

# Establishing Forest Inventory Reference Definitions for Forest and Growing Stock: a Study towards Common Reporting

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International agreements such as the Kyoto protocol and Convention on Biological Diversity (1992), as well as, criteria and indicator processes require reports on the status of nations' forests. Any comparison of the current status and trends of forest resources among nations presumes that the nations' applied definitions and concepts produce comparable estimates of the status of forests. In spite of this, the FAO has already collected global information for 60 years and made noticeable efforts in creating common definitions, but forest related data are still collected using diverse definitions, even regarding basic concepts such as forest and forest area. A simple consequence is that the cross-countries estimates are not comparable. The reasons behind the differences in the definitions are diverse histories, and sometimes different use of forests. In an ideal case, national forest inventories should fulfil both national and international needs. In addition to the FAO's Forest Resources Assessment process, other efforts are made to assess the status of forests in European countries, e.g. European Forest Information and Communication System (EFICS). EFICS produced reports about forest inventories but does not suggest any common definition or method to convert estimates from one definition to another one. This article presents principles and methods to create commonly acceptable and adoptable definitions for forest inventories. The principles and methods are demonstrated using two examples: the reference definitions of forest and growing stock. The article is based on the work of COST Action E43 (<http://www.metla.fi/eu/cost/e43/>).

**Keywords** National forest inventories, reference definitions, growing stock, harmonisation, analytical decomposition

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# 1 Introduction

## 1.1 Need for Harmonised Forest Information at the International Level

The role of forests and forestry varies among European countries. Industrial use of timber is still the main benefit of forests in many European countries, while the role of forests in global carbon balance as well as in non-wood goods and services – including protection, recreational aspects and biodiversity – is gaining more importance especially in urbanised societies.

The need for information about forest and its functions at both the national and international levels is increasing. Traditionally, forest information has been collected through user-driven national forest inventories (NFIs). The NFIs have different histories in different countries. Various forms of information were gathered in many countries (e.g. Belgium, France, United Kingdom) in 19th century, but systematic assessments based on sampling started in the 20th century. In Europe, the first sample-based inventories began in the Nordic countries in the early 1920's. Many other countries followed from the 1960's to the 1990's. Today, sampling inventories are conducted in most European Union (EU) countries. However, some European countries still gather national data by aggregating stand inventories originally designed for management planning purposes. The total number of field plots visited in Europe is over 500 000. As a result, the NFIs are major information sources of forest information in Europe in terms of precision and exhaustiveness.

With the changed role of forests, the scope of NFIs has broadened and new variables for assessment have been introduced to address both national needs and the need for common reporting at the international level. The needs emerge from international conventions and policy processes, such as the Kyoto protocol addressing climate change. In the framework of the Ministerial Conference on the Protection of Forests in Europe (MCPFE) (<http://www.mcpfe.org/>), the European Countries and the EU have agreed on 35 indicators, for the evaluation of the forest management sustainability. Many of these indicators originate from NFIs and are reported in the FAO's

(Food and Agriculture Organization of the United Nations) Forest Resources Assessment (FRA) (<http://www.fao.org/forestry/site/1191/en/>).

FAO has compiled the Forest Resources Assessment (FRA) at the world level (Global FRA or GFRA) and UNECE/FAO (United Nations Economic Commission for Europe) has compiled the Temperate and Boreal Forest Resources Assessment (TBFRA) from NFIs since 1946. The first FRA report was published in 1948 (FAO 1948). FAO's FRA work is notably assisted and supported by expert consultations, Kotka I to V, the advisory board and regional teams of specialists, e.g., the TBFRA Team of Specialists and the UNECE/FAO secretariat in Geneva. The countries are asked to report estimates according to the commonly agreed FRA definitions. If the FRA and the national definitions differ, countries have to report the process used to derive FRA estimates. A new feature in FRA 2005 was the prediction and extrapolation of the data to selected time points, 1990, 2000 and 2005 (FAO 2005). Common definitions had to be applied to data in all time points. In many cases, FRA 2005 and also FRA 2000 definitions were adopted after 1990 or even after 2000, or have not been adopted at all (FAO 2005, FAO 2000). The lack of tools to convert data from national definitions to the FAO FRA definitions implied that the final reported results are not comparable.

