journal-of-Insect-Conservation. 1999; 3(2): 125-143

Kozak J., Estreguil C., Vogt P., 2007: Forest cover and pattern changes in the Carpathians over the last decades. Eur. J. For. Res. 126: 77-90

Krebs C.J., 1989: Ecological methodology. Harper and Row, New York, 471 s.

Kreyer D., Zerbe S., 2006: Short-lived tree species and their role as indicators for plant diversity in the restoration of natural forests.Restoration-Ecology. 2006; 14(1): 137-147

La monaca A., Corona P., Portoghesi L., 2005. Analisi strutturale multilivello in un bosco vetusto di faggio. V Convegno SISEF, Foreste e Società: cambiamenti, conflitti, sinergie. Torino 27-30 settembre 2005.

Lähde E., 2000: Pro Silva Ideen in borealen Wäldern. Forst und Holz 55: 18

Lähde E., Laiho O., Norokorpi Y., Saksa T., 1999: Stand structure as the basis of diversity index. Forest Ecology and Management 115, s. 213-220.

Lambeck R.J., 1997: Focal species: a multi-species umbrella for nature conservation. Conservation Biology 11: 849-856.

Langor D.W., Spence J.R., 2006: Arthropods as ecological indicators of sustainability in Canadian forests. Forestry-Chronicle. 2006; 82(3): 344-350

Larsson T.B., 2001: Biodiversity evaluation tools for European forest. Ecol. Bull., 50, 1-237

Laxmi-Goparaju, Anshuman-Tripathi, Jha C.S., 2005: Forest fragmentation impacts on phytodiversity - an analysis using remote sensing and GIS. Current-Science. 88(8): 1264-1274

Ledermann T., 1999: Charakterisierung der Bestandesstruktur in Stichprobenverfahren. Diplomarbeit am Institut f. Waldwachstumsforschung der Universität für Bodenkultur, Wien.

Lefsky M.A., Cohen W.B., Spies,T.A., 2001: An evaluation of alternate remote sensing products for forest inventory, monitoring, and mapping of Douglas-fir forests in western Oregon. Canadian-Journal-of-Forest-Research. 31(1): 78-87

Lexer M.J., Lexer W., Hasenauer H., 2000: The Use of Forest Models for Biodiversity Assessments at the Stand Level. Invest. Agr.: Sist. Recur. For.: Fuera de Serie n.º 1, p. 297–316.

Lindenmayer D.B., Margules, C.R., Botkin D.B., 2000: Indicators of biodiversity for ecologically sustainable forest management. Conservation-Biology. 2000; 14(4): 941-950

Lindenmayer D.B., 1999: Future directions for biodiversity conservation in managed forests: indicator species, impact studies and monitoring programs. Forest-Ecology-and-Management. 1999; 115(2/3): 277-287

Lloyd M., Ghelardi R.J., 1964: A table for calculating the "equitability" component of species diverzity. J. Anim. Ecology, 33, s. 217 – 225

Loyn R.H., Mcalpine C., 2001: Spatial patterns and fragmentation: indicators for conserving biodiversity in forest landscapes. Criteria-and-indicators-for-sustainable-forest-management'--Papers--presented-at-a-IUFRO/CIFOR/FAO-conference-'-Sustainable-forest-management:-fostering-stakeholder-input-to-advance-development-of-scientifically-based-indicators'--held-in-Melbourne,-Australia,-August-1998. 391-422

Lübbers P., 1999: Diversitätsindizes und Stichprobenverfahren. Universität Freiburg, 10pp.

Ludwig J.A., Reynolds J.F., 1988: Statistical Ecology a primer on methods and computing. John Willey & Sons, 337 s.

Luoto M., Toivonen T., Heikkinen R.K., 2002: Prediction of total and rare plant species richness in agricultural landscapes from satellite images and topographic data. Landscape Ecology 17: 195–217.

Magura T., Tothmeresz B., Molnar T., 2001: Forest edge and diversity: carabids along forest-grassland transects. Biodiversity and Conservation. 2001; 10(2): 287-300

Maltamo M., Malinen J., Packalen P., Suvanto A., Kangas,J., 2006: Nonparametric estimation of stem volume using airborne laser scanning, aerial photography, and stand-register data. Canadian-Journal-of-Forest-Research. 36(2): 426-436.

