Assessing and monitoring the status of biodiversity-related aspects in Flemish forests by use of the Flemish forest inventory data

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Abstract
Ecological aspects are increasingly influencing silvicultural management. Estimating forest biodiversity has become one of the major tools for evaluating management strategies. A standardised and practical methodology was developed for the monitoring of some important aspects for biodiversity in forests on a stand-scale level. The scoring system was conceived in such way that it should be applicable to the forest inventory dataset for Flanders (Belgium). Only these aspects that are both easily measurable and susceptible to changes through silvicultural measures, such as stand structure and dead wood amounts, are included. Other important aspects for forest biodiversity like forest history, size and connectivity are not included.
Therefore the index is not described as a 'biodiversity index' but as an 'authenticity index', as defined by Dudley (1996): 'a reflection of the extent to which a forest corresponds to a naturally functioning forest in terms of composition and ecology', and thus a measure for 'potential biodiversity'.

Test calculations were performed and proved the index to be sensitive to changes due to management and to be reflecting the actual structural and compositional diversity of forest stands.
Through automatic calculation, the index values could be produced for the complete data set of the forest inventory. This lead to authenticity values for over 1300 plots, giving a general impression of the status of some important elements for forest biodiversity in the Flemish forests.
The total value of the index and the values of the subindices are discussed. The overall 'authenticity' value of the Flemish forests is low and confirms certain general shortcomings of the forests towards biodiversity. Nevertheless, for almost every indicator a maximum value could be reached for at least one plot, indicating that the index is not too strict.
Further preliminary analysis of relationships of the index with forest history, soil texture type and type of ownership were performed. The results point out that ancient woodlands and forests on richer soils generally have slightly higher index values, while ownership seems to have no influence on the index.
The authenticity index proves to be a powerful and practical tool for evaluation and monitoring of the future development of the Flemish forest as far as important aspects for biodiversity are involved, through its direct link to the forest inventory.

Keywords: authenticity, biodiversity evaluation tool, index, forest inventory.

1. Introduction

Forest ecosystems are very important in the preservation of biological diversity. The engagements taken at the UNCED (CBD) and a number of European initiatives like Helsinki Resolution 2, Pan-European Biological and Landscape Diversity Strategy (PEBLDS) have lead to the 'European Work Programme on the Conservation and Enhancement of Biological and Landscape Diversity in Forest Ecosystems (WP-CEBLDF). First objective of this work programme is to identify indicators for evaluation of biodiversity in forest ecosystems both on national and sub-national level.

The Flemish Government also committed herself to fulfil the obligations on biodiversity conservation in forests. Therefore there is a definite need for tools to monitor the overall performance of this policy towards forest biodiversity.
Direct assessment of this performance through monitoring of species richness is labour intensive, time consuming and requires specialist knowledge, which makes it inapplicable on a large scale.
An alternative approach consists of the use of sets of biological and / or structural indicators.
Larsson et al. (2001) suggest to link the monitoring of forest biodiversity to the national forest inventories, as these inventory programmes are especially designed to reflect changes in the status of

selected indicators. Moreover, the integration of biodiversity aspects into forest inventory programmes has become an important issue recently.
In this study the development of an evaluation index for forest biodiversity on the level of a forest stand is intended, based on available data on forest structure and floral species composition from the Flemish forest inventory.
The presented authenticity index covers easily measurable features of forest structure, woody and herbal layer composition and dead wood, serving as indicators for biodiversity. The concept of the index and its indicators is based on a virtual image of the authentic structure and composition of primary natural forest ecosystems. It is conceived under the assumption that a varied and complex forest structure induces a high biological richness due to the creation of a diversity of niches (Altenkirch 1988, Franklin 1988). As this index should serve as a monitoring tool to evaluate the impact of forest management on biodiversity, a high sensitivity to silvicultural measures is necessary. This requirement excludes other important aspects determining forest biodiversity like site history, connectivity, forest area, site condition, etc. (Van Den Meersschaut and Vandekerkhove 2000).

2. Methods

2.1. The Flemish Forest Inventory

The forest inventory of the Flemish Region is based on a systematic sampling technique using a geo-referenced grid of 1 × 0,5 km (Waterinckx and Haelvoet 1997). Due to a low forest index of 10 % and a high degree of fragmentation, a limited number of intersections of the grid are actually situated in forest, resulting in 2665 plots.

A forest inventory plot consists of a general description of the stand, combined with measurements of the woody layer. The herbal layer is recorded in half of the plots (1331 plots), widening the grid to 1 x 1 km.
The general stand description includes figures on stand type (high forest, coppice with standards, coppice), estimated or recorded age of the stand, canopy closure (1/3, 1/3-2/3, >2/3), vertical stand structure (one storey, multi-storey) and horizontal stand structure (homogeneous, group-mixed / line-mixed or individually mixed).
The woody layer is sampled by a nested plot design of 4 concentric circular sample units (A1, A2, A3 and A4) with a variable radius (R1, R2, R3 and R4) according to the dimension of trees and shrubs (FIGURE 1).
In circles A1 and A2, respectively seedlings and shrubs / small trees are sampled. Species and stem number are recorded. Trees over 7 cm DBH are sampled in A3: species is recorded, DBH and height are measured and the individual trees are positioned using polar co-ordinates. For trees over 40 cm DBH, the circular plot A4 is sampled, and similar measurements as in A3 are performed. These measurements apply to living as well as dead standing trees (snags).
The herbal layer is sampled on the same place using a 16 × 16 m square plot. All vascular plants and mosses are identified and their cover is estimated using an adapted version of the Braun-Blanquet scale (Barkman et al. 1964).
Within the herbal layer plot, special attention is given to the lying dead wood (logs). Logs are divided into 4 diameter classes (2 to 7 cm, 7 to 22 cm, 22 to 40 cm and more than 40 cm). Density and stem length of the logs are estimated for respectively the first and last two classes (Waterinckx and Haelvoet 1997, Afdeling Bos & Groen 2001b).
The data used in this study originate from the first forest inventory, collected during the period 1997-2000. The Flemish forest inventory will be repeated every ten years.