Global Forest Resource Assessments 2000 and 2005 (FAO 2000, FAO 2005) included several new variables to meet the new information needs. These new variables have been planned and defined in expert level meetings organised by FAO and UNECE/FAO. FRA 2000 was the first assessment to use a homogeneous set of global definitions and it is, to date, the most comprehensive assessment of global forest resources. Yet, the FRA 2000 and FRA 2005 reports indicate severe problems in the harmonisation of some variables, not only forest and volume of growing stock, but also definitions for natural forests (no human intervention), forest available for wood supply and forest area by protection categories. Also, implementing the harmonised definition of base line variables (e.g. forest) in practical data collection has been problematic.

The need for harmonised European forest information is critical with the development of

international conventions and reporting activities on topics involving forestry, e.g. the Convention on Biological Diversity (Convention ... 1992), the Intergovernmental Panel on Climate Change (IPCC 2003), the UN Framework Convention on Climate Change (United Nations 1992) or the Kyoto protocol. Some Europe-wide data collection systems exist, e.g. ICP Forests (International Co-operative Programme on assessment and monitoring of air pollution effects on Forests), carried out since 1994 (ICP-Forests 2007), or LUCAS (Eurostat 2000) and CORINE Landcover (Büttner et al. 2002), but none of them can provide adequate data to meet the actual needs and to cover, at the same time, different scales and a long period.

As a result, one of the solutions for providing data at the international level covering major forestry interests, like wood production, biodiversity or carbon pools, is to use NFI data that will eventually be combined with data from other monitoring systems. But this implies that we will have to face the same difficulties as the FAO for the FRA: practices and definitions differ between countries. As a consequence, the harmonisation of NFI results is required to take advantage of the quality of their assessment at a scale larger than the national level.

## 1.2 Earlier Research on Common Practices in Europe

The EU Council Regulation (EEC) No 1615/89 extended by Council Regulation (EEC) No 400/94 established a European Forestry Information and Communication System (EFICS) (European Communities 1997). The objective of EFICS was to collect comparable and objective information on the structure and operation of the forestry sector in the community. Within this context, the European Commission entrusted the European Forest Institute (EFI), in 1996, with a planning task with the overall aim to analyse in detail the sources of forest resource statistics in the EU Member States. The EFICS study produced detailed information on differences and similarities among NFIs in EU countries and some other countries in Europe. It was found that there is a set of key variables of interest to all stakeholders,

and not all of them were sufficiently harmonised between the NFIs in European countries.

A significant number of European countries participated in project FAIR CT98 4045, funded by the European Commission on ‘Scale Dependent Monitoring of Non-Timber Forest Resource based on Indicators assessed in Various Scale’ (Scale-dependent monitoring... 2003). The project identified appropriate characteristics and indicators applicable over different ecological zones. Large area harmonised forest resource information is presented in the report of the ‘Bionord’ project, funded by the Nordic Council of Ministers (Stokland et al. 2003).

The European office for the development of CoOperation in the field of Scientific and Technical research (COST 2007) supported several cooperations of European institutes. COST Actions E4 “Forest Reserves Research Network” (Parviainen et al. 1999) and E27 “Protected Forests in Europe – analysis and harmonisation” (Frank et al. 2007) have provided valuable information for improving the harmonisation of protection categories in close cooperation with the TBfRA national correspondents (COST E4 1999, COST E27 2007). These Actions improved the harmonisation level of protection categories and the definition for natural forests, which are important elements of sustainable forestry. These results have been utilised in the context of the Ministerial Conference on the Protection of Forest in Europe (MCPFE).

Outcomes of earlier research on common practices showed that harmonisation in the field of forestry could provide good results, but much work had to be done concerning basic NFI definitions to be able to provide harmonised results.

