

## Chapter 2

# Essential Features of Forest Biodiversity for Assessment Purposes

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**Abstract** Forest biodiversity assessments may be based on species or taxon groups, structural traits of forest ecosystems and/or biodiversity indicators derived from these variables. Working Group 3 (WG3) of COST Action E43 initially selected 41 candidate biodiversity variables based on current ecological knowledge. The next step entailed construction and distribution of a questionnaire regarding the importance of the candidate variables for assessing forest biodiversity and their feasibility for assessment by national forest inventories (NFI). Responses were received from 22 countries. Analyses of the responses with respect to importance and feasibility resulted in further selection of 17 biodiversity variables that were

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then grouped into seven essential biodiversity features: forest categories, forest age, forest structure, deadwood, regeneration, ground vegetation and naturalness. These seven essential features constitute the second level of WG3's 4-level reference framework: (1) concept, (2) essential feature, (3) indicator, and (4) NFI variable. This chapter addresses in detail the analyses of the questionnaire responses, selection of the 17 biodiversity variables, and derivation of the seven essential forest biodiversity features.

## **2.1 Forest Biodiversity Reference Framework**

The investigations of Working Group 3 (WG3) of COST Action E43 were guided by a 4-level reference framework: concept, essential feature, indicator, and NFI variable (Table 1.2). From among the large set of forest management and ecological variables that could be used to assess forest biodiversity, those that can be reasonably assessed by national forest inventories (NFI) must be identified and grouped into a smaller number of categories that are deemed essential for the assessments. To this end, WG3 undertook a systematic approach that included selection of relevant biodiversity variables, evaluation of them with respect to their importance and feasibility for assessment by NFIs, and aggregation of them into essential features. Once the essential features were selected, relevant indicators that can be estimated using NFI variables could then be identified and evaluated with respect to their potential for harmonization. This chapter focuses on the process by which the essential forest biodiversity features were selected.

## **2.2 Forest Biodiversity Variables**

### ***2.2.1 Selecting Forest Biodiversity Variables***

The first step in the procedure to select the essential forest biodiversity features was to identify a set of relevant candidate forest management and ecological variables. The selection of these candidate variables was based on information from multiple sources including the Convention on Biological Diversity (CBD 1992; UNEP 2003), the indicators for sustainable forest management established by the Ministerial Conference on the Protection of Forests in Europe (MCPFE 1997, 2003a, b), the Biodiversity Evaluation Tools for European Forests developed in the BEAR project (Larsson et al. 2001), the European Environmental Agency (EEA) Core Set of Indicators for Biodiversity and Nature Protection (EEA 2003), the published forest ecology literature and the expert knowledge of the WG3 participants. On the basis of information from the above cited sources, 41 candidate variables were selected (Table 2.1).

**Table 2.1** Candidate variables for assessing forest biodiversity

Variable	Description
Bird species	Number and list of bird species or taxon groups
Bryophyte species	Number and list of bryophyte species or taxon groups
Fungal species	Number and list of fungal species or taxon groups
Herb and grass species	Number and list of herb and grass species or taxon groups
Invertebrate species	Number and list of invertebrate species or taxon groups
Lichen species	Number and list of epiphytic lichen species or taxon groups
Other woody species	Number and list of other woody species or taxon groups
Shrub species	Number and list of shrub species or taxon groups
Tree species	Number and list of tree species or taxon groups
Vertebrate species	Number and list of vertebrates species or taxon groups
Big logs	Lying deadwood with a minimum diameter of 10 cm (the threshold definition is based on the experience acquired in several NFI)
Dead parts on living trees	Potential microhabitats at living trees such as dead branches or crown parts
Decay class	Decay level of the deadwood on the basis of standard definitions of decomposition processes
Deadwood length	Length of lying deadwood
Small logs	Lying deadwood (based on the experience acquired in several NFI the threshold is: minimum diameter smaller than 10 cm)
Snags	Standing deadwood (entire or broken part of dead trees)
Deadwood species	Number of deadwood species or species groups
Stumps	Part of the stem close to the tree roots
Forest category	Classification of forest on the basis of ecological based standardised system of nomenclature (such as EUNIS or BEAR systems)
Naturalness	Similarity of the current forest composition and structure with the natural situation
Information on forest management system	Information regarding silvicultural system (i.e. clearcut system, selection system, shelterwood system, coppice system)
Information on disturbances/damages	Information regarding level of recent man-induced disturbances
Occurrence of microsites	Information regarding presence, quantity and type of microsites as potential microhabitats (such as anthills, rocks accumulation, small humid areas and individual trees features like nesting wholes, crown breakage (Winter and Möller 2008)