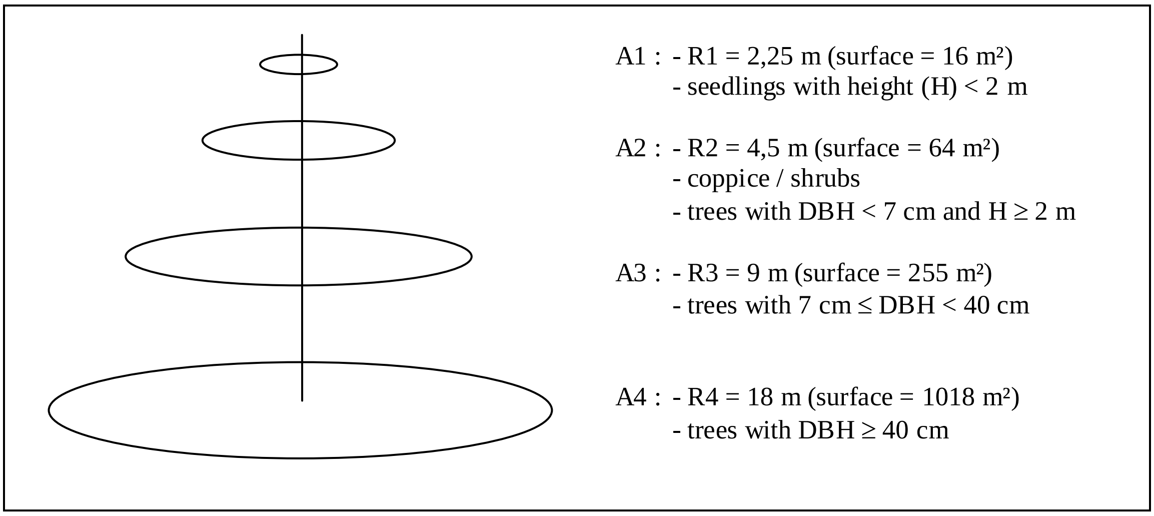

FIGURE 1. Plot design for the inventory of the woody vegetation consisting of concentric circular sample units (A1-4) with variable radius (R1-4) (after Waterinckx and Haelvoet (1997)).

2.2 Elaboration of the index

The index is composed of four aspects (subindex):

- stand structure (vertical and horizontal);
- species composition of the tree and shrub layer;
- species composition of the herbal layer;
- dead wood elements (standing and lying coarse woody debris).

Each subindex consists of a set of indicators derived from the available data of the Flemish forest inventory. The indicators are given a score using the ‘Delphi technique’, which stipulates that, as long as biodiversity cannot be unambiguously measured in the field, biodiversity indicators and their weights or scores can be determined on the basis of a common agreement of different specialists (Alho et al. 1996, Dalkey and Helmer 1962, Kangas et al. 1993).

During application of this technique, special attention is given to evenly balancing the weights of the different indicators, presuming that their contribution to biodiversity is more or less equal. The maximum score of the index is set to 100. TABLE 1 gives a detailed overview of the score system with its indicators and their weights. For the indicators of woody and herbal layer composition and dead wood, the classification of the numbers and maximum values is based on analysis of elaborate data sets from the Flemish forest reserve inventory, in which sample plots of comparable size are used (Van Den Meersschaut et al. 1996, Vanmechelen et al. 1997, Viaene et al. 1997), in order to provide realistic cut-off levels.

Habitat complexity and structural heterogeneity are generally recognised as important indicators for forest biodiversity (Köhl 1995, Noss 1990, Rune 1997, Schuck et al. 1994). The forest structure indicators in this study, are based on a qualitative description of characteristics of the stand in which a sample plot is located. These characteristics consist of canopy closure or cover, stand age, number of storeys and spatial tree species mixture. Woody layer, herbal layer and dead wood are also part of what can be called forest structure, but are treated separately, because they are based on actual measurements.

TABLE 1. Overview of the scoring system of the authenticity index based on the forest inventory data.

FOREST STRUCTURE	Score	WOODY LAYER	Score	HERBAL LAYER	Score	DEAD WOOD	Score
Canopy closure		**Number of tree**		**Number of plant**		**Basal area snags**	
> 2/3 of the area	2	**species**		**species**		**(m²/ha)**	
1/3-2/3 of the area	4	0	0	0	0	0	0
<1/3 of the area	3	1-2	1	1-5	1	< 2	1
		3-4	2	6-10	2	2 – 3,5	2
Stand age (years)		5-6	3	11-15	3	3,6 – 5	3
Clearcut area	0	7-8	4	16-20	4	> 5	4
1-60	1	> 8	5	21-25	5		
61-100	2	exotic species	(1)	26-30	6	**Number of large**	
101-160	5			31-35	7	**snags (>40cm)**	
Uneven aged (<160)	5	**Number of large**		35-40	8	0	0
Overmature stands (>160)	7	**trees (DBH >40 cm)**		41-45	9	1	3
(even- and uneven-aged)		0	0	>45	10	2-3	4
		1-5	1			>3	5
Number of storeys		6-10	2	**Degree of rareness**			
Clearcut area	0	11-15	3	0	0	**Stand. deviation**	
1	2	16-20	4	1-5	1	**on DBH snags**	
> 1	4	> 20	5	6-10	2	<10	0
				11-15	3	10-15	1
Spatial tree species		**Number of very**		16-20	4	16-20	2
mixture		**large trees (>80 cm)**		21-25	5	21-25	3
Clearcut area	0	0	0	26-30	6	26-30	4
Homogeneous	1	1	3	>30	7	31-35	5
Clustered	3	2-3	4			>35	6
Individual	5	> 4	5	**Number of**			
				bryophytes		**Total stem length**	
		Number of		0	0	**logs (in plot) (m)**	
		indigenous species		1-5	1	0	0
		in nat. Regeneration		6-10	2	1-10	3
		0	0	11-15	3	11-20	5
		1-4	1	16-20	4	>20	7
		5-8	2	> 20	5		
		9-12	3			**Number of DBH-**	
		>12	4	**Total cover (%)**		**classes**	
				0	0	0	0
		Stand. Deviation of		1-25	1	1	2
		DBH (cm)		26-50	2	2	4
		<10	0	51-75	3	3	6
		10-15	1	> 75	1	4	8
		16-20	2			If class 4 present	+1
		21-25	3				
		26-30	4				
		31-35	5				
		> 35	6				
MAXIMUM SCORE :	20		25		25		30

(1) *if basal area or stem number of exotic species is < 5% of the total for all species, the exotic species are accounted; if coverage is 5-50% they are not accounted; if they cover >50% the score for this subindex is subtracted by 1.*

The indicators for the diversity of the woody layer (number of tree species, number of large and very large trees, number of indigenous tree species in natural regeneration and standard deviation of DBH), are all based on measurements in the circular sample plots. Mixed forest stands will accommodate more animal and plant species than single species stands. Exotic tree species may also make contribution here. because of a certain, nevertheless limited, amount of organisms related to them (Kennedy and Southwood 1984).A small amount of exotic species intermixed in an indigenous stand can indeed produce a higher overall species richness. However, if their share increases and they start dominating the stand and competing with native species, their influence on biodiversity is negative. Exotic tree species are therefore only taken into account provided that their proportional share in the total basal area or stem number is less than 5 percent. If their proportional share amounts between 5 and 50 percent, they are not accounted. If it exceeds 50 percent, they are negatively accounted. The idea to positively score exotic species when they are not dominating is quite controversial but not new : a similar principle is also applied by Hekhuis et al. (1994), Standovar (1997) and Rune (1997).