## 1.3 ENFIN and COST Action E43

In order to respond to the need for harmonised information at the European level, representatives of the European National Forest Inventories established an informal network called ENFIN – European National Forest Inventory Network. ENFIN initiated an EU COST Action project, to work towards to the goal that NFIs would be able to provide comparable forest resource information. COST Action E43 was launched in June of 2004. Twenty-seven European countries

have joined the action (Fig. 1). The total area of the countries in the Action is 4 374 680 km<sup>2</sup> and the total forest area is estimated to be 1 534 210 km<sup>2</sup>. Furthermore, United States Department of Agriculture, Forest Inventory and Analysis (FIA) Program and New Zealand, Ministry of Environment, Carbon Monitoring System have joined COST Action E43 as non-cost participants.

The findings of the EFICS study provided a good baseline for COST Action E43. Further, the study has been followed by developing a prototype of a European Forest Information System (EFIS) for the Joint Research Centre (JRC) of the European Commission (Contract No 17186-2000-12 F1ED ISP FI), aiming at resource discovery and data presentation.

Since the EFICS study, new countries and new forest information needs have emerged and the scope of forest inventories has widened. Moreover, many countries changed the design and data collection system of their NFI. Currently, one of the most important tasks of NFIs, in addition to providing data for building national forestry plans and assessing their sustainability, is to produce information on forest carbon pools and carbon pool changes. The level of harmonisation in measurement and estimation procedures related to carbon balance was very low when COST Action E43 was established. The example of carbon balance reporting emphasises that there is a need for an international forum where European NFIs can respond to new information needs, discuss and further develop scientifically sound estimation procedures and definitions related to both traditional and new variables. Another issue is measuring and monitoring biodiversity in such a way that the results are comparable over many countries.

#### 1.4 The Concept of “Reference Definition”

The main objective of COST Action E43 is to improve and harmonise the concepts and definitions of the existing national forest inventories in Europe in such a way that the inventories will provide comparable forest resource information. The other objectives are, 1) to support new inventories so that they will meet national, European and global level requirements in supplying up-to-date,



**Fig. 1.** 27 European countries participating in the COST Action E43.

harmonised and transparent forest resource information, and 2) to promote the use of scientifically sound and validated methods in forest inventory designs, data collection and data analysis. The Working Groups of COST Action E43 collected, analysed and will distribute information concerning currently applied definitions, measurement practices and methods to improve the dialogue among NFIs on the one hand and between NFIs and NFI data users on the other.

The ultimate goal is to enable the creation of the European forestry information services from the national level inventories, so that the benefits from inventories will be improved, promoting the advantage of local knowledge and satisfying the local requirements together with international requirements. The goal is also to maximise the synergy among NFIs and European and global level processes and policies that require forestry information.

The first step towards harmonisation is to define the target. In our case, the target is to provide harmonised estimates of relevant variables. Each estimate is the result of the assessment of a variable (e.g. area, volume, and mass) for a clearly

defined object (e.g. forest, growing stock, tree biomass). When countries' definitions differ, results are not comparable. As a result, the first step consists of listing the relevant variables that are to be estimated and to create a precise and unique definition, called "reference definition", in such a way that the differences between national definitions and the reference definition can be determined.

Work Group 1 (WG1) of COST Action E43 works towards proposing reference definitions to be used for international reporting and developing recommendations for new definitions and measurement practices to be applied in NFIs, which will form a crucial part of NFI methodology.

WG1 reviews the current practices and definitions of NFIs conducted in participating countries, and their differences. A core set of objects are identified which are needed to produce harmonised basic forest inventory results. For these objects, reference definitions and harmonisation procedures will be created. Information needs of international agreements and processes, such as FAO/FRA, UNFCCC, Biodiversity agreement and MCPFE will be taken into account in selecting the objects. WG1 will produce recommendations for definitions and measurement practices to be applied in NFIs.

WG1 also works on methods to convert forest inventory estimates based on non-reference definitions to correspond to the estimates based on reference definitions.

The two other working groups of COST Action E43 also aim at harmonising indicators derived from the national forest inventories to meet the international needs. WG2 builds a status of forest carbon stock and flux estimations and proposes references to ensure the comparability of the carbon accounts. WG3 aims at defining common indicators of biodiversity and finding out how to compute them.

The main purpose of this article is to present a method to create commonly acceptable and relevant definitions for forest variables, called reference definitions. The reference definitions should meet international requirements and be applicable at the national level. This method is demonstrated by two practical examples: the reference definitions for forest and for growing stock.