Marchetti M., 2004: Monitoring and Indicators of Forest Biodiversity in Europe – From Ideas to Operationality. EFI Proceedings No. 51, 2004.

Margalef R., 1958: Information theory in ecology. General Systematics 3, s.36-71

Martikainen P., Kouki,J., 2003: Sampling the rarest: threatened beetles in boreal forest biodiversity inventories. Biodiversity-and-Conservation. 2003; 12(9): 1815-1831

Martikainen P., Siitonen J., Punttila P., Kaila L., Rauh J., 2000: Species richness of Coleoptera in mature managed and old-growth boreal forests in southern Finland. Biological Conservation 94 : 199-209.

Maselli F., Chirici G., Bottai L., Corona P., Marchetti M., 2005: Estimation of Mediterranean forest attributes by the application of k-nn classifiers to multitemporal Landsat ETM+ images. In press on International Journal of Remote Sensing.

Maselli F., Bottai L., Chirici G., Corona P., Marchetti M., Travaglini D., 2003: Estimation of forest attributes by integration of field sampling and remotely sensed data under Mediterranean environments. Italia-Forestale-e-Montana. 58(4): 251-263.

McBratney A.B. 1998: Some considerations on methods for spatially aggregating and disaggregating soil information. Nutrient-Cycling-in-Agroecosystems. 50(1/3): 51-62

McCarthy J., 2001: Gap dynamics of forest trees: A review with particular attention to boreal forests. Environmental Reviews 9 (1): 1-59.

McIntosh R.P., 1967: An index of diversity and the relation of certain concepts to diversity. Ecology, 48: 392–404

MCPFE, 1997: Work-Programme on the Conservation and Enhancement of Biological and Landscape biodiversity in Forest Ecosystems. Adopted at Expert-Level by the Third Meeting of the Executive Bureau of the Pan-European Biological and Landscape Diversity Strategy 20-21 November, 1997, Geneva, Switzerland

MCPFE, 2002: Improved pan-european indicators for sustainable forest management. MCPFE Liaison Unit, Vienna.

MCPFE, 2003a: Vienna Declaration and Vienna Resolutions adopted at the Fourth Ministerial Conference on the Protection of Forests in Europe, 28-30 April 2003, Vienna Austria

MCPFE, 2003b: Improved Pan-European Indicators for Sustainable Forest Management as adopted by the MCPFE Expert Level Meeting 7-8 October 2002, Vienna, Austria

MCPFE, 2003c: State of Europe's Forests: The MCPFE Report on Sustainable Forest Management in Europe. 2003. Ministerial Conference on Protection of Forests in Europe. Liaison Unit, Vienna, Austria.

McRoberts R.E., 2005: Estimation for small areas using maps based on forest inventory data and satellite imagery. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. (138): 284-292.

McRoberts R.E., Gormanson D.D., Hansen M.H., 2005: Can a land cover change map be used to increase the precision of forest inventory change estimates? Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. 2005; (138): 74-82.

McRoberts R.E., McWilliams W.H., Reams G.A., Schmidt T.L., Jenkins J.C., O'Neill K.P., Miles P.D. and Brand G.J., 2004: Assessing sustainability using data from the Forest Inventory and Analysis program of the United States Forest Service. Journal of Sustainable Forestry 18: 23-46.

McRoberts R.E., Nelson ,M.D., Wendt ,D.G., 2003: Stratified estimates of forest area using the k-Nearest Neighbors technique and satellite imagery. General-Technical-Report-North-Central-Research-Station,-USDA-Forest-Service. (NC-230): 80-86

Medellin R.A., Equihua M., Amin M.A., 2000: Bat diversity and abundance as indicators of disturbance in neotropical rainforests. Conservation-Biology. 2000; 14(6): 1666-1675

Meerschaut D., Vanden Vandekerkhove K., 1998: Development of a Stand-Scale Forest Biodiversity Index based on the State Forest Inventory. Integrated Tools Proceedings. Boise, Idaho, USa, August 16-20. p. 340-349.

Menhinick C.F., 1964: A comparison of some species – individuals diversity indices applied to samples of field insects. Ecology 45, s.859-861

Merganič J., Quednau H.D., Šmelko Š., 2004: Influence of Morphometrical Characteristics of Georelief on Species Diversity of Forest Ecosystems and its Regionalisation. European J. of Forest Research, 1, 123, p. 75-85

Merganič J., Šmelko Š., 2004: Quantification of tree species diversity in forest stands Model BIODIVERSS. European J. of Forest Research, 2, 123, p. 157-165

Merganič J., 2001: Regional forest survey with main emphasis on biodiversity quantification. Dissertation thesis, TU Zvolen, 176 S.