Large trees (40 ≤ DBH < 80 cm), irrespective of the species, create important niches for invertebrates, birds, mammals, fungi and epiphytes, thus contributing to biodiversity. This contribution is even bigger for very large trees (DBH ≥ 80 cm). Very large trees normally occupy a larger growth area, which automatically results in a limited number per sample plot. Both facts explain why large and very large trees are separately scored. In this subindex, no distinction is made between indigenous and exotic tree species because tree size is a purely structural parameter making the identity of a species of minor importance.

In the total score however, large indigenous trees will have a higher overall input on the score (scoring high on both structure and species) than large exotic trees.

The influence of natural regeneration of indigenous tree species on current biodiversity is probably rather limited. Regeneration diversity is mainly of interest for future biodiversity. However, because of its sensitivity for silvicultural measures, it is an important parameter for evaluating the impact of forest management on future biodiversity (Bradshaw and Lindén 1997).

Variation in stem diameter and the occurrence of different succession stages in a forest stand are often associated with a high degree of biodiversity (Esseen et al. 1992). The standard deviation of stem diameter is an important mode to express this variation (Bradshaw and Lindén 1997). The calculations are performed for trees with DBH ≥ 7 cm.

Diversity and degree of rareness of vascular plants, diversity of non-epiphytic bryophytes and proportional cover of both are used as indicators of biodiversity for the herbal layer.

Floral diversity is considered to have a major impact on faunal diversity. Plants are also very sensitive to silvicultural measures influencing biodiversity. They are easy to inventory and identify, which makes them suitable to serve as indicators. In this indicator all plant species are treated likewise for scoring floral diversity.

The pure quantitative approach for determining floral diversity is supplemented by a qualitative aspect, which takes into account the degree of rareness of the plants. The degree of rareness is based on the occurrence of a species in a geo-referenced grid of 4 × 4 km using a logarithmic frequency distribution (Stieperaere and Fransen 1982). Calculation of the score is explained in Van Den Meersschaut and Vandekerkhove (2000).

Bryophytes also contribute to biodiversity and react even faster to changing environmental conditions than vascular plants (Biernath and Roloff 1993, Roloff and Stetzka 1995). Non-epiphytic bryophyte diversity per area unit is usually smaller than vascular plant diversity. The maximum score is therefore set to a smaller number of bryophyte species.

Spatial variation in proportional cover of the herbal layer contributes to biodiversity (Bradshaw and Lindén 1997). A cover of 50 percent theoretically offers the biggest chance on maximum variation. Chances for equal variation are the same for a cover of 25 and 75 percent. Because the latter is usually related to an increased biomass, it scores higher. Plant biomass plays an important role in the food chain of an ecosystem, thus influencing diversity.

The importance of dead wood for conservation of biodiversity in forest ecosystems is generally acknowledged. The importance of dead wood quantity, occurrence, size and shape diversity and status of decomposition are stressed in relation to specialised invertebrates, fungi and cavity nesting animals. Snags and logs create different niches to which certain organisms are adapted, and are therefore treated separately in this study. From the available data in the Flemish forest inventory, it is possible to calculate basal area, number of large trees and standard deviation of DBH of the snags and total stem length and number of diameter classes of the logs.

The amount of standing dead wood is expressed in absolute units of basal area.

Large snags (DBH ≥ 40 cm) are usually associated with a high diversity of species, including numerous specialised and rare species (Hekhuis et al. 1994, Rauh 1993, Siitonen and Martikainen 1994). Because of their importance and relative rareness the occurrence of a single snag receives a high score.

The standard deviation of stem diameter is an important mode to express the variation in size of standing dead wood. As for the living aspect of the woody layer, the calculations are performed for trees with DBH ≥ 7 cm.

The information provided by the forest inventory on the occurrence of lying dead wood is limited: only the occurring diameter classes are registered, as well as the total estimated stem length of larger logs (DBH ≥ 22 cm). The diameter classes of the logs are the same as used in the Flemish forest inventory. These classes are used to indicate variation in lying dead wood. The occurrence of class 4 with the largest logs is extra rewarded.

2.3. Test calculations of the index

After the elaboration of the index, the resulting scoring system is tested on its consistency (does the index value reflects the actual stand diversity) and its sensitivity to changes in management.

A first data set is used to check if and to what extent the calculated index values reflect site and structural variability of forests in Flanders. It includes 20 sample plots (from the Flemish forest inventory and the forest reserves network) covering the major variability of forest stands and sites in Flanders, from young homogeneous conifer plantations to old mixed deciduous forests with a rich forest structure and species composition. A second data set was used to test if the index is sensitive enough to indicate changes for monitoring purposes. As it was not possible to test changes of one site over time, a location was selected where different forest types on similar site conditions are present (homogeneous young pine stands to mixed oak-birch stands), thus reflecting the different stand types that can be created through management on these particular site conditions.

2.4. Automatic calculation of the index values for the forest inventory dataset

A programme was written (Visual Basic) to automatically calculate the authenticity index for all the forest inventory plots. The scores for the separate indicators and the total score are saved in an Access-table linking the index value to other data of the forest inventory.

The calculation of the indicators for forest structure and woody layer composition is made for all the plots (2665) with general stand description and measurements of the woody layer, while the calculation of herbal layer composition, dead wood and the total value are only possible for the plots in which also vegetation characteristics were sampled (1331 plots).

After calculation, the index values for Flanders are further analysed. Other very important factors influencing biological diversity, such as forest history and site type were specifically not taken into account in the calculation, because they cannot be changed by forest management and are therefore not useful for monitoring changes and effects of management (Van Den Meersschaut and Vandekerkhove 2000, Vandekerkhove et al. 2001).

Still they are analysed for every plot and confronted with the authenticity index and subindices values. For every plot soil texture type and land use history have been examined, using GIS layers of the plot locations, digital soil map and digital forest history map. The complexity and possible interaction with other (unknown) influencing factors however, inhibit the detection of a univocal relationship between these factors and the index.

It is a general belief that public forests are ecologically better managed than private forests. Since the type of ownership (public / private) of every forest plot is known, it is possible to investigate these assumptions with the results from the authenticity index.

A careful approach towards these results is required. The results have not yet been reviewed in-depth, so only general trends can be concluded.

3. Results and discussion

3.1 Consistency and sensitivity

A description of the stands and their scores for the different subindices and the authenticity index are given in TABLES 2 and 3.