## 2 Material and Methods for Building Reference Definitions

### 2.1 Material

Existing definitions were developed at different geographical scales but mainly at the national and the international levels. At the country level, they are usually elaborated for national purposes, sometimes taking into account national legislation and international process considerations. International definitions usually result from a consensus of country representatives.

Due to the multiplicity of definitions for the same object, an exhaustive review of existing definitions was first required. The review was based on a) a collection of definitions published at the international level and b) an in-depth analysis of specific questionnaires on national definitions addressed to countries.

The international definitions were extracted from the FAO Global Forest Resource Assessments (FAO 2000 and 2005), UNECE/FAO Temperate and Boreal Forest Resource Assessments (UNECE/FAO 2000), IPCC (2003) and CBD reports.

For national definitions, two questionnaires were prepared by COST Action E43 WG1. The first questionnaire aimed at collecting basic information. It was complemented by a second one to check for misunderstandings and to improve the results. Both questionnaires included different aspects such as 1) the origin of the forest definition (e.g. if the definition was established in relation to FAO definition) 2) the inclusion of different variables and threshold values (e.g. a minimum extension for wooded areas) 3) considerations about the applications of these definitions, the assessment method, the possibility of providing data according to different definitions, even when these definitions are not applied for national purposes. This collected information is stored in a database for easy use, and it is the basic material for the establishment of "reference definitions".

NFI definitions refer to many terms that are usually not defined by NFIs, e.g. tree, shrub, stump, stem, bark. To create precise and clear reference

definitions, a good understanding of these terms is required. In this publication, we will use the terms in the general botanical and forestry sense.

## 2.2 Principles for Reference Definitions

Reference definitions are first established for common reporting at the international level. They must be consistent with the definitions used in international processes. Other issues, like local or regional analysis of questions concerning several countries (e.g. study on the alpine space), should also be possible using these definitions. They shall provide directives for forthcoming international reporting processes and national or regional studies that require international comparability.

As a result, nine criteria were identified to create a sound reference definition. A reference definition:

- shall be adopted by national and international institutions for international reporting (“**Acceptability**”).
- must be free of particular interests of individual NFIs, countries or stakeholders. It should not be designed under the pressure of any institution or country (“**Objectivity**”).
- must be easily grasped and clearly stated, such that no room is left for ambiguous interpretation (“**Clearness**”).
- shall cover all relevant cases. Points that would have a minor impact on the result should not be integrated if they induce too many complications (“**Sufficiency**”).
- must meet forestry, industry and environmental policy needs and industry requirements both at the European and at the national level. It should be usable for several purposes so that the effort put on building bridges and providing data according to the definition do not have to be multiplied (“**Usefulness**”).
- must be valid in the long-term to provide a stable and definite goal to which countries can stick to in the long run and to enable time comparisons (“**Sustainability**”). However, reference definitions might be reviewed from time to time to correspond to the current needs.
- is not an instrument to assess the quality of individual NFIs. It is not designed to evaluate the quality of definitions used at the national level (“**Neutrality**”).

- must be such that existing European national forest inventories are capable of providing results conforming to the reference definitions (“**Practicability**”).
- is a definition of an object. It is not a measurement instruction, and is valid independently of the measurement device applied in the survey (“**Measurement device independency**”).

These principles have to be taken into account during the establishment of a reference definition. Therefore, the method to create such reference definitions is designed in such a way that it creates favourable conditions for the achievement of the principles.

## 2.3 Method

To build the reference definition of an object while respecting the previous principles, a four steps method is used:

- 1) Existing national and international definitions are reviewed.
- 2) The “space” in which the object is included (e.g. the inventoried territory for forest land) is decomposed using a 2-step analytical decomposition: first, a list of variables used to characterise the object is elaborated and second, classes are created for each variable.
- 3) Relevant variables and criteria are selected using a “weighted average” to get an optimal definition.
- 4) The reference definition is written and reviewed until final acceptance.

