Development of a Stand-scale Forest Biodiversity Index Based on the State Forest Inventory

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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 stand-scale forest biodiversity index is developed, based on available data from the state forest inventory. The index combines aspects of forest structure, woody and herbal layer composition, and deadwood, as biodiversity indicators. The index is calculated by means of a score system following a standard procedure. It reflects the variability of forests in Flanders in a logical way and is sensitive enough to indicate changes for monitoring purposes.

The Flemish government has committed itself to fulfill the obligations towards biodiversity conservation set out in the UN's Convention on Biological Diversity (Rio de Janeiro 1992), the Resolution on Conservation of Biodiversity in European Forests (H2) of the Ministerial Conference on the Protection of Forests in Europe (Helsinki 1993), the Flemish Environmental Policy Plan, and the new Decree on Nature Conservation and the Natural Environment (1997). Therefore, there is a definite need for monitoring tools for biodiversity in general and forest biodiversity in particular. This study focuses on forest biodiversity, limiting its possible interpretation to its still most important measure of species richness.

Assessing and monitoring species richness is labor intensive, time consuming, and requires specialist knowledge, which makes it inapplicable on a large scale. Total potential species richness is never completely known. Even in intensely investigated European forest ecosystems, new species are still frequently identified. The use of indicators for forest biodiversity is confronted with a range of problems related to a general lack of knowledge (EWGRB 1997). The use of certain well-known taxa as indicators deals with a lack of scientific evidence for the primary condition of an indicator, namely significant correlation with diversity of other taxa. Existing research on this subject even suggests that a single taxon or a combination of taxa cannot serve as reliable indicators for species richness of most other taxa because of contradictory or weak across-taxon correlations (Nilsson *et al.* 1995, Oliver and Beattie 1996). Keystone species, i.e., species that are functionally important for a wider part of biodiversity, could serve as potential indicators of biodiversity, but there seems at present to be insufficient scientific basis or empirical ways to optimally construct an indicator system based on these. Moreover, an a priori problem with species-based indicator systems is that species often have varying ecological demands and/or do not respond similarly to altered conditions in different parts of their distribution.

An alternative approach consists of the use of sets of biological and/or structural indicators. In this study, a biodiversity index is developed on the level of a forest stand based on available data on forest structure and floral species composition from the state forest inventory. It covers easily measurable features of forest structure, woody and herbal layer composition, and deadwood, 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. Since the Neolithic period, some 10,000 years ago, increasingly intensive human influence has resulted in a loss of the authenticity of most European forests (Christensen and Emborg 1996, Dudley 1996, Peterken 1996). The authentic structure, composition, and dynamics will probably never be entirely detected. Nevertheless, some major aspects of this authenticity can be identified including varied and complex forest structure; rich composition of tree and shrub species; large old trees; deadwood; and characteristic disturbances caused by storm, grazing, pathogens, and fire (Bradshaw and Lindén 1997). The biodiversity index 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 different niches (Altenkirch 1988, Franklin 1988, MacArthur *et al.* 1962, Otte 1989). Because the index will serve as a monitoring tool to evaluate the impact of forest management on biodiversity, a high sensitivity to silvicultural measures is necessary. This requirement rules out other important indicators of biodiversity like site history, connectivity, forest area, and site condition. Moreover, these indicators are rigid in a sense that they are not apt to change at short notice.

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STATE FOREST INVENTORY

The state forest inventory of the Flemish region is based on a systematic sampling technique using a geo-referenced grid of 1 X 1 km (Waterinckx and Haelvoet 1997). Due to a low forest index of 10 percent and a high degree of fragmentation (Van Den Meersschaut and Lust 1994), only a limited number of intersections of the grid are actually situated in forest, resulting in approximately 1,500 plots. Each plot is located in the field by means of aerial photographs and shifted into the nearest homogeneous forest stand if necessary, following a standard procedure.