(continued)

**Table 2.1** (continued)

Variable	Description
Ecotones of microsites	Evaluation of presence, quantity or quality of ecotones (i.e.: by plot partitioning or line intersect sampling)
Regeneration area	Forest area regenerating with forest tree species
Regeneration species	Evaluation of tree species regenerating
Regeneration type	Evaluation of origin of regeneration (natural, planted, seeded)
Shrub height	Evaluation of shrub height
Soil moisture	Evaluation of soil moisture according to national or international standards of classification
Organic layer type	Evaluation of organic component of soil according to national or international standards of classification; mineral versus organic layers
Soil type	Evaluation of soil type according to national or international standards of classification
Development phase	Development phases or stages classifying the natural life cycle
Horizontal structure	Evaluation of the horizontal structure of trees and relative spatial pattern (single trees, groups of trees, etc.)
Vertical structure	Evaluation of the forest layer structure (one, two, more than two layers)
Tree age	Evaluation of age of trees
Tree crown length	Evaluation of crown length
Tree diameter	Evaluation of tree diameter at breast height
Tree health status	Evaluation of vitality or health status on the basis of crown (discoloration, transparency, etc.) or other parts of trees
Tree height	Evaluation of the tree height
Tree infections	Evaluation of the number of trees infected by fungi or other biotic damages including damages by game
Veteran trees	Evaluation of the presence of very old trees

### ***2.2.2 The Importance and Feasibility of Forest Biodiversity Variables***

The second step in the procedure consisted of constructing a questionnaire regarding the importance of the candidate variables for assessing forest biodiversity and their feasibility for assessment by NFIs. The questionnaire was made available online to the NFIs of all countries participating in COST Action E43. For each of the 41 candidate variables, the questionnaire included eight questions with predefined multiple choice responses and two questions with unspecified answers (Table 2.2). The experts who responded to the questionnaire had considerable NFI and biodiversity experience and were officially authorized by their countries to complete the questionnaire.

**Table 2.2** Questions included in the biodiversity questionnaire for each of the 41 candidate variables

Question		Possible responses	Description
1	Is the biodiversity feature important as indicator of forest biodiversity?	High importance Moderate importance Low importance	Subjective evaluation of the contribution of the biodiversity feature for the overall assessment of forest biodiversity. Medium refers to average contribution, high refers to essential feature candidates, low refers to an importance clearly lower than the average
2	How feasible is the monitoring of the biodiversity feature by NFI?	High feasibility Moderate feasibility Low feasibility	Assessed evaluation of the total amount of resources needed to incorporate the biodiversity feature in basic field protocols of traditional inventories
3	Is the biodiversity feature currently assessed in your country NFI?	Yes No	Indication whether the biodiversity feature is used or not in field activities of NFI of each country
4	What is the unit used to assess the biodiversity feature?	Open answer	Information regarding the unit used for measuring the biodiversity feature
5	Is the biodiversity feature assessed for all species/types or just for a part of it?	All Selection	Indication whether the biodiversity feature is assessed for all the investigated population or just for a sub-sample (i.e. in a pre-edited list)
6	Which is the source of information?	Sampling plot forest inventory Compartment forest inventory Research Other sources	Indication whether the biodiversity feature is assessed in the full implementation of (e.g. plot or standwise) NFI in the field phase, or if the biodiversity feature is assessed within research or experimental field tests just in selected areas
7	For which kind of land use the biodiversity feature is assessed?	Forest and other woody land Forest only Other woody land only Part of forest and/or other woody land	Indication whether the biodiversity feature is assessed for all population of forest and other wooded land sampling units or just in a sub-sample of it. Definitions of forest and tree may refer to Vidal et al. (2008)
8	What is the assessment method?	Measured Visual estimation Derivation/calculation Determination	Indication whether the biodiversity feature is assessed in the field work by measuring or visual estimation or mathematical derivation by other biodiversity features or proxy biodiversity features. Determination is for those biodiversity features assessed on the basis of pre-edited lists (typically for species)