### 2.3.1 A required Analytical Decomposition Approach

The existing international definitions were applied as the starting points in designing reference definitions. However, these definitions are not necessarily unique or leave room for different interpretations. Therefore, they cannot necessarily serve as unique reference definitions.

Our approach is to identify the core variables and their values applied in definitions, e.g. for forest definition: 1) crown cover at maturity in situ and its values 2) land use and its categories. Definitions usually imply several variables, and therefore, require a multi-dimensional approach.

Variables employed in definitions are firstly listed. Each variable represents a dimension in the multi-dimensional space of the definition. The value space of each variable is divided into interval classes (continuous variables) or categories (nominal scale variables). Interval classes and categories are derived from the reviewed definitions.

This process creates a partition of the multi-dimensional space. Here, it has been called “analytic decomposition”. The analytic decomposition is object-specific, i.e. for each object (forest, tree...), there is one analytic decomposition. Choosing a definition consists of deciding, for each single part of the partition, if it is included or not. The decomposition can be used to represent any existing definition.

Analytic decompositions are necessary for the comparison of different definitions, highlighting their similarities and differences. Therefore, it is a useful tool for designing the final reference definition. It also helps in identifying differences between national definitions and the reference definitions and in evaluating the impact of these differences on the results. This is the last step before the establishment of a tool called “bridge” to convert data obtained according to one national definition to the results corresponding to the reference definition.

### 2.3.2 Mathematical Description

Let us formulate the analytical approach in a mathematical way.

Our target is to split an object into classes. Let us denote the set of objects to be considered by  $O$ , e.g., land or a set of trees, and  $o$  an element of  $O$ , e.g., a field plot, a single tree. In mathematical notations,  $O$  is the space of the elements  $o$ . The purpose is to classify first the elements  $o$  into the classes denoted by  $C$ ,  $C = \{C_1, \dots, C_s\}$  (e.g. forest land, other wooded land, other land for a land use classification) and also to carry out a delineation of  $O$  to classes denoted in a same way, i.e.,  $C = \{C_1, \dots, C_s\}$ . The subsets of  $O$  resulting from the delineation, form a finite partition of  $O$  denoted by  $O = \{O_1, \dots, O_n\}$ . Please note that  $C$  refers to the names of the classes and  $O$  to the

physical objects. There is an injective mapping from  $O \rightarrow C$ .

Let us denote the set of variables applied in the classification – i.e., in attaching an object  $o$  to a class  $C_i$  – by  $V$ ,  $V = (V_1, \dots, V_p)$ .

Let us denote by  $g$  a function which maps the elements of the space  $O$  to the space of variables  $V$ ,

$$g: O \rightarrow V$$

$$o \rightarrow v = g(o)$$

Let us denote by  $f$  a function which maps an element of the space of variables  $V$  (i.e., a vector  $v \in V$ ) to the class space  $C$ ,

$$f: V \rightarrow C$$

$$v \rightarrow f(v)$$

The composite function  $h(o) = (f \circ g)(o) = f(g(o))$  maps an object  $o \in O$  to a certain class  $C_i$ . Different classification applies different function  $f_i$ . Each function  $f_i$  creates a finite partition of the value space of the variables  $V$ , denoted by  $P_i$ , i.e.,  $P_i$  is a finite family of nonempty subsets of  $V$ , pairwise disjoint and with union  $V$ . Let us denote the smallest Boolean  $\sigma$ -algebra generated by  $P_i$  by  $\mathcal{A}_i$ .

#### Definition

An international or national classification rule is a composite mapping  $h_i = f_i \circ g : O \rightarrow (V, \mathcal{A}_i) \rightarrow C$  in such a way that the rule creates a partition of the space  $O$  into subsets  $A_i$  so that they are disjoint, i.e.,  $A_i \cap A_j = \emptyset$  when  $i \neq j$  and the  $\bigcup_i A_i = O$  and each element  $o \in O$  and for all  $i$   $o \in O$  there exist a unique  $C_i$ .

This classification rule includes two mapping functions:

- 1) the measurement of variables:  $g: O \rightarrow V$  applied to the object to be characterised. This function makes it possible to classify each variable of an object in a subset of  $V$ ;
- 2) the classification of the object:  $f: V \rightarrow C$  that makes the link between the observed variables and a class.