The forest inventory includes a general description of the stand, with special attention to the stand type, age distribution, canopy closure, horizontal and vertical stand structure, combined with measurements of the woody and herbal layer (Waterinckx and Haelvoet 1997). The woody layer is sampled using a plot design of four concentric circular sample units (A1, A2, A3, and A4) with variable radius (R1, R2, R3, and R4) according to the dimension of trees and shrubs (fig. 1). In A1 and A2, only tree species and stem numbers are measured. In A3 and A4, individual trees and shrubs are also positioned using polar coordinates after measuring their circumference at a height of 1.5 m ($C_{1.5}$)[1]. These measurements apply to living as well as dead standing trees (snags). The herbal layer is sampled on the same spot using a 16- X 16-m plot. All vascular plants and bryophytes[2] are identified, and their cover is estimated using an adapted version of the Braun-Blanquet scale (Barkman *et al.* 1964, Braun-Blanquet 1951). Within the plot, special attention is given to the lying deadwood (logs). Logs are divided into four diameter classes (2 < ∅ < 7 cm; 7 < ∅ < 22 cm; 22 < ∅ < 40 cm; and ∅ > 40 cm). Density and stem length of the logs is estimated for the first and last two classes, respectively.

This is the first time that the Flemish forest area has been sampled by means of a systematic technique. The state forest inventory will be repeated every 10 years.

BIODIVERSITY INDEX

The biodiversity index is calculated by means of a score system based on four major aspects of a forest ecosystem determining forest biodiversity: forest structure, woody and herbal layer composition, and deadwood. Each aspect consists of a set of indicators derived from the available data of the state forest inventory. The indicators are given a score taking into account 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

[1] *$C_{1.5}$ is a traditional local measure easily transformed into diameter at breast height (dbh), which is used for the biodiversity index.*

[2] *The sampled bryophytes include non-epiphytic mosses (Musci) and Liverworts (Hepaticae).*