Meyer P.,1999b: Bestimmung der Waldentwicklungsphasen und der Texturdiversität in Naturwäldern. AFJZ 170 (10-11): 203-211.

Miller N.L., Kim-JinWon, Hartman R.K., Farrara J. 1999: Downscaled climate and streamflow study of the southwestern United States. Journal-of-the-American-Water-Resources-Association 35(6): 1525-1537

Mironga J.M., 2004: Biodiversity mapping in Kenya: the use of geographic information systems (GIS). Biodiversity-. 5(3): 16-25

Moisen G.G., Edwards T.C. Jr., 1999: Use of generalized linear models and digital data in a forest inventory of northern Utah. Journal-of-Agricultural,-Biological,-and-Environmental-Statistics. 4(4): 372-390

Molinari J., 1989: A calibrated index for the measurement of evenness. Oikos, 56: 319–326

Montes F., Caňellas I., Montero G., 2004: Characterisation of Coarse Woody Debris in Two Scots Pine Forests in Spain. EFI Proceedings 51: 171-180.

Motiejunaite J., Czyzewska K., Cieslinski S., 2004: Lichens - indicators of old-growth forests in biocentres of Lithuania and North-East Poland. Botanica-Lithuanica. 2004; 10(1): 59-74

Mpelasoka F.S., Mullan A.B., Heerdegen R.G., 2001: New Zealand climate change information derived by multivariate statistical and artificial neural networks approaches. International-Journal-of-Climatology 21(11): 1415-1433

Murphy J., 2000: Predictions of climate change over Europe using statistical and dynamical downscaling techniques. International-Journal-of-Climatology 20(5): 489-501

Nagendra H., 2001: Using remote sensing to assess biodiversity. Int. J. Remote Sensing 22(12): 2377–2400

NAGENDRA H., GADGIL M. 1999: Biodiversity assessment at multiple scales: Linking remotely sensed data with field information. Proc. Natl. Acad. Sci. USA Vol. 96, pp. 9154–9158

Nally R.M., Ellis M., Barrett G., 2004: Avian biodiversity monitoring in Australian rangelands. Austral-Ecology. 2004; 29(1): 93-99

NCEA, 2007: www.epa.gov/ncea/ROEIndicators

Neumann, M., Starlinger, F., 2001: The significance of different indices for stand structure and diversity in forests,

Nguyen VTV, Nguyen TD, Gachon P. 2006. On the linkage of large-scale climate variability with local characteristics of daily precipitation and temperature extremes: an evaluation of statistical downscaling methods. Advances in Geosciences (WSPC/SPI-B368) 4(16): 1-9.

Nilsson S.G., Hedin J., Niklasson M., 2001: Biodiversity and its assessment in boreal and nemoral forests. Scandinavian Journal of Forest Research. 2001; (Suppl.3): 10-26

Norddahlkirsch N.M., Bradshaw R.H.W., 2004: European Forest Types for Biodiversity Assessment – Quantitative Approaches. EFI Proceedings 51: 127-134.

Noss, R.F. 1999. Assessing and monitoring forest biodiversity: A suggested framework and indicators. Forest Ecology and Management. 115 (2-3): 135-146.

Noss R.F., 1990. Indicators for monitoring biodiversity - a hierarchical approach. Conservation Biology. 4 (4): 355-364.

Nuske R.S., Nieschulze J., 2005: Remotely sensed digital height models and GIS for monitoring and modeling ecological characteristics of forest stands. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. 2005; (138): 83-92.