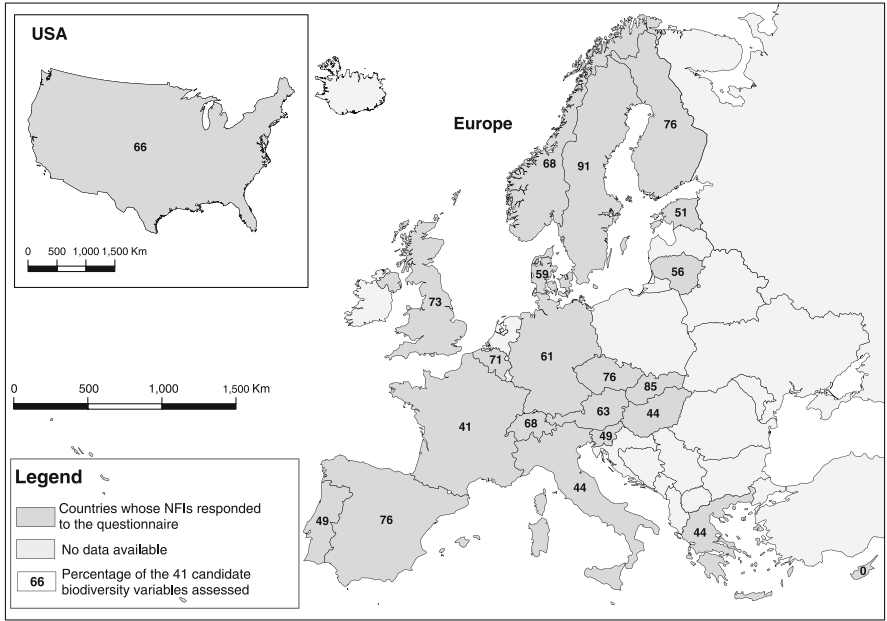
(continued)

**Table 2.2** (continued)

	Question	Possible responses	Description
9	What is the time series of the biodiversity feature in your NFI?	Open answer	Number of years of available comparable data (i.e.: if a NFI is carried out every 5 years and the biodiversity feature was acquired for 2 inventories, the time series is 10 years long)
10	What level of expertise is needed?	No expert Special training Expert	“No expert” refers to field staff usually devoted to field work in the NFI with ordinary forestry background and assessment skills. “Special training” refers to field staff with special training. “Expert” refers to staff with specialized education (e.g. lichenologists for epiphytic lichens, entomologists, soil scientists)

Responses to the questionnaire were received from 22 countries (21 European: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Lithuania, Norway, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom) and the Forest Inventory and Analysis (FIA) programme of the United States of America (USA)). No responses were received from countries such as Iceland, Ireland, Latvia that joined COST Action E43 at dates subsequent to the distribution of the questionnaire.

Generally, the more northern and central European countries already include more of the 41 candidate biodiversity variables in their NFIs than did Atlantic and Mediterranean countries (Fig. 2.1). Exceptions were United Kingdom and Spain which both include a large number of relevant biodiversity variables in their NFIs. All 22 responding countries already monitor at least 40% of the 41 biodiversity variables, and 17 countries already monitor at least 50% of the variables. Sweden has the most complete NFI for biodiversity assessment with 91% of the biodiversity variables already assessed, followed by the Slovak Republic with 85%, and the Czech Republic, Finland and Spain with 76% each. Deadwood in the form of big logs and snags is assessed by all responding countries with the exception of Hungary and Portugal. The Slovak Republic, Spain and Switzerland assess all eight of the questionnaire biodiversity variables related to deadwood. All countries assess tree species diversity; all countries except Germany and Hungary assess shrubs or other wooded species; 11 countries assess herbs and grasses; nine countries assess lichens; and six countries assess bryophytes. All responding countries can provide NFI information on tree age or veteran trees with the exception of Switzerland and the USA. All responding countries acquire some kind of information on forest management. Also, assessment of soils is common among NFIs, whereas assessment of fauna-related biodiversity variables is rare;



**Fig. 2.1** Countries whose NFIs responded to the questionnaire and the percentages of the 41 candidate biodiversity variables that their NFIs assess

only Germany records information on vertebrates and only Lithuania records information on birds.