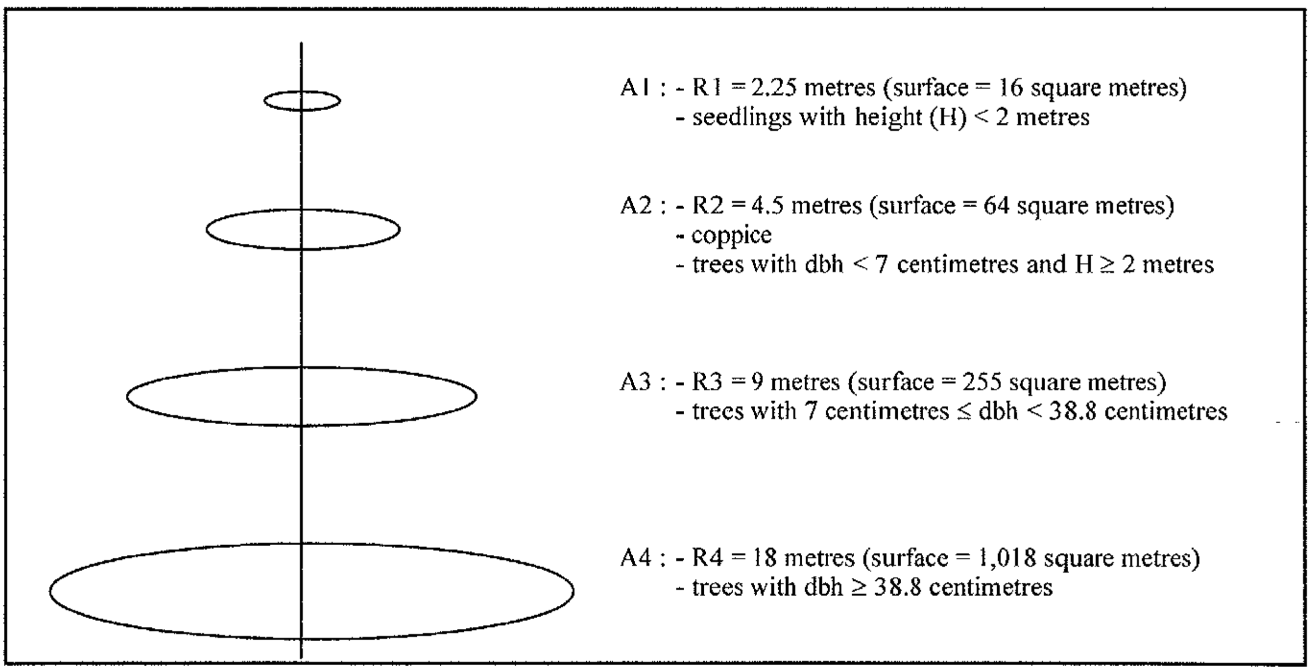

Figure 1.—*Plot design for the inventory of the woody vegetation consisting of concentric circular sample units (A1,2,3,4) with variable radius (R1,2,3,4) (after Waterinckx and Haelvoet (1997)).*

determined on the basis of a common agreement of different specialists (table 1) (Alho *et al.* 1996, Dalkey and Helmer 1962, Kangas *et al.* 1993, Pukkala *et al.* 1997). During application of this technique, special attention is given to evenly balancing the weights of the different indicators, presuming their contribution to biodiversity is more or less equal. The maximum score of the biodiversity index is set to 100. Appendix 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 deadwood, 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 were used.

Forest Structure

Habitat complexity and structural heterogeneity are generally recognized as important indicators for forest biodiversity (Köhl 1995, Noss 1990, Rune 1997, Schuck *et al.* 1994). The forest structure, mentioned as a biodiversity indicator in this study, is based on a description of the visual characteristics of the whole stand in which a

Table 1.—*Overview of the different indicators and their maximum scores forming the biodiversity index*

Indicator	Maximum score
FOREST STRUCTURE (a+b+c+d) :	20
(a) Canopy closure/cover	4
(b) Stand age	7
(c) Number of stories	4
(d) Spatial tree species mixture	5
WOODY LAYER (e+f+g+h+i) :	25
(e) Number of (indigenous) tree species (height ≥ 2 m)	5
(f) Number of large trees (40 ≤ dbh < 80 cm)	5
(g) Number of very large trees (dbh ≥ 80 cm)	5
(h) Number of indigenous tree species in natural regeneration (height < 2 m)	4
(i) Standard deviation of dbh	6
HERBAL LAYER (j+k+l+m) :	25
(j) Number of vascular plant species	10
(k) Degree of rareness	7
(l) Number of bryophytes	5
(m) Total cover	3
DEADWOOD (n+o+p+q+r) :	30
* Snags (n+o+p) :	15
(n) Basal area	4
(o) Number of large trees (dbh ≥ 40 cm)	6
(p) Standard deviation of dbh	5
* Logs (q+r) :	15
(q) Sum of stem-length of large trees (∅ ≥ 40 cm)	7
(r) Number of diameter classes	8
BIODIVERSITY INDEX (a→r)	100

sample plot is located. These characteristics consist of canopy closure or cover, stand age, number of stories, and spatial tree species mixture. Woody layer, herbal layer, and deadwood are also part of what can be called forest structure but are treated separately because they are based on actual measurements.

The closure of the upper canopy layer is considered to be a measure of habitat variation because it causes different light and humidity regimes or microclimatic conditions in general (Noss 1990). A canopy cover of 1/3 to 2/3 of the total area is supposed to offer the biggest structural variety and is thus awarded a maximum score of 4. Open stands (canopy cover < 1/3) score a little higher than closed stands (canopy cover > 2/3) for the same reasons.

A higher stand age positively influences forest structure. Maturing stands diversify naturally providing more opportunities for nesting, shelter and nourishment, which may be important for the survival of different animal and plant species (Helmer 1987, Mitchell and Kirby 1989). Stand age and scores are therefore positively linked. Uneven-aged stands score a little lower than older stands (> 160 years), because an uneven stand age does not automatically imply an old age.

The number of stories is a valuable parameter for describing the vertical structure and diversity of a forest stand. Multilayered forest stands create a higher and more diversified amount of niches, and receive a maximum score.

The spatial tree species mixture is a valuable parameter for describing the horizontal structure of a forest stand. The weighing of the scores is based on the idea of the biggest possible variety on the smallest possible surface resulting in the maximum score for stands with an individual tree species mixture.