Let us denote by  $P$  the finite partition of space  $V$  which is finer than any partition  $P_i$ ,  $i = 1, \dots, m$  and by  $\mathcal{A}$ , a Boolean  $\sigma$ -algebra generated by  $P$ . This Boolean  $\sigma$ -algebra is called an “analytic decomposition” of space  $V$ .

An example: Let us suppose that two variables are applied in land use classification: the crown cover of trees at maturity *in situ*  $V_1$ , and the minimum patch size  $V_2$ . Let us suppose that the thresholds 5% and 10% are applied in one country, for other wooded land and forest land respectively, and the threshold 5% and 20% in an other country. Let also suppose that the minimum patch sizes are respectively 0.5 ha and 0.25 ha. Then,  $\mathcal{A}$  is the Boolean  $\sigma$ -algebra created by the partition  $[0, 5], (5, 10], (10, 20], (20, 100]$  in space  $V_1$  and the partition  $[0, 0.25], (0.25, 0.5], (0.5, \infty]$  in space  $V_2$ .

### 2.3.3 Choosing Variables and Values

After an analytic decomposition has been defined, the next phase is to select the subsets of the space  $V$  employed in defining the reference definition, which is a general classification rule.

For each value of each  $V_i$ , applied in classification – i.e., defining the function  $f_i$  – the following criteria were evaluated:

- the frequency of use in national definitions;
- the availability of data for the value of  $V_i$  in countries in which it is not the national definition;
- the relevance for international reporting;
- difficulties (major problems) in using a definition including this value of  $V_i$ .

A reference definition is a combination of functions  $h = f \circ g$  that creates a partition of space  $O$  in such a way that it follows the partition caused by an international definition ‘as much as possible’ and it makes it possible to apply national rules ‘as much as possible’.

We formulate this, using mathematical notations, as follows:

We define a weighting (set) function  $W = \{W_1, \dots, W_p\}$  from the space  $(P, \mathcal{A})$  to real axis  $R$ . The value of the function  $W_i(A)$  could, for example, be the area or the volume of growing

stock falling into class  $A$ . As an example, in the case of forest,  $W_1$  could tell the land area assessed using a specific “tree crown cover at maturity *in situ*” subset, or in the case of volume of growing stock, how big the proportion of volume is assessed “including the stem top” (Chapter 4.3.3). In the Chapters 3 and 4, the values of  $W_i$  functions,  $i = \{1, \dots, p\}$  are presented in tables. To compute the total area, the forest area or the growing stock on which definitions are applied, harmonised data from NFIs are not available yet. We consequently use the latest status of forests at the European level published in the Global Forest Resources Assessment 2005 report (FAO 2005).

A similar weighting function is developed to analyse the availability of data for a specific class  $A$ , even if this class is not included in the national definition.

The relevance to include a class  $A$  in the reference definition for international reporting is a result from discussions. It is determined by taking into account the compatibility of this class with existing international definitions. The relevance is a binary function (has the values 0 = not relevant, and 1 = relevant). Only the value “1” is accepted.

The difficulty for a country to provide data included in the class  $A$  is evaluated by each data producer.

From a practical point of view, tables are built to present the available and applied information. The decomposition and the selection are done in two steps. First, the applied variables  $V_i$  are listed (e.g., the “minimum land area”, or the “minimum DBH”). Second, the value space of the variable is partitioned using all values used in the definitions. The partition can be based on a quantitative value (e.g. minimum crown cover of 10%) or a qualitative value (e.g. land use is wood production, agriculture...). The possibilities are represented in a table.

In the working group the necessity or the interest to use a certain variable or its value in a reference definition is agreed, according to the type of expected reference, the principles to build the reference (see Chapter 2.2) or discussions.



### 2.3.4 Preparation of the Reference Definition

As presented in the previous paragraph, after an analytical decomposition of the space of the object, the creation of a definition consists of the selection of classes included in the definition. The weighting results show the classes that are always included in the existing definitions of an object. These “core classes” will be integrated in the reference definition of this object. The integration of other classes is discussed on the basis of the results of the weighting functions.