The calculated index values for data set 1 reflect the variability in stand composition in a logical way, when the values are ranked in an increasing order. The difference between extreme values amounts to 1/3 of the maximum score, allowing enough space for sound distinctions of diversity status between stands. None of the stands reaches half of the maximum score, though some have a quite high score for one or more of the subindices. The index values for all of the selected stands can still significantly increase, parallel to an improved stand development towards a more semi-natural optimum. The dead wood aspect, for example, is systematically low, indicating its inferior role in general forest management in the past.

TABLE 2. General description and index scores for the forest stands of data set 1.

Forest stand	Description	Scores				
		Forest structure	Woody layer	Herbal layer	Dead wood	Total
Zoniën13	very old Beech stand mixed with oak	16	12	11	9	**48**
Zoniën1	very old Beech stand	18	13	7	8	**46**
Meerdaal7	old oak stand mixed with Hornbeam / Sycamore	18	14	11	3	**46**
Parike1	mature poplar stand, rich understorey and herb layer	18	10	11	6	**45**
Neigembos5	old Beech stand mixed with oak / Ash	16	12	9	3	**40**
Zoniën27	old mixed stand of Beech, oak and Ash	16	6	11	3	**36**
84097	relatively old alder stand, rich herb layer	17	4	13	2	**36**
178132	mixed birch stand, rich herb layer	14	3	13	5	**35**
Neigembos6	young Ash stand mixed with alder / willow	18	4	13	0	**35**
Neigembos4	old Beech stand mixed with oak	14	11	5	5	**35**
317103	very young oak stand mixed with chestnut	11	3	13	4	**31**
257003	young, open homogeneous Scots pine stand	10	6	10	5	**31**
318113	young homogeneous oak stand	6	1	13	2	**22**
Jagersborg24d	young stand with Scots / Corsican pine clusters	10	2	8	2	**22**
318018	homogeneous Corsican pine stand	6	2	6	7	**21**
95120	young homogeneous Scots pine stand	6	2	10	3	**21**
Pijnven4	relatively young homogeneous Red oak stand	9	6	5	0	**20**
Pijnven50	relatively young homogeneous Scots pine stand	9	2	6	2	**19**
251081	relatively old Corsican pine stand	6	2	5	4	**17**
95053	young homogeneous Scots pine stand	6	1	8	2	**17**

Data set 2 includes young planted homogeneous stands as well as relatively old semi-naturally developed mixed stands, approaching the natural situation under similar site conditions. A difference of almost 20 points between these stands, indicates a sensitivity of the index for management impacts. Depending on the management regime, stands with low scores can actually remain at the same level or develop to the highest recorded scores and even higher. This test calculation clearly indicates that the index is sensitive enough to evaluate the performance of management regimes, aiming at higher structural diversity and naturalness.

TABLE 3. Stand description and index scores for 10 different forest stands at the same site (data set 2).

Forest stand	Description	Scores				
		Forest structure	Woody layer	Herbal layer	Dead wood	Total
KM 7	Semi-nat. mixed stand of birch, oak and very old Scots pine	18	6	7	5	**36**
KM 5	Semi-natural relatively old birch stand mixed with oak	18	4	6	6	**34**
KM 9	Planted old mixed Scots pine stand; rich understorey	9	5	9	11	**34**
KM 10	Semi-natural old Scots pine stand mixed with birch	16	3	7	7	**33**
KM 8	Planted Scots pine stand, some very old pines, rich understorey	12	6	7	6	**31**
KM 6	Semi-natural relatively old birch stand mixed with oak	13	2	9	5	**29**
KM 4	Semi-natural young birch stand mixed with Alder buckthorn	14	4	6	5	**29**
KM 1	Planted, relatively old homogeneous Scots pine stand	12	5	5	5	**27**
KM 2	Planted, 80 year old, homogeneous Beech stand	11	6	4	0	**21**
KM 3	Planted, relatively old homogeneous Corsican pine stand	7	4	7	0	**18**

3.2. Authenticity index for Flanders

The general value for the authenticity index in Flanders is very low (FIGURE 2). Only 4 plots (0,3 %) reach a value of more than 50 / 100. Half of the plots have a value equal or lower than 25 / 100.

The contribution of every subindex to the total value of the authenticity index is not equal. The Forest structure subindex is contributing the most, although its maximum possible score is lower than for the other subindices. The relative score for the other subindices is mostly much lower. This partially indicates a true 'bad' condition of forest biodiversity. On the other hand, some indicators are probably more strict than the ones applied in the index for forest structure. In the case of structure, there is few possibility for differentiation (e.g. only two classes for number of storeys), due to the nature of the forest inventory data, whereas the other subindices are calculated with very detailed information from the plot.

The overall view of these figures points out the bottleneck for diversity in Flemish forests: the lack of trees with large dimensions (woody layer) and dead wood. The main reason for the lack of large dimensions is the age of the Flemish forest stands: 55 % of the forest stands is younger than 40 years, only 2,5 % is older than 80 years (Afdeling Bos & Groen 2001b). The lack of dead wood is clearly linked to the management history of the stands: upto recent times, all forests were intensively managed, removing all dead and dying trees (sanitary reflex).

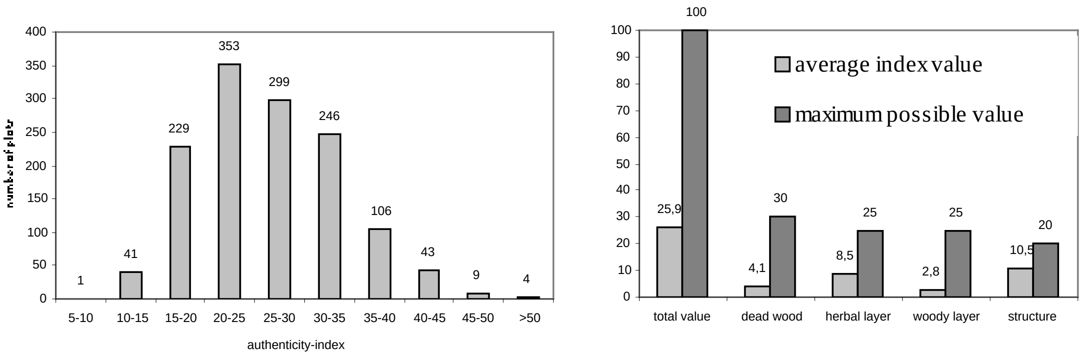

FIGURE 2. Overview of the value of the authenticity index and the average values of the subindices for 1331 plots of the Flemish forest inventory.

3.3. Forest structure

The overall value for forest stand structure is good (FIGURE 3). The median is at half of the maximum possible value (10 / 20) and very low scores are lacking. 429 plots (16 %) have a score higher than 16 / 20. As mentioned before, this could be due to a less strict way of scoring for this subindex; when a woody layer is present, a minimum score of 5 is always obtained. Nevertheless, it is a fact that the vertical structure of the Flemish forests is quite diverse: most stands have a more or less developed understorey (70 %) (Afdeling Bos & Groen 2001b).