Woody Layer

The indicators—number of tree species, number of large and very large trees, number of indigenous tree species in natural regeneration, and standard deviation of $\varnothing_{1.5}$—are based on measurements in circular sample plots.

The tree species composition is a very important indicator of diversity. Many organisms are linked to specific tree species and vice versa (Kennedy and Southwood 1984, Southwood 1961). Mixed forest stands will accommodate more animal and plant species than single species stands. Exotic tree species contribute to biodiversity because a certain, nevertheless limited, amount of organisms can be related to them (Kennedy and Southwood 1984) and because they contribute to forest structure. Therefore, they cannot be totally neglected. However, if their share increases and they start dominating the stand and outcompeting native species, they have a negative influence on biodiversity. Exotic tree species are 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 to 5 to 50 percent, they are treated indifferently. An extra point is subtracted for each exotic species whose proportional share exceeds 50 percent. An analogous qualitative intervention is also applied by Hekhuis *et al.* (1994) and advised by Standovar (1997).

Large trees ($40 \leq$ dbh < 80 cm) 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 that automatically results in a limited number per sample plot. Both facts explain why large and very large trees are separately scored. In this case no distinction is made between indigenous and exotic tree species because tree size is a structural parameter making the identity of a species of minor importance.

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 mean to express this variation (Bradshaw and Lindén 1997). The calculations are performed for trees with dbh ≥ 7 cm.

Herbal Layer

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.

Many vascular plants specifically host certain specialized animal species, so that 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. The Flemish flora consists of 1,279 vascular plants species of which 310 are confined to the socioecological group of "forest plants" (Cosyns *et al.* 1994, Stieperaere and Fransen 1982). However, due to the occurrence of different habitats within a forest, this number can increase significantly (Hermy *et al.* 1996). Therefore, plants that are not restricted to closed forest situations and that contribute to biodiversity cannot be ignored. Thus, all plants are treated alike for determining and 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 all plants. This is especially important for monitoring purposes towards evaluation of forest management in the framework of nature conservation. The degree of rareness is based on the occurrence of a species in a georeferenced grid of 4 x 4 km using a logarithmic frequency distribution (Stieperaere and Fransen 1982). According to its occurrence, each species receives a preliminary score (table 2). The preliminary scores of all species in a sample plot are added and scored a final time considering the classification given in appendix 1.

Table 2.—*Preliminary scoring of plant species according to their proportional occurrence in a 4- x 4-km grid*

Proportional occurrence in a 4- x 4-km grid	Preliminary score
Percent	
< 1.38	8
1.38-10	5
10-23.97	2
23.97-48.97	1
> 48.97	0

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 for maximum variation. Chances for equal variation are the same for covers 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.

Deadwood

The importance of deadwood for conservation of biodiversity in forest ecosystems is generally acknowledged (Albrecht 1991, Detsch *et al.* 1994, Eckloff and Ziegler 1991, Kirby and Drake 1992, Möller 1994, Packam *et al.* 1992, Rabl 1993, Samuelsson *et al.* 1994). The importance of deadwood quantity, occurrence, size and shape diversity, and status of decomposition are stressed in relation to specialized invertebrates, fungi, and cavity-nesting animals (Altenkirch 1988, Ammer 1991, Barkman *et al.* 1983, Hodge and Peterken 1998, Komdeur and Vestjens 1983, Mabelis 1983, Rauh 1993, Schales 1992, Speight 1989). 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 state forest inventory, it is possible to calculate basal area, number of large trees, standard deviation of dbh of the snags, and total stem length and number of diameter classes of the logs. The identity of deadwood is not included, although its influence on certain faunal and floral aspects was determined (Hilt 1992, Stevens 1986). This influence decreases as the decomposition process continues (Palm 1959, Rauh 1993). Moreover, identification of deadwood is not always possible in the field.

The amount of standing deadwood is expressed in absolute units of basal area (square meters per hectare) instead of its proportional share in the total basal area of a forest stand. This is in order to avoid, for example, the possible false impression of an increased amount of deadwood after thinning a stand (without cutting the deadwood).