Responses to the first three questions (Table 2.2) were used to evaluate the candidate variables with respect to their ecological importance and their technical feasibility for monitoring via NFIs. Analyses of responses to the other questions are reported in Chap. 3. Each NFI response for each of the 41 variables was assigned to one of three categories: low, moderate, or high. Variables assigned to the low category were assessed by the country NFI as less than average with respect to importance or feasibility; variables assigned to the moderate category were assessed as mid-level with respect to importance or feasibility; and variables assigned to the high category were assessed as important or feasible variables for assessing biodiversity. The assessment of importance was based on the utility of the variable for describing quantitative or qualitative aspects of forest biodiversity. The assessment of feasibility was based on the total resources in terms of manpower, time, knowledge, and both initial and current costs necessary to incorporate the biodiversity variable into the country's NFI.

Approximately two-thirds of the 41 candidate variables included in the questionnaire were evaluated as very important for monitoring by NFIs, whereas only approximately one-third were evaluated as very feasible. Most other biodiversity variables were evaluated as moderately important and feasible with only a few variables evaluated as less important or less feasible (Table 2.3). Variables evaluated

**Table 2.3** Importance and feasibility of candidate biodiversity variables

Variable	Importance				Feasibility			
	Countries responding	High (%)	Medium (%)	Low (%)	Countries responding	High (%)	Medium (%)	Low (%)
Invertebrate species	15	93	7	0	15	7	20	73
Fungal species	14	93	0	7	14	14	43	43
Lichen species	18	83	11	6	18	11	17	72
Veteran trees	17	82	18	0	18	66	28	6
Shrub species	20	80	15	5	20	45	40	15
Tree species	22	77	23	0	22	50	36	14
Big logs	21	76	24	0	21	33	62	5
Snags	20	75	25	0	20	45	50	5
Herb and grass species	18	72	17	11	18	12	44	44
Bird species	17	71	29	0	16	13	25	62
Naturalness	14	71	29	0	14	57	29	14
Development phase	16	69	19	12	17	53	47	0
Forest category	22	68	27	5	22	54	32	14
Other woody species	21	67	24	9	20	30	50	20
Trees age	20	65	35	0	19	21	42	37
Decay class	19	63	37	0	19	47	42	11
Horizontal structure	15	60	33	7	15	60	33	7
Vertical structure	16	56	31	13	17	70	24	6
Microsites	15	53	47	0	15	40	53	7



Information on recent disturbances/damages	19	53	37	10	20	55	40	5
Ecotones of Microsites	14	50	43	7	14	36	36	28
Vertebrate species	16	50	37	13	15	13	27	60
Information on forest management system	22	50	36	14	22	64	36	0
Soil type	20	50	35	15	20	25	35	40
Bryophyte species	15	47	53	0	14	14	43	43
Soil organic layer type	19	47	42	11	19	37	47	16
Deadwood species	22	45	37	18	22	36	59	5
Soil moisture	18	45	22	33	17	30	35	35
Regeneration species	18	44	50	6	18	39	44	17
Regeneration area	19	37	58	5	19	32	57	11
Tree infections	19	37	47	16	20	30	60	10
Tree diameter	22	36	59	5	22	41	50	9
Small logs	20	35	50	15	19	48	26	26
Stumps	18	33	61	6	18	44	44	12
Tree health status	18	33	56	11	19	37	58	5
Dead parts on living trees	18	33	50	17	18	61	33	6
Deadwood length	17	29	59	12	17	29	71	0
Regeneration type	18	28	61	11	18	72	22	6
Shrub height	18	28	33	39	18	50	39	11
Tree height	22	18	68	14	22	27	50	23
Tree crown length	19	16	37	47	19	37	47	16