When the separate indicators for forest structure are considered, it is clear that some indicators, due to restrictions of the data set, are easier to match.

The score for canopy closure is not particularly low, however studies indicate that the canopy cover of the Flemish forest is increasing (Bauwens 2001).

The score for stand age is low, as could be expected, since old stands are rare.

The score for number of storeys is high and very straightforward (one storey / multi-storey) which makes it difficult to evaluate differences between stands. A possible way to make this indicator more sensitive is to introduce more classes, using the standard deviation of the measured tree height.

Finally, spatial tree species mixture is comparable with canopy closure: from a structural point of view, the mixture is good, but the species composition could be better (see 3.4).

Each of the indicators is realistic, as maximum scores were obtained for all indicators.

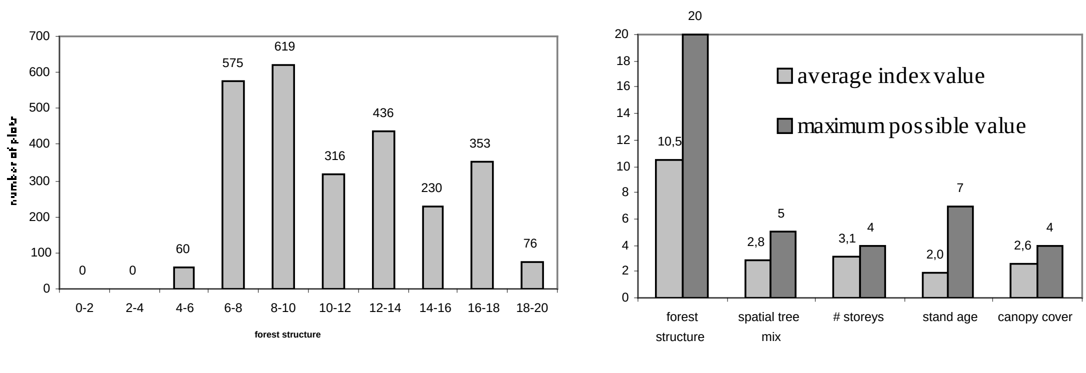

FIGURE 3. Overview of the value of the forest structure subindex and the average value of the indicators for 2665 plots of the Flemish forest inventory.

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3.4. Woody layer composition

These subindex reveals the lowest scores (FIGURE 4). The maximum calculated value is 15 / 25. Half of the plots score equal or lower than 2 / 25. Only 138 plots (5 %) reach a value of more than 8 / 25. This indicates not only the fact that this subindex is quite strict, but also reflects reality: the Flemish forests have a very young stand age with many exotic tree species (Afdeling Bos & Groen 2001b). The method of subtracting the score with one point if the proportion of an exotic species exceeds 50 %, leads to figures of 0 for number of tree species. This explains the low score for this particular indicator.

Indicators for large trees and very large trees have a very low score. Again stand age is the reason. Moreover, large dimensions are economically not desired (difficult to sell and to transport, risk of hidden defects like discoloration) and forest management is tailored to this.

The number of naturally regenerating species is also low. Regeneration is found in 54 % of the forest inventory plots and the number of species per plot is not high. In the list of the 5 most found tree species in natural regeneration, the exotic species Black cherry (*Prunus serotina*) and Northern red oak (*Quercus rubra*) are prominent (Afdeling Bos & Groen 2001b). No score is given to these species.

The score for standard deviation of DBH cannot be high, considering the large number of homogeneous stands.

Nevertheless for almost every indicator at least one plot was found reaching the maximum value. Only for the indicator 'natural regeneration' the maximum value in this data set is 3 / 4.

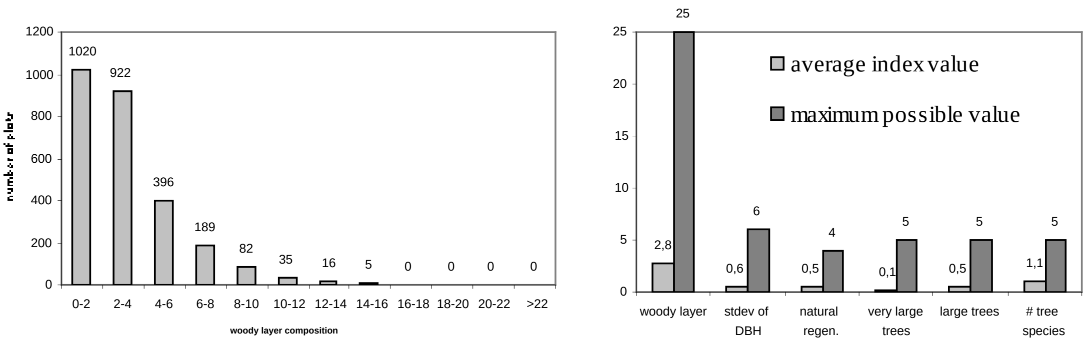

FIGURE 4. Overview of the value of the woody layer composition subindex and the average value of the indicators for 2665 plots of the Flemish forest inventory.

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3.5. Herbal layer composition

In this subindex half of the plots have a value lower than 8 / 25 (FIGURE 5). 103 plots (8 %) have scored over 14 / 25. All individual indicators contribute almost equally to the total value for this subindex.

The average score for number of plant species is not very high: lots of forest inventory plots are poor in vegetation or even empty. On the other hand, also very rich plots with a maximum score for this indicator are found. No distinction however is made between typical forest plants and species of other plant communities.

The indicator for degree of rareness provides further refinement of the previous indicator, because several typical forest species are rare plants. Actual scores for this indicator are quite low.

Also for the indicator for bryophyte diversity, only species number is taken into account, regardless of the fact that they are forest species or not.

The contribution of the indicator for total cover of plants and bryophytes is slightly higher than for the other indicators of the subindex herbal layer.

Again for every indicator the maximum possible value was recorded, proving the subindex to be realistic and not too strict.

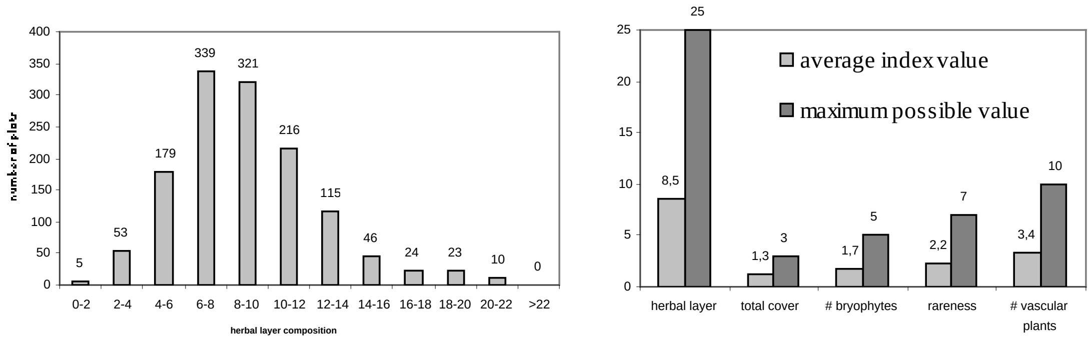


FIGURE 5. Overview of the value of the herbal layer composition subindex and the average value of the indicators for 1331 plots of the Flemish forest inventory.