Olsson H., Nilsson M., Hagner O., Reese H., Pahlen T.G, Persson A., 2005: Operational use of Landsat-/SPOT-type satellite data among Swedish forest authorities. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. (138): 195-203

Omule A.Y., Gillis M.D., 2005: Establishment of Canada´s National Forest Inventory: Approach and Issues. (McRoberts,R.E., Reams,G.A., Deusen,P.C., McWilliams,W.H., eds. 2005: Proceedings of the Fifth Annual Forest Inventory and Analysis Symposium, 2003 November 18-20, New Orleans, LA Gen Tech Rep. WO-69, Washington, DC, U.S. Department of Agriculture Forest Service, 222p.), USDA, 9-12

Ozdemir I., Asan U., Koch B., Yesil A., Ozkan U.Y., Hemphill S., 2005: Comparison of Quickbird-2 and Landsat-7 ETM+ data for mapping of vegetation cover in Fethiye-Kumluova coastal dune in the Mediterranean region of Turkey. Fresenius-Environmental-Bulletin. 14(9): 823-831

Payne J.T., Wood A.W., Hamlet A.F., Palmer R.N., Lettenmaier D.P., 2004: Mitigating the effects of climate change on the water resources of the Columbia River Basin. Climatic-Change 62(1/3): 233-256

Peet R.K., 1974: The measurement of species diversity. Ann. Rev. Ec. Sys. 5, s. 285-307

Penttila R., Siitonen J., Kuusinen M., 2004: Polypore diversity in managed and old-growth boreal Picea abies forests in southern Finland. Biological Conservation 117 : 271-283.

Pickett S.T.A., White P. S., 1985: The ecology of natural disturbance and patch dynamics. Academic Press, San Diego.

Pielou E.C., 1959: The use of point to plant distances in the study of the pattern of plant populations. J. Ecol. 47, 607-613

Pielou E.C., 1977: Mathematical Ecology. Willey, New York

Pielou E.C., 1975: Ecological Diversity. Wiley, New York

Pielou E.C., 1969: An introduction to mathematical ecology. Wiley, New York, 280 s.

Pommerening A., 2002: Approaches to quantifying forest structures. Forestry-Oxford. 75(3): 305-324

Prasad V.K., Rajagopal T., Yogesh-Kant, Badarinath K.V.S., 1998: Biodiversity studies using spectral and spatial information from IRS-1C LISS-III satellite data. Journal-of-Ecobiology. 10(3): 179-184

Pretzsch H., 1998: Struktural Diversity as a result of silvicultural operations. Lestnictví- Forestry, 44, 10, p. 429-439

Pretzsch H., 1996: Strukturvielfalt als Ergebnis Waldbaulichen Handels. AFJZ 167, p. 213-221

Prudhomme C, Jakob D., Svensson C., 2002: Impact of climate change on flooding in the UK: a methodology for estimating uncertainty. FRIEND-2002-regional-hydrology:-bridging-the-gap-between-research-and-practice-Fourth-International-Conference-on-FRIEND-Flow-Regimes-from-International-Network-Data,-Cape-Town,-South-Africa,-18-22-March-2002. pp. 109-116

Rahbek C, Graves G.R., 2001: Multiscale assessment of patterns of avian species richness. PNAS 98(8): 4534-4539. www.pnas.orgycgiydoiy10.1073ypnas.071034898

Rainio J., Niemela J., 2003: Ground beetles (Coleoptera: Carabidae) as bioindicators. Biodiversity-and-Conservation. 2003; 12(3): 487-506

Rajat-Bindlish, Barros A.P., 2000: Disaggregation of rainfall for one-way coupling of atmospheric and hydrological models in regions of complex terrain. Global-and-Planetary-Change. 2000; 25(1/2): 111-132

Ranius T., Kindvall O., Kruys N., Jonsson B.G., 2003: Modelling dead wood in Norway spruce stands subject to different management regimes. Forest-Ecology-and-Management. 182(1/3): 13-29

Ranius T., 2002: Osmoderma eremita as an indicator of species richness of beetles in tree hollows.Biodiversity-and-Conservation. 2002; 11(5): 931-941

Räty M., Kangas A., 2007: Localizing general models based on local indices of spatial association. Eur J Forest Res (2007)126:279 –289

Rautjarvi N., Luquea, S., Tomppo E., 2005: Mapping spatial patterns from National Forest Inventory data: a regional conservation planning tool. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. (138): 293-302

Reese H., Nilsson M., Granqvist P.T., Hagner O., Joyce S., Tingelöf U • Egberth M., Olsson H., 2003: Countrywide Estimates of Forest Variables Using Satellite Data and Field Data from the National Forest Inventory Ambio 542 – 548.