(% refers to percentage of responding countries)

as very important are reported below with those also regarded as very feasible reported using *italics*:

- nine variables related to the number of species (*trees, shrubs*, bryophytes, fungi, herbs and grasses, invertebrates, lichens, and other woody plants);
- three deadwood variables (*snags, decay class* and big logs);
- three forest structure variables (*development phases, horizontal* and *vertical stand structure*);
- two individual tree attribute variables (*veteran trees* and age);
- two variables related to microsites (*occurrence of microsites* and their ecotones);
- two management variables (*information on forest management system* and *information on recent disturbances/damages*);
- *forest category* as it relates to the classification of forests on the basis of an ecological-based standardised system of nomenclature, and knowledge about the organic layer type;
- *forest naturalness*

The third step in the procedure was to combine the responses from individual country NFIs to obtain overall assessments of importance and feasibility for each candidate variable.

### 2.2.3 Ranking Biodiversity Variables

Based on the aggregation of the questionnaire responses, each of the 41 candidate forest biodiversity variables received an overall evaluation of its importance and feasibility using three measures.

- **Modal value:** Nominal values were assigned to each of the importance and feasibility categories: 1 for low, 2 for mid-level, 3 for high. The modal value is the nominal value associated with the greatest number of responses (Bühl and Zöfel 1999).
- **Index<sub>1</sub>:**

$$Index_1 = \frac{3 * n_{high} + 2 * n_{moderate} + n_{low}}{n_{responses}} \quad (2.1)$$

where  $n_{high}$ ,  $n_{moderate}$ , and  $n_{low}$  were the numbers of high, moderate and low responses, respectively, for each question, and  $n_{responses}$  was the total number of responses; values of  $Index_1$  ranged between 1 and 3.

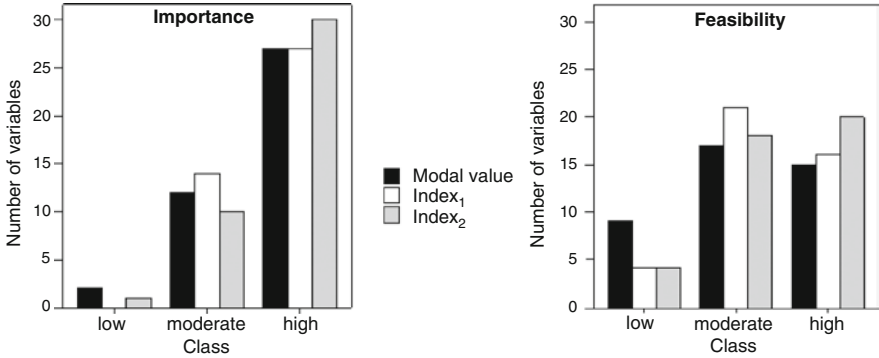
- **Index<sub>2</sub>:**

$$Index_2 = \frac{n_{high} + \frac{n_{moderate} + n_{low}}{2}}{n_{responses}} \quad (2.2)$$

where the definitions were the same as for  $Index_1$ ; values of  $Index_2$  ranged between 0 and 1.

**Table 2.4** Importance and feasibility thresholds and classes

Class	Modal value	Thresholds for Index <sub>1</sub>	Thresholds for Index <sub>2</sub>	Importance of biodiversity feature	Feasibility of biodiversity feature
1	3	>2.33	>0.66	Very important	Very feasible
2	2 and 2.5	1.66–2.33	0.33–0.66	Moderately important	Moderately feasible
3	1 and 1.5	1.00–1.66	0.00–0.33	Less important	Less feasible



**Fig. 2.2** Overall importance and feasibility of candidate variables for monitoring biodiversity in European forests

Each of the 41 candidate biodiversity variables was then assigned to an importance class and to a feasibility class on the basis of selected thresholds (Table 2.4).