Definitions include many variables whose conjunction let us determine if the characterised object corresponds to the definition. The definition has to be written in the most effective and simple way, therefore, the definition should start with simple characteristics that allow delimiting the object to be analysed. Then information on this object can be used to determine if it fits into the definition. However, it is sometimes impossible to define which variable comes first. For clearer understanding of the reference definition, determination schemes are proposed with the written composed version.

Reference definitions are built for common purposes. As a result, they have to be accepted by all countries involved in the harmonisation process. Therefore, the work is conducted in close co-operation. The proposal built by a small group is submitted to the community for improvement until adoption. This way, the support of all NFIs is ensured.

The method described previously is used to create reference definitions. Two practical examples will follow: reference definitions for *forest* and *growing stock*.

## 3 Forest

### 3.1 Forest and Other Wooded Land: Two Related Key-Definitions

The perception of forest is subjective since it may be influenced by local ecological, cultural and economical factors. For the purpose of forest inventory, an objective definition is required. In this sense, for the NFIs needs, forest is an

“object”, which corresponds to a well defined type of land. This object has to be defined by objective variables, some of which can be measured. The case is similar for other wooded land.

Forest and Other Wooded Land (OWL) are of major importance for NFIs. Classifying a piece of land as forest or OWL determines the assessment that will be made, e.g. tree measurement. Moreover, forest and OWL areas are first outcomes of NFIs.

These two land categories are disjoint (i.e. a single place cannot be forest and other wooded land at the same time in the same assessment). It implies that the two definitions use the same type of variables ( $V_i$ ) but with different value subsets. As they are highly related, they cannot be independently created. Therefore, OWL definition is partly discussed in this paragraph that mainly focuses on forest definition.

### 3.2 Review of Forest Definitions

At the international level, many definitions have been developed, depending on the issue of international processes. FAO proposed a first common definition in 1998 for the compilation of data in the GFRA 2000 (FAO 1998, 2001). This definition was used for the UNECE/FAO regional reporting: TBFRA 2000. It was slightly modified in 2000 (FAO 2001). The same general definition has been adopted recently in GFRA 2005 but with rewording and slight adjustments of land use inclusion/exclusion from forest. Since 1998, many international processes based their forest definitions on the FAO definition, e.g. the Convention on Biological Diversity (1992), the Ministerial Conference on the Protection of Forest in Europe, and the Intergovernmental Panel on Climate Change (IPCC 2003), with a slight modification that consists of indicating the threshold value range instead of a single threshold value for quantitative parameters. Lund (2006) presents a decision tree and dichotomous key for classifying lands according to the Good Practice Guidance for Land Use, Land Use Change and Forestry (GPG-LULUCF) (IPCC 2003).

FAO definition can be expressed as follows:

*“Forest is land spanning more than 0.5 ha with trees higher than 5 metres and a canopy cover of more than 10%, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.”*

This definition also includes explanatory notes about what is meant by “not under agriculture or urban land use” and adds a minimum width of 20 m for windbreaks, shelterbelts and corridors of trees.

The review of forest definitions applied in the twenty-seven European countries participating in Cost Action E43 shows a high diversity. However, most definitions have the same structure: a list of measurable quantitative variables together with threshold values and qualitative variables. They consider at the same time land use and land cover variables. Differences mainly arise from the threshold values established for quantitative parameters, and from the land use categories to be referred to as forest. Concerning land cover, most common quantitative variables are “area” and “width” of the place to be characterised and “tree crown cover” in this area.

Differences among national definitions are sometimes related to the type of vegetation in each country and to all the local aspects that affect the idea of forest, as discussed above. For example, countries where coppice forests are common have usually lower crown cover threshold than countries where more natural type forests or artificially regenerated forests are common. However, the study reveals an increase in the use of the FAO definition at the national level in Europe during recent years. At the present time, seven countries base their national definition on that used for the GFRA 2000 (Cyprus, Denmark, France, Greece, Italy, Netherlands, Portugal). The land area of these countries is approximately 27% of the twenty-seven countries’ area. In the Scandinavian countries (Finland, Sweden and Norway), a national definition is in use but data are also collected using the FAO definition (with slight adaptations in Norway, where a minimum potential height for trees is not required) in order to provide harmonised data for international reporting. Austria, Switzerland and Iceland will be able to provide data according the FAO definition from

their next NFI cycle. As a result, the NFIs from 10 countries collecting data on 52% of the total area of the 27 countries can provide information about their forest area according to the FAO definition. Their total forest area covers 61% of the forest area in these 27 countries (Fig. 2).