Rego F., Godinho-Ferreira P., Uva J.S., Cunha J., 2004: Combination of structural and compositional factors for describing forest types using National Forest Inventory data. EFI-Proceedings. (51): 153-162

Riitters K. H., 2005: Downscaling indicators of forest habitat structure from national assessments. Ecological Indicators 5: 273–279

Riitters K., Wickham J., Coulston J., 2004: Use of road maps in national assessments of forest fragmentation in the United States. Ecology and Society 9(2): 13. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art13

Riitters K.H., Wickham J.D., O'Neill R.V., Jones K.B., Smith E.R., Coulston J.W., Wade T.G. and Smith J.H., 2002. Fragmentation of Continental United States Forests, Springer Verlag, ECOSYSTEM (2002) 5: 815-822, DOI: 10.1007/s10021002-0209-2

Roberge J.M., Angelstam P., 2006: Indicator species among resident forest birds - a cross-regional evaluation in northern Europe. Biological-Conservation. 2006; 130(1): 134-147

Rosendal G. K., 2000. Convention on biological diversity: a viable instrument for conservation and sustainable use? Yearbook of International Cooperation on Environment and Development 1995: 69-81.

Roy P.S, Hitendra-Padalia, Nidhi-Chauhan, Porwal M.C., Gupta S., Biswas S., Jagdale R., 2005: Validation of geospatial model for Biodiversity Characterization at Landscape Level - a study in Andaman & Nicobar Islands, India. Ecological-Modelling. 185(2/4): 349-369

Roy P.S., Behera M.D., 2002: Biodiversity assessment at landscape level. Tropical Ecology 43(1): 151-171

Roy P.S., Sanjay-Tomar, 2000: Biodiversity characterization at landscape level using geospatial modelling technique. Biological-Conservation. 95(1): 95-109

Sanders H.L., 1968: Marine benthic diversity: a comparative study. Am. Natur., 102: 243–282

Schardt M., Grancia K., Hischmugl M., Luckel H.W., Klaushofer F., 2005: Mapping Protection Forests in the Province of Salzburg Using Remote Sensing. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. 2005; (138): 204-213.

Scheer L., Sitko R., 2005: Growing stock assessment and regionalization employing IKONOS satellite data. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. (138): 303-311

Schieler K., Hauk E., 2001: Instruktion für die Feldarbeit, Österreichische Waldinventur 2000/2002 Dienstanweisung. FBVA Wien, 99-101.http://web.bfw.ac.at/700/pdf/ da_ges_neu.pdf (2.3.2006)

Schmidli J., Goodess C. M., Frei C., Haylock M. R., Hundecha Y., Ribalaygua J., and Schmith T., 2007: Statistical and dynamical downscaling of precipitation: An evaluation and comparison of scenarios for the European Alps, J. Geophys. Res., 112, D04105, doi:10.1029/2005JD007026.

Schmidt M., Kreft H., Thiombiano A., Zizka G., 2005: Herbarium collections and field data-based plant diversity maps for Burkina Faso. Diversity-and-Distributions. 11(6): 509-516

Schmit J.P., Mueller G.M., Leacock P.R., Mata J.L., Wu Q.X., Huang Y.G., 2005: Assessment of tree species richness as a surrogate for macrofungal species richness. Biological-Conservation. 2005; 121(1): 99-110

Schoof J.T., Pryor S.C., 2001: Downscaling temperature and precipitation: a comparison of regression-based methods and artificial neural networks. International-Journal-of-Climatology 21(7): 773-790

Schuck A., Meyer P., Menke N., Lier M., Lindner M., 2004: Forest biodiversity indicator: dead wood - a proposed approach towards operationalising the MCPFE indicator. EFI-Proceedings. (51): 49-77

Seem R.C., 2004: Forecasting plant disease in a changing climate: a question of scale. Canadian-Journal-of-Plant-Pathology 26(3): 274-283

Shannon C., Weaver W., 1949: The Mathematical Theory of Communication. University of Illinois Press. Urbana. Illinois

Shannon C. E, 1948: In: Shannon C.E., Weaver W. (Eds): The Mathematical Theory of Communication. University of Illinois Press, Urbana and Chicago, 125 pp.

Sheldon A.L., 1969: Equitability indices: dependence on the species count. Ecology, 50, s. 466 – 467

Simila M., Kouki J., Monkkonen M., Sippola A.L., Huhta E., 2006: Co-variation and indicators, of species diversity: Can richness of forest-dwelling species be predicted in northern boreal forests ? Ecological Indicators 6 : 686-700.