Large snags (dbh ≥ 40 cm) are monitored separately because they are usually associated with a high diversity of sizes and shapes creating different niches. Their large size offers opportunities for numerous rare species (Hekhuis *et al.* 1994, Rauh 1993, Siitonen and Martikainen 1994). Because of their importance, the occurrence of a single snag receives a high score.

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

The amount of lying deadwood is limited to the occurrence of large logs (∅ ≥ 40 cm) and expressed as the total estimated stem length. Because of their importance to biodiversity, the occurrence of a cumulated stem length of 1 to 10 m receives a high score.

The diameter classes of the logs are the same as those used in the state forest inventory. These classes are used to indicate variation in lying deadwood. The occurrence of class 4 with the largest logs is rewarded with an extra point.

CASE STUDY

The biodiversity index is calculated for two types of data sets to check if the index reflects site and structural variability of forests in Flanders and if it is sensitive enough to indicate changes for monitoring purposes. The first data set includes 20 sample plots covering the major variability of forest stands and sites in Flanders. The second data set is confined to one forest and covers 10 forest stands with different structure and composition but with similar site conditions.

The forest stands of the first data set range from young homogeneous pine plantations to old mixed deciduous forests with a rich forest structure and species composition (table 3). The calculated biodiversity indexes reflect this variability in a logical way, ranking them in an increasing order. The difference between extreme values

Table 3.—*General description and intermediate scores of the different forest stands (encoded) of data set one and two*

Forest stand	Description	Scores: Forest structure	Woody layer	Herbal layer	Dead wood	Total
Dataset 1:						
Zoniën13	old Beech stand mixed with oak	16	12	11	9	48
Zoniën1	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	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	17	4	13	2	36
178132	young birch stand	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	young 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
Dataset 2:						
Koeimook7	old Scots pine stand mixed with birch/oak	18	6	7	5	36
Koeimook5	relatively old birch stand mixed with oak	18	4	6	6	34
Koeimook9	old Scots pine stand	9	5	9	11	34
Koeimook10	old Scots pine stand mixed with birch	16	3	7	7	33
Koeimook8	old Scots pine stand	12	6	7	6	31
Koeimook6	relatively old birch stand mixed with oak	13	2	9	5	29
Koeimook4	young birch stand mixed with Alder buckthorn	14	4	6	5	29
Koeimook1	old Scots pine stand	12	5	5	5	27
Koeimook2	young homogeneous Beech stand	11	6	4	0	21
Koeimook3	relatively old homogeneous Corsican pine stand	7	4	7	0	18

amounts to 1/3 of the maximum score, leaving enough space for sound distinctions of biodiversity status between stands. None of the stands reach half of the maximum score, nor is the intermediate score for the four major indicators (forest structure, woody and herbal layers, and deadwood) systematically high (table 3). This indicates that none of the stands have reached a seminatural optimum so that the index may still significantly increase parallel to an improved stand development. The deadwood aspect, for example, is systematically low, indicating its inferior role in general forest management in the past.

One of the major disadvantages when using a biodiversity indicator system for temperate forests in western Europe is the lack of relicts of natural forest stands serving as reference for the different forest types. Data set two allows the investigation of a potential maximum score of the biodiversity index, because it includes young planted homogeneous stands as well as relatively old semi-naturally developed mixed stands on the same site. Table 3 illustrates that the score for human-made forest stands like Koeimook3 and Koeimook2 can potentially increase to the level of stands like Koeimook5 and Koeimook7, which were able to develop spontaneously, resulting in a species composition and forest structure probably approaching the natural situation. A difference of almost 20 points between these stands indicates a sensitivity of the index that is useful for monitoring purposes. Koeimook5 and Koeimook7 only resemble the natural situation so that their score is not the absolute maximum and can still increase. Due to site conditions, this absolute maximum will probably be lower in comparison with richer sites. Sensitivity of the index for monitoring purposes can be tested for other forest sites in the same manner. Since the data are georeferenced and digital soils maps are available, separate index calculations and thus biodiversity monitoring for different soil types are possible.