The three combined evaluation indices (Modal value, Index<sub>1</sub>, and Index<sub>2</sub>) produced nearly the same results (Fig. 2.2).

As a means of evaluating the overall suitability of variables for assessing forest biodiversity by NFIs, the measures of importance and feasibility were combined using three indices:

- **Modal sum:**

$$Modalsum = m_1 + m_2 \quad (2.3)$$

where  $m_1$ =modal value of responses to questions of importance, and  $m_2$ =modal value of responses to questions of feasibility; values of modal sum ranged between 2 and 6.

- **Combination<sub>1</sub>:**

$$Combination_1 = \frac{Index_{1,importance} + Index_{1,feasibility}}{2} \quad (2.4)$$

where  $Index_{1,importance}$  and  $Index_{2,feasibility}$  are as defined in Sect. 2.2.3; values of  $Combination_1$  ranged between 1 and 3.

• **Combination<sub>2</sub>:**

$$Combination_2 = \frac{Index_{2,importance} + Index_{2,feasibility}}{2}$$

(2.5)

where  $Index_{2,importance}$  and  $Index_{2,feasibility}$  were as defined in Sect. 2.2.3; values of  $Combination_2$  ranged between 0 and 1.

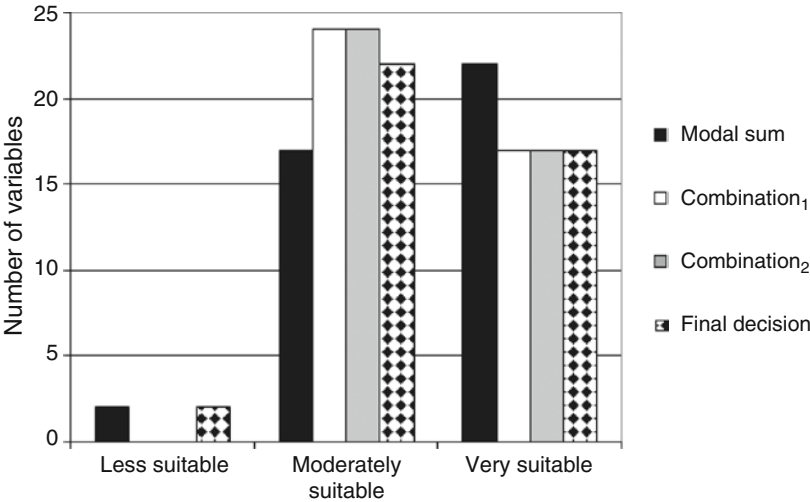
All 41 forest biodiversity candidate variables were then assigned to suitability classes based on the values of the combined indices (Table 2.5).

The combined data analyses showed that most of the 41 variables were evaluated as at least moderately suitable for assessing forest biodiversity (Fig. 2.3).

Only two variables, bryophyte species and crown length, were deemed less suitable for biodiversity assessments using NFI data. The bryophyte species were assessed as moderately important for reporting biodiversity and moderately to less feasible for field assessment (Table 2.3). The crown length variable was

**Table 2.5** Combined index classification of the importance and feasibility for candidate biodiversity variables

Modal sum	Thresholds for Combination <sub>1</sub>	Thresholds for Combination <sub>2</sub>	Suitability for forest biodiversity monitoring by NFI
5, 5.5 and 6	>2.33	>0.66	Very suitable
3.5, 4 and 4.5	>1.66–2.33	>0.33–0.66	Moderately suitable
2, 2.5 and 3	1–1.66	0–0.33	Less suitable



**Fig. 2.3** Distribution of the biodiversity variables by the three suitability categories

evaluated as least suitable for biodiversity assessments using NFI data. Most other plant and animal groups were evaluated as moderately suitable for NFI on the basis of high importance but low feasibility. For example, invertebrate species were considered as a very important biodiversity variable by 93% of respondents, but 73% assessed its feasibility as low. A second example is lichen species for which 83% of the experts responded that it was important but 72% evaluated its feasibility as low.