Simpson E.H., 1949: Measurement of diversity. Nature 163, s. 688

Sim-Sim M., Carvalho S., Fontinha S., Lobo C., Esquivel M.G., Figueiredo A.C., 2004: Diversity of bryophytes - useful indicators of Madeira Laurel forest conservation. EFI-Proceedings. 2004; (51): 247-257

Skånes H.M. & Bunce R.G.H. 1997. Directions of landscape change (1741-1993) in Virestad, Sweden - characterised by multivariate analysis. Landscape and urban planning. 38 (1-2): 61-75.

Sobek E.A, Zak J.C., 2003: The Soil FungiLog procedure: method and analytical approaches toward understanding fungal functional diversity. Mycologia-. 95(4): 590-602

Söderberg U., Fridman J., 1998: Monitoring of Forest Biodiversity from Forest resource Inentory Data. Assessment-of-biodiversity-for-improved-forest-planning-Proceedings-of-the-conference-on-assessment-of-biodiversity-of-improved-forest-planning,-7-11-October-1996,-Monte-Verita,-Switzerland. 1998; 233-240.

Spak S., T. Holloway, Lynn B. and Goldberg R., 2007: A comparison of statistical and dynamical downscaling for surface temperature in North America, J. Geophys. Res., 112, D08101, doi:10.1029/2005JD006712.

Speight M.C.D., 1989: Les invertébrés saproxyliques et leur conservation. Conseil de l'Europe, Strasbourg (France). 69 p.

Stofer S., 2006: Working Report ForestBIOTA - Epiphytic Lichen Monitoring. http://www.forestbiota.org/

Stokland J.N., Tomter S.M., Söderberg U., 2004: Development of Dead Wood Indicators for Biodiversity Monitoring: Experiences from Scandinavia. EFI Proceedings: 207-228.

Stokland J.N., Eriksen R., Tomter S.M., Korhonen K., Tomppo E., Rajaniemi S., Söderberg U., Toet H., Riis Nielsen T., 2003: Forest biodiversity indicators in the Nordic countries. Status based on national forest inventories. TemaNord, Copenhagen. 108 pp.

Strand L., 1953: Mal for fordelingen av individer over et omrade. Det Norske Skogforsoksvesen 42, 191-207

Suchant R., 2001: Wie kann Vielfalt im Wald gemessen werden? AFZ/Der-Wald,-Allgemeine-Forst-Zeitschrift-fur-Waldwirtschaft-und-Umweltvorsorge. 2001; 56(20): 1053-1055

Suchant R., Baritz R., 2001: A species-habitat-model for the improvement and monitoring of biodiversity in modern ecological silviculture - Capercaillie (Tetrao urogallus) in the Black Forest. EFI-Proceedings. 2001; (38): 109-122

Sunar F., Özkan C., 2001: Forest fire analysis with remote sensing data. Int. J. Remote Sensing 22(12): 2265–2277

Sverdrup-Thygeson A., 2001: Can 'continuity indicator species' predict species richness or red-listed species of saproxylic beetles? Biodiversity-and-Conservation. 2001; 10(5): 815-832

Tabaku V., 2000: Struktur von Buchen-Urwäldern in Albanien im Vergleich mit deutschen Buchen-Naturwaldreservaten und -Wirtschaftswäldern. Cuvillier Verlag, Göttingen, 206 S.

Tatl H., Dalfes H.N., Mentes S.S., 2004: A statistical downscaling method for monthly total precipitation over Turkey. International-Journal-of-Climatology 24(2): 161-180

Thomas J.A., 2005: Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. Philosophical-Transactions-of-the-Royal-Society-of-London-Series-B,-Biological-Sciences. 2005; 360(1454): 339-357

Thompson M.W, Whitehead K., 1992: An overview of remote sensing in forestry and related activities: its potential application in South Africa. South-African-Forestry-Journal. (161): 59-68

Thormann M.N., 2006: Lichens as indicators of forest health in Canada. Forestry-Chronicle. 2006; 82(3): 335-343

Tilman D., Reich B., Knops J., Wedin D., Mielke T. and Lehman C. 2001: Diversity and productivity in a long-term grassland experiment. Science 294: 843-845.