3.6. Dead wood

The value of this subindex is comparable with woody layer composition (FIGURE 6). Half of the plots score 4 / 30 or less. Only 7 plots (0,5 %) score more than 15 / 30. Not all the indicators contribute equally to the total value of the subindex on dead wood.
When no dead wood or only small logs are found, several indicators for this index score 0 and lower the average value for the subindex. The overall value for the indicators is very low, indicating the lack of dead wood in the Flemish forests.
Especially large logs and snags are missing. Smaller dead wood is often found (branches), as can be derived from the higher score in number of diameter classes (with the smallest two classes often present).
Another reason for the low value is the low stochastic probability of actually finding larger dimensions of dead wood in the plot. As an example a plot from the forest reserve of Zoniën Forest can be mentioned. The stand in which the plot is situated has an average of more than 130 m³/ha of dead wood with many snags and logs of large dimension (Van Den Berge et al. 1990, De Keersmaeker et al. 2002). However, in the sample plot of the forest inventory no large snags and few smaller logs were found, resulting in a very low score of 4. This problem is directly linked to the conceptual bases of the inventory, which is primarily aimed at producing figures on global stand properties and not fit to sample rare data. Other methods like Transect Relascope Sampling could provide better results (Ståhl 1998).
For every indicator of this subindex, except for number of large trees, the maximum value was reached in at least one plot, proving it to be realistic.

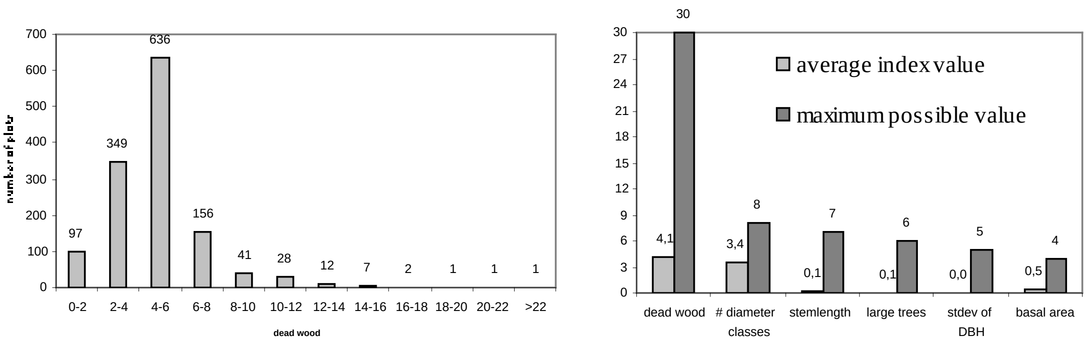


FIGURE 6. Overview of the value of the dead wood subindex and the average value of the indicators for 1331 plots of the Flemish forest inventory.

3.7. Maximum scores

The maximum possible and the maximum obtained scores for every indicator are listed in TABLE 4. Most of the indicators can reach a maximum, but a plot will rarely score high for every indicator, explaining the general low value of the authenticity index. A high value of the index is mostly related to a high value for one of the subindices.

By not scoring too high, the index certainly provides perspectives for improvement of the plots and is thus very useful for monitoring purposes.

TABLE 4. Overview of the maximum obtained value in the calculation (upper figure) and the maximum possible value (lower figure) for every indicator and for every subindex of the authenticity index.

canopy cover	stand age	# storeys	spatial tree mix		***Forest structure***
4 4	7 7	4 4	5 5		***18*** ***20***
# tree species	large trees	very large trees	regeneration	stdev of DBH	***Woody layer***
5 5	5 5	5 5	3 4	6 6	***13*** ***25***
# vascular plants	rareness	# bryophytes	total cover		***Herbal layer***
10 10	7 7	5 5	3 3		***21*** ***25***
basal area	large trees	stdev of DBH	stem length	diameter classes	***Dead wood***
4 4	4 6	5 5	7 7	8 8	***24*** ***30***

3.8. Spatial analysis

In FIGURE 7 a map is produced to see in which way the values of the authenticity index are scattered over Flanders. It can be seen that there is no particular spatial pattern in the values, high and low values are randomly scattered over the area.

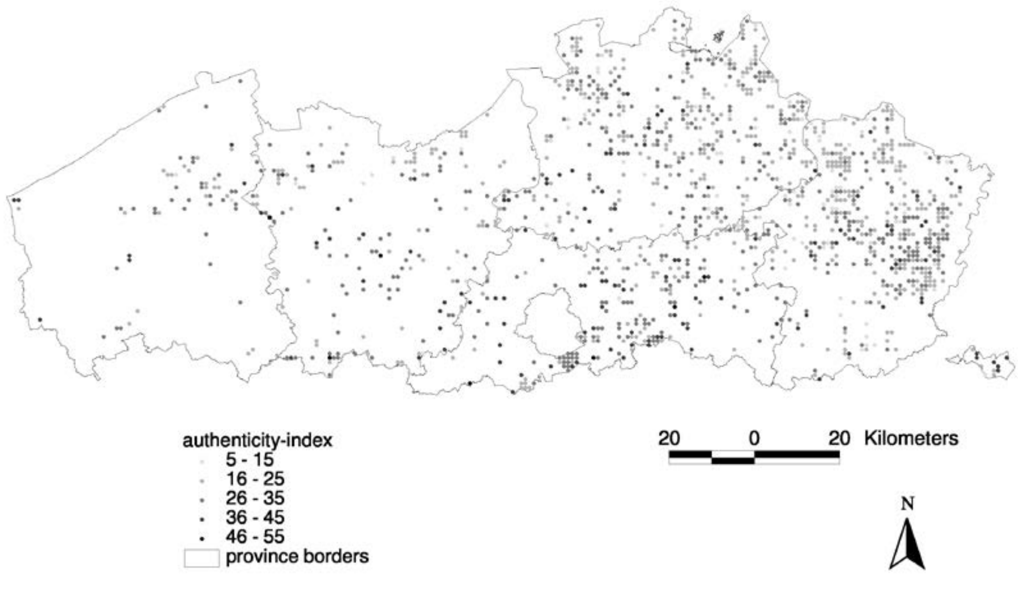


FIGURE 7. View on the spatial distribution of the authenticity index value.