## 2.3 The Essential Forest Biodiversity Features

The results of combining indices of importance and feasibility were that 17 biodiversity variables were classified as very suitable. To simplify the harmonization analyses (Chaps. 3 and 5), 13 of the 17 variables were aggregated into seven groups which were then designated as essential features of forest biodiversity (Table 2.6). Of the four remaining variables, information on forest management system and recent disturbances were not selected because of their widely varying assessment methods among countries, suggesting a low potential for harmonization. Microsites and dead parts of living trees were not selected because they were generally not assessed by NFIs. However, lack of assessment for the latter two variables provides an opportunity for construction and widespread adoption of a common reference definition before individual NFIs construct their own differing national definitions, thus eliminating the need for harmonization.

**Table 2.6** The Working Group 3 essential features of forest biodiversity

Biodiversity variable	Number of countries that assessed the variable	Essential feature of forest biodiversity
Forest category	19	Forest categories
Development phase	11	Forest structure
Horizontal structure	10	
Vertical structure	16	
Trees species	21	
Tree diameter	21	
Big logs	19	Deadwood
Snags	17	
Decay class	15	
Regeneration type	19	Regeneration
Veteran trees	12	Forest age
Shrub species	16	Ground vegetation
Naturalness	10	Naturalness

## 2.4 Discussion

NFI participants seldom responded to all questions in the questionnaire. Thus, suitability assessments for bryophyte and fungi species, microsites and their ecotones, and forest naturalness are considered less reliable because they received few responses. However, the suitability assessments for tree diameter, height and species, forest category, deadwood species, and information on the forest management system are considered highly reliable for European countries and the USA because they received responses for both importance and feasibility from all 22 countries. Participants may reasonably be assumed to have provided responses mainly for biodiversity variables used by their own NFIs and for which they have assessment experience.

Additionally, participants may have responded more frequently to questions about biodiversity variables they regarded as having high or moderate relevance for biodiversity. Of the 41 candidate variables, the ranking analysis based on the modal value classified 26 of them as highly important for biodiversity monitoring by NFIs; only two variables were evaluated as less important. A possible confounding issue is that only a few biodiversity variables were classified as low with respect to importance or feasibility. This phenomenon may possibly be attributed to three factors. First, the reasons for selecting the biodiversity variables for inclusion in the questionnaire are ecologically based and are well-documented in the literature. Second, the participants may not have responded when they judged the importance or feasibility of a biodiversity variable as low or when they were not sure about its importance (13 variables were only assessed by 13–17 of the participating 22 countries). Third, some biodiversity variables such as microsites may be unfamiliar to participants whose countries do not assess them. However, increasing knowledge of forest ecosystems and their biodiversity and natural structure could change this judgment in the future.

Beyond these possible limitations, information obtained from the questionnaire and the subsequent analyses clearly showed that currently most of the 41 candidate forest biodiversity variables are monitored by the 22 NFIs that responded to the questionnaire. With respect to the number and type of questionnaire biodiversity variables, the FIA programme of the U.S. Forest Service collects an average amount of information. In addition, most of the countries already collect information on nearly all the essential biodiversity features (Table 2.6).

The importance and feasibility analyses clearly confirmed that NFIs prefer biodiversity variables based more on forest structure indicators such as vertical, horizontal and tree compositional diversity or deadwood than on direct biological diversity measures of animals such as birds and invertebrates or vegetal life forms such as bryophytes, fungi, herbs, grasses and lichens. In general, biota biodiversity variables were evaluated as important but not feasible because their assessment is excessively intensive relative to time, cost, and necessary expertise. However, the thematic resolution of information on structural indicators is much coarser than the fine resolution information associated with individual species and their ecological

niches. Thus, biodiversity assessments based on structural variables cannot produce estimates that are fully comparable to results obtained from direct measures of biodiversity.

The responses to the other eight questions indicated in Table 2.2 and to a second questionnaire on methods used by NFIs to assess variables associated with the essential features of forest biodiversity are reported in Chap. 3.

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National Forest Inventories: Contributions to Forest  
Biodiversity Assessments

Chirici, G.; Winter, S.; McRoberts, R.E. (Eds.)

2011, XVIII, 206 p., Hardcover

ISBN: 978-94-007-0481-7