Toivonen T., 2005: Managing and analysing observational data using GIS and remote sensing. In: Sarvala M., Vieno M., Toivonen T. (eds.): Observations on Observational Biodiversity Data. UTU-LCC Publications 9:.56-65

Tomppo E., 1986: Models and methods for analysing spatial patterns of trees. Communicationes Instituti Forestalis Fenniae, 138, 65 pp.

Travaglini D., Barbati A., Chirici, G., Lombardi F., Marchetti M., Corona P., 2007: ForestBIOTA data on deadwood monitoring in Europe. Plant Biosystems 141(2): 222-230.

Tuominen S, Haakana M., 2005: Landsat TM imagery and high altitude aerial photographs in estimation of forest characteristics. Silva-Fennica. 39(4): 573-584

Tuominen S, Pekkarinen A., 2005: Performance of different spectral and textural aerial photograph features in multi-source forest inventory. Remote-Sensing-of-Environment. 94(2): 256-268

Tuominen S., Fish S., Poso S., 2003: Combining remote sensing, data from earlier inventories, and geostatistical interpolation in multisource forest inventory. Canadian-Journal-of-Forest-Research. 33(4): 624-634

Turner W., Spector S., Gardiner N., Fladeland M., Sterling E., Steininger M., 2003: Remote sensing for biodiversity science and conservation. TRENDS in Ecology and Evolution 18(6): 306-314

Uliczka H., 2003: Forest biodiversity maintenance. Acta-Universitatis-Agriculturae-Sueciae-Silvestria. 2003; (291): 40 pp.

UN-ECE/FAO, 2000: Forest Resources of Europe, CIS, North America, Australia, Japan and New Zealand. UN-ECE/FAO Contribution to the Global Forest Resources Assessment 2000. Main report, Geneva Timber and Forest Study Papers, no. 17. New York and Geneva, 2000, 445 p.

UNEP (United Nations Environment Programme), 2001: Indicators and environmental impact assessment: Designing national-level monitoring and indicator programmes, UNEP/CBD/SBSTTA/7/12, Subsidiary body on scientific, technical and technological advice (http://www.biodiv.org/doc/meetings/sbstta/sbstta-07/official/sbstta-07-12-en.pdf).

UNEP (United Nations Environment Programme), 2003a: Proposed biodiversity indicators relevant to the 2010 target. UNEP/CBD/SBSTTA/9/INF/26.

UNEP (United Nations Environment Programme), 2003b: Recommendation IX/13. UNEP/CBD/SBSTTA/IX/13. Montreal.

UNEP (United Nations Environment Programme), 2004: Implementation of the strategic plan: evaluation of progress toward the 2010 biodiversity target: development of specific targets, indicators and a reporting framework. UNEP/CBD/COP/7/20/add 3. Montreal.

Uuttera J, Hyppanen H., 1998: Determination of potential key-biotope areas in managed forests of Finland using existing inventory data and digital aerial photographs. Forest-and-Landscape-Research. 1(5): 415-429

Veerkamp M.T., 2003: The importance of large dead beech wood for fungi. Nederlands-Bosbouwtijdschrift. 75(5): 10-14.

Vidal, C., Lanz, A., Tomppo, E., Schadauer, K., Gschwantner, T., di Cosmo, L., & Robert, N. (2008). Establishing forest inventory reference definitions for forest and growing stock: a study towards common reporting. Silva Fennica, 42, 247-266.

Virkkala R., 2006: Why study woodpeckers? The significance of woodpeckers in forest ecosystems. Annales-Zoologici-Fennici. 2006; 43(2): 82-85

Vogt P., Riitters K.H., Estreguil C., Kozak J., Wade T.G., Wickham J.D., 2007a: Mapping spatial patterns with morphological image processing. Landscape Ecol. 22: 171-177.

Vogt P., Riitters K.H., Iwanowski M., Estreguil C., Kozak J., Soille P. 2007b: Mapping landscape corridors. Ecological Indicators 7: 481–488

Wack R., Oliveira T., 2005: Analysis of vertical vegetation structures for fire management by means of airborne laser scanning. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. 2005; (138): 127-135.

Wallerman J., 2003: Remote sensing aided spatial prediction of forest stem volume. Acta-Universitatis-Agriculturae-Sueciae-Silvestria. (271): 42 pp. + Papers I-IV

Waring H.R. and Running S.W., 1998: Forest Ecosystems. Analysis at Multiples Scales. 2nd edition. Academic Press, San Diego.