3.9. History

Ancient woodlands can be expected to have a higher average value of the authenticity index than recently afforested farm- and heathland: at least some aspects of the index (very large trees, large quantities of dead wood) are more likely to occur in ancient woodlands; in young afforestations these simply cannot be present. From historic maps the time of afforestation for each sample plot is calculated (not to be confused with stand age, being the age of the trees).

313 out of the 1331 plots are considered to be ancient woodland. The index values of these plots are compared to the score for the other plots. The mean index value for ancient woodland is 28,2 ± 0,8, while the mean for the other plots is 25,2 ± 0,5. The average value for the authenticity index is thus higher in ancient woodland than in younger forests.
In FIGURE 8 an overview is given of the average value for each indicator, comparing ancient woodland and afforestations.
It is clear that for some indicators no difference can be made between ancient woodlands or afforestations. Forest structure and woody layer composition are however significantly different. Recent afforestations don't carry large or very large trees as some older forests do. Also the number of tree species is much higher in ancient woodland.
The significant difference in rareness is probably due to the occurrence of rare plant species that are strictly confined to ancient woodlands.
Higher index scores can thus be related, for some aspects, to the history of the forest.

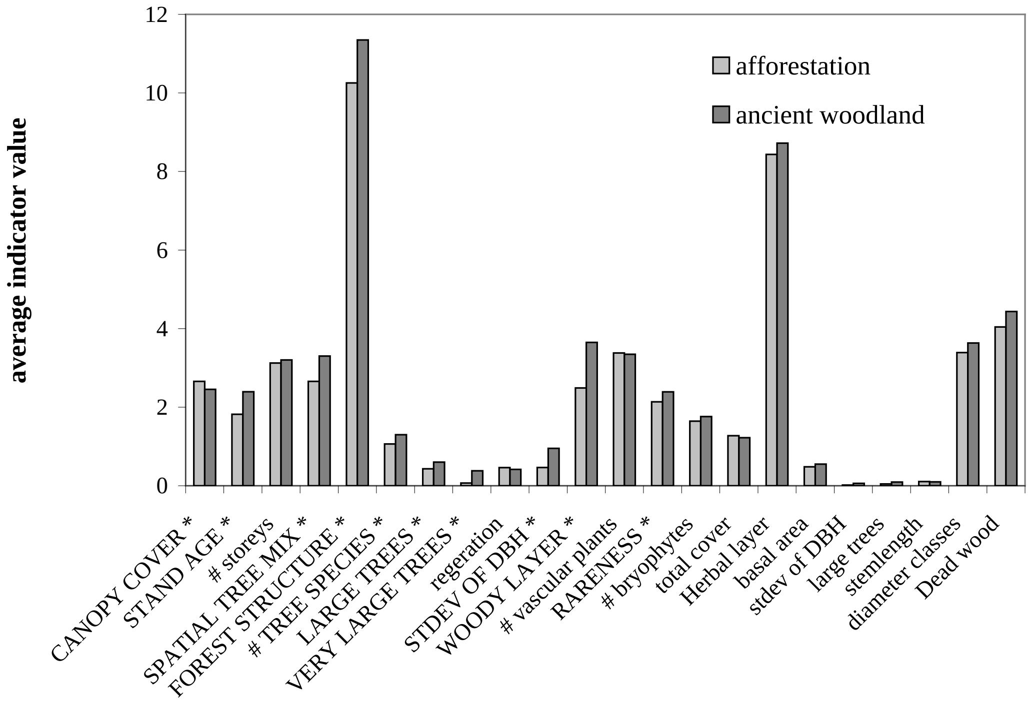


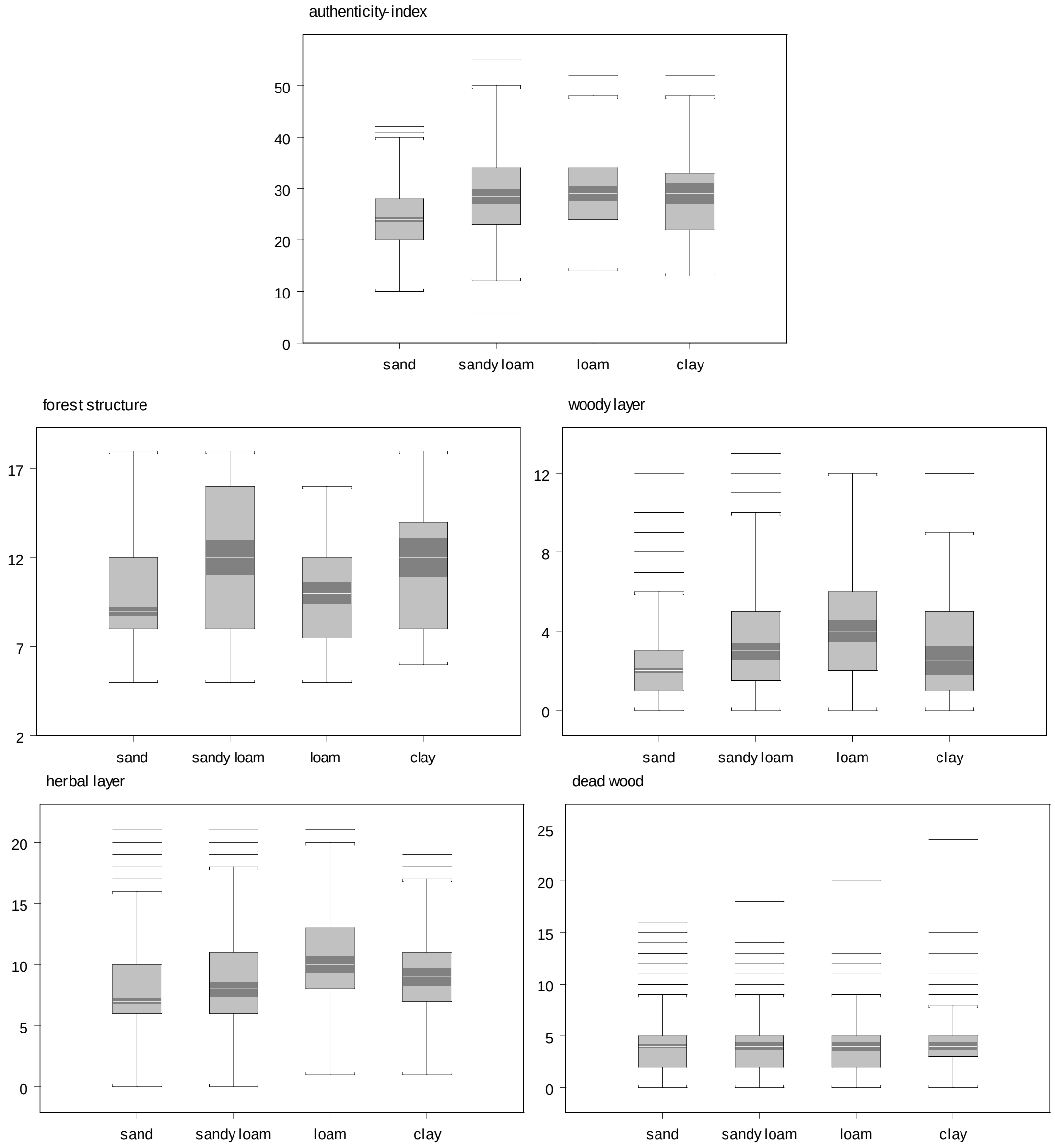
FIGURE 8. Comparison of the value for the subindices and indicators between ancient woodland and afforestation. Significantly (α = 0,05) different values are in capital and marked (*).