CONCLUSION

The score system for calculating the biodiversity index proves to be simple and easy to use. From a practical point of view, the system qualifies as a Biodiversity Evaluation Tool (BET) according to the criteria presented by the new European project aiming at developing indicators for biodiversity in European forests (BEAR 1998). The suggested stand-scale forest biodiversity index combines biological and structural indicators, based on available data from the state forest inventory. This strategy allows an immediate application on the level of the Flemish region without the need for extra measurements. A major disadvantage of this strategy is the limitation on including other potentially valuable indicators. Due to a general lack of detailed knowledge, 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 in by the expected organism. All depends on colonization processes, which are linked to the occurrence of relict populations, species mobility, and isolation. Therefore, the index will serve as a monitoring tool to evaluate the impact of forest management on potential biodiversity rather than on biodiversity itself. The lack of references on natural forest structure and species composition and the fact that other important biodiversity indicators like forest history, connectivity, forest area, and site conditions are not taken into account limit its use to monitoring purposes. Therefore, the index is not meant to judge different forests on their biodiversity status and certainly not sufficient to compare forests on their value for nature conservation, due to its emphasis on the quantitative aspect of biodiversity. The suggested stand-scale forest biodiversity index can, however, be recommended as a provisional Biodiversity Evaluation Tool for developing forest stand management in strongly anthropogenically influenced forest landscapes.

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Appendix 1.—*Detailed overview of the score system for calculating the biodiversity index.*

Forest Structure

CANOPY CLOSURE	Score
- > 2/3 of the area	2
- 1/3-2/3 of the area	4
- < 1/3 of the area	3

STAND AGE *Years*	
- 1-60	1
- 61-100	2
- 101-160	5
- > 160	7
- Uneven aged	5

NUMBER OF STOREYS	
- 1	2
- > 1	4

SPATIAL TREE SPECIES MIXTURE	
- homogeneous	1
- clustered	3
- individual	5

Woody Layer

NUMBER OF TREE SPECIES	Score
- 1-2	1
- 3-4	2
- 5-6	3
- 7-8	4
- > 8	5

NUMBER OF LARGE TREES	
- 1-5	1
- 6-10	2
- 11-15	3
- 16-20	4
- > 20	5

NUMBER OF VERY LARGE TREES	
- 1	3
- 2-3	4
- ≥ 4	5

NATURAL REGENERATING SPECIES	
- 1-4	1
- 5-8	2
- 9-12	3
- > 12	4

STANDARD DEVIATION OF DBH *Centimetres*	
- 10-15	1
- 16-20	2
- 21-25	3
- 26-30	4
- 31-35	5
- > 35	6

Herbal Layer

NUMBER OF PLANT SPECIES	Score
- 1-5	1
- 6-10	2
- 11-15	3
- 16-20	4
- 21-25	5
- 26-30	6
- 31-35	7
- 36-40	8
- 41-45	9
- > 45	10

DEGREE OF RARENESS	
- 1-5	1
- 6-10	2
- 11-15	3
- 16-20	4
- 21-25	5
- 26-30	6
- > 30	7

NUMBER OF BRYOPHYTES	
- 1-5	1
- 6-10	2
- 11-15	3
- 16-20	4
- > 20	5

TOTAL COVER *Percent*	
- 6-25	1
- 26-50	2
- 51-75	3
- > 75	1

Deadwood

SNAGS

BASAL AREA *Square metres per hectare*	Score
- < 2	1
- 2-3.5	2
- 3.6-5	3
- > 5	4

NUMBER OF LARGE TREES	
- 1	3
- 2-3	4
- ≥ 4	5

STANDARD DEVIATION OF DBH *Centimetres*	
- 10-15	1
- 16-20	2
- 21-25	3
- 26-30	4
- 31-35	5
- > 35	6

LOGS

STEM-LENGTH LARGE TREES *Metres*	
- 1-10	3
- 11-20	5
- > 20	7

NUMBER OF DIAMETER CLASSES	
- 1	2
- 2	4
- 3	6
- 4	8