Wezyk P., Tracz W., Guzik M., 2005: Evaluation of landscape structure changes iN Tatra Mountains (Poland) based on 4D GIS analysis. Schriften-aus-der-Forstlichen-Fakultat-der-Universitat-Gottingen-und-der-Niedersachsischen-Forstlichen-Versuchsanstalt. 2005; (138): 224-232.

Whittaker R.H. (1972) Evolution and measurement of species diversity. Taxon, 21, 213-251

Wilby R.L., Hay L.E., Leavesley G.H., 1999: A comparison of downscaled and raw GCM output: implications for climate change scenarios in the San Juan River basin, Colorado. Journal-of-Hydrology-Amsterdam 225(1/2): 67-91

Winter S., 2005: Ermittlung von Struktur-Indikatoren zur Abschätzung des Einflusses forstlicher Bewirtschaftung auf die Biozönosen von Tiefland-Buchenwäldern. Diss. TU Dresden, 322 S. see http://hsss.slub-dresden.de/documents/1129722204456-7612/1129722204456-7612.pdf.

Winter S., Chirici G., McRoberts R.E., Hauk E., Tomppo E., 2008. Possibilities for harmonizing national forest inventory data for use in forest biodiversity assessments. Forestry, 81: 33-44.

Wood A.W., Leung L.R., Sridhar V., Lettenmaier D.P., 2004: Hydrologic implications of dynamical and statistical approaches to downscaling climate model outputs. Climatic-Change. 2004; 62(1/3): 189-216

Woodall C., Williams M.S., 2005: Sampling protocol, estimation, and analysis procedures for the down woody materials indicator of the FIA program. General-Technical-Report-North-Central-Research-Station,-USDA-Forest-Service. (NC-256): iii + 47 pp.

Zenner E.K., Hibbs D.E., 2000: A new method for modeling the heterogeneity of forest structure. Forest Ecology and Management 129: 75-87

Zenner E.K., 1999: Eine neue Methode zur Untersuchung der Dreidimensionalität in Waldbeständen. Universität Freiburg, 11 pp.

Zukrigl K., 1995: Ergebnisse der Naturwaldforschung in Oesterreich : Tagung der ostalpin-dinarischen Gesellschaft fuer Vegetationskunde 1992 in Grafenau (Bayrischer Wald) BRD und Neukirchen am Grossvenediger, Salzburg 1993 (Tagungsbeiträge der Tagung der ostalpin-dinarischen Gesellschaft für Vegetationskunde 1992 in Grafenau und der 7. Österreichischen Botanikertagung 1993 in Neukirchen am Großvenediger; Bd. Nr. 6.- Salzburg : Abakus Verlag, 1995. - 236 S. - Band: Nr. 6 - S. 133-138 [In: Sauteria: Schriftenreihe für systematische Botanik, Floristik und Geobotanik ; 6]) (Sauteria).

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Abstract

The project "Use of National Forest Inventories to downscale European forest diversity spatial information in five test areas, covering different geo-physical and geo-botanical conditions", referred also as "forest downscaling" (JRC contract 382340 F1SC) covers one of the seven topics that have been studied in the frame of the Regulation (EC) 2152/2003 on the monitoring of forest and environmental interactions, the so-called "Forest Focus" Regulation.

This study was conducted by a European consortium coordinated by the Italian Academy of Forest Sciences (Italy) and included partners from the Swedish University of Agricultural Sciences, the Institute of Forest Ecosystem Research of the Czech Republic, the German Federal Research Centre for Forestry and Forest Products, and the Swiss Federal Institute for Forest, Snow and Landscape Research. The overall supervision of the project and the processing of forest spatial pattern were done by the Joint Research Centre.

This study addressed the link between field based forest biological diversity data and landscape-level forest pattern information. The former were made available from National Forest Inventories (NFIs) at plot level in five different countries; their harmonisation was implemented for the first time and benefited from outcomes of the COST Action-E43 on core biodiversity variables. For the latter, landscape level forest spatial pattern maps were automatically derived from available remote sensing based forest cover maps. The relation-ships between selected pattern and biodiversity variables available from the two different data sources were studied.

Seven case studies for a total area of about 100,000 km2 were selected in five European ecological regions: one site in Germany (Atlantic zone), one in Sweden (Boreal zone), two in Czech Republic (Continental zone), one in Switzerland (Alpine zone) and two in Italy (Mediterranean zone).

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