3.10. Forest soil type

In order to examine the relation between index values and soil type, the plots were divided into 4 general texture groups, based on the digital soil map. In FIGURE 9 boxplots of the four groups are presented for each subindex and the total value of the authenticity index.
It is clear that the forest soil texture has an effect on the value of the authenticity index. In general, a sandy soil texture has a lower index value than the other types. Several herb-rich and well structured forest types (Alno-Padion, Fagion and Carpinion types) are typical for soils with a clayey, loamy and sandy loamy texture, while homogeneous conifer plantations with monotonous herb layers are often related to poor sandy soils. However, the recorded differences are much lower than could be expected. The figure shows that the range of index values is very large for every soil texture type. Low values for the index can be seen in loamy soils, while high values are also possible on sandy soils. This proves that management history and practice is in fact determinant for the actual score of the plot, and not the potential development (biomass, growth, natural species composition) conditioned by the site quality. More detail is given when every subindex is considered.
For forest structure the value for sandy loam and clay is distinctly higher than for other texture types. A higher value for loam would be expected, but these soils are often covered with very homogeneous, economically productive beech stands. Probably for that reason the value is lower.

When woody layer is considered, the value rises from sand to loam, indicating that on these fertile soils larger trees can develop over shorter time. Clay forms an exception, because forests on these grounds usually consist of very recent afforestation on grassland or have been treated as coppice in the recent past. Moreover, large dimensions are avoided here, because of exploitation difficulties.
For herbal layer, loam and clay have higher values. This is expected: forests on sandy soils are naturally poorer in species than forests on loam and clay. The many young forests on clayey soils (with a species poor herbal layer) probably decrease the value for this subindex on clay. Finally the values for dead wood show no difference between the several soil types, as it is completely determined by forest management.

FIGURE 8. Overview of the value of the authenticity index and subindices in relation to soil texture type.



Boxplots indicate median (white line), confidence bounds on 95%-significance level (dark grey), lower to upper quartile (light grey), range (whiskers) and values beyond range (horizontal dashes).

3.11. Ownership
The Forest Decree of 1990 requires that a forest management plan is made up for all forests. For public forests, higher standards are set as multifunctional management is required, which involves economic, social, ecological and scientific aims. For this reason public forest is believed to have a greater biological value than private forest, which is predominantly managed for hunting and wood production.

The average index value for private forest owners is 26,1 ± 0,5; for public forest owners the average value is 25,5 ± 0,6. Statistically there are no differences between the index values of the two types of ownership. The subindices show no significant differences either.
A possible explanation for the indifference is the less intensive management in private forests, allowing more natural processes to occur. The multifunctional management in public forests is only recent: in past decades wood production and recreation were dominant, with only limited attention to ecological factors. The effects of the new forest management are probably not yet clearly detectable. Since 2001, much higher requirements for biodiversity (considering dead wood amounts, canopy gaps, …) are imposed for the management of public forests (Afdeling Bos & Groen 2001a). It is to be expected that future similar comparisons will reveal significant higher scores for public forests.

4. Conclusion

The developed index proves to be a useful, powerful and very practical tool for the monitoring of the performance of management measures and policies on some important aspects of forest biodiversity. From a practical point of view the system thus qualifies as a Biodiversity Evaluation Tool (BET) (Larsson et al. 2001).

The suggested stand-scale index combines biological and structural indicators, based on available data from the Flemish forest inventory. This strategy allows an immediate application on the level of the Flemish region without much extra effort. As the forest inventory is repeated every ten years, continuity of data for monitoring purposes is guaranteed. A disadvantage of this strategy are the limitations of the recorded data in the forest inventory. Other potentially valuable indicators cannot be included.
The indicator choice is based on widely accepted assumptions of increased species richness in relation to a more varied and complex forest structure. However the creation of new niches does not always guarantee that they will be filled by the expected organism. Moreover, a higher species richness does not allways coincide with a higher biological value, as other aspects like ‘rareness’, ‘habitat completeness’, … also play an important role in this evaluation. The index is therefore not meant to compare different forests on their biodiversity status and is not sufficient to judge forests on their value for nature conservation.
It only tries to provide an unbiased measure for the potential biological diversity of a stand, and the actual performance of the management in relation to this. It is a monitoring tool to evaluate the impact of forest management on ‘biological diversity potential’, rather than on the actual species richness itself. That is why it is not called a ‘biodiversity index’ but an ‘authenticity index’, as defined by Dudley (1996): 'a reflection of the extent to which a forest corresponds to a naturally functioning forest in terms of composition and ecology’.

The calculation of the authenticity index on the larger scale of Flanders shows that the index is strict; some subindices have an overall low score and only few index values are higher than 50 / 100.
However, the low score is not only due to the strictness of the index, it also reflects the unfavourable overall status of Flemish forests, as far as some important aspects of forest biodiversity are concerned. The absence of old trees, natural gaps and dead wood, and the strong dominance of exotic tree species are considered to be the main shortcomings within the forest stands. These factors, combined with low forest index and high fragmentation, resulting in adverse anthropogenic influences, are considered to be the main reasons for the moderate overall status of biodiversity in Flemish forests. 1/3 of the fauna and flora species in Flanders are considered endangered or extinct. Among them many forest-related species (Kuijken et al. 2001).
Nevertheless the forest management has made a turn during the last decades and the new Guidelines on Forest Management (Afdeling Bos & Groen 2001a) are promising for the future development of forest biodiversity. The overall low value of the index makes it possible for the forest inventory plots to make a significant and detectable progression when younger stands reach maturity, or stands improve through changes in management (conversion to mixed stands, leaving dead wood).
Recalculation of the authenticity index after the next forest inventory (2007-2010) will provide an ideal and objective tool to evaluate further progress on this matter.

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