However, GFRA 2000-derived national definitions differ slightly from the original definition. It might be a marginal difference in the threshold, e.g. in Greece, the minimum width of a strip of land is 30 m. Some differences are also driven by the need for more precision when determining if an inventory plot is in forest or not – e.g. if the minimal width is to be measured from stem to stem, from crown to crown, etc. – or if a forest road, a river, a firebreak, a glade, etc. should be counted as forest usually depending on their size.

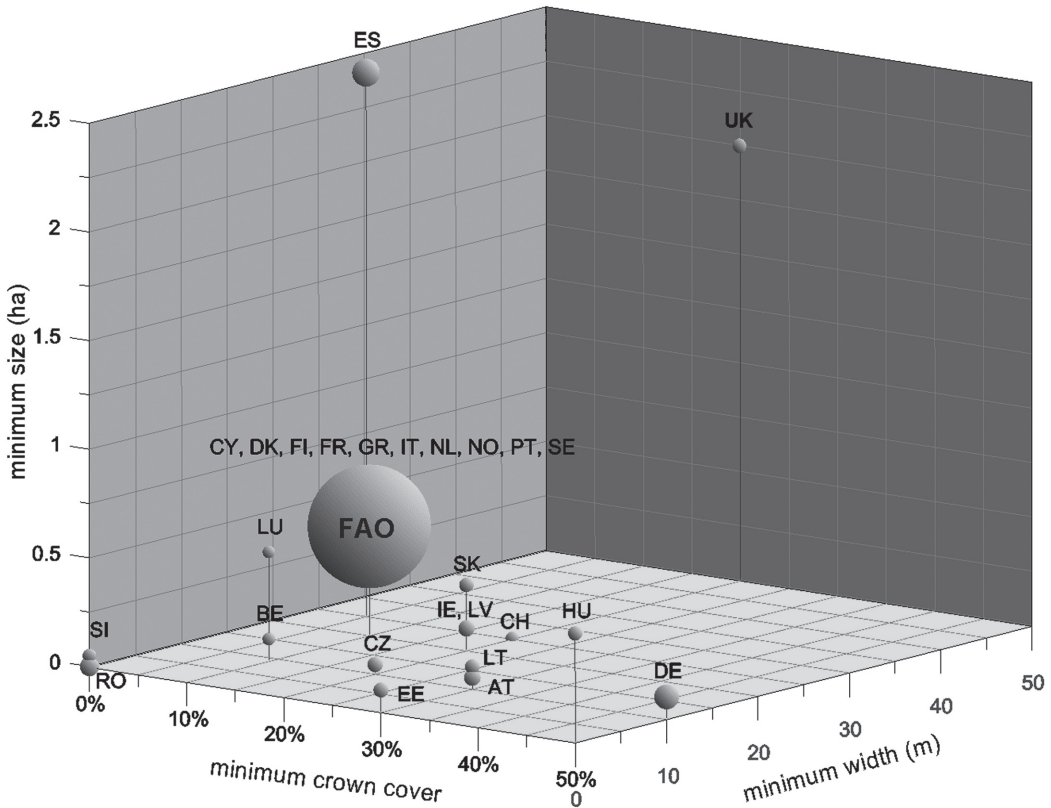
In a few countries additional variables are also taken into account, e.g. minimum productivity in terms of annual volume increment or legal designation of the territory. These variables are not included in the FAO definition.

### 3.3 Two-Dimension Analytical Decomposition

#### 3.3.1 Two Dimensions of the Space of Land Definitions

To prepare a reference definition, we have to clarify the object and the set it belongs to. Forest  $C_1$  and other wooded land  $C_2$  belong to the land categories  $C$ . They are used to classify pieces of land  $o$  in a set  $O$  that consists of the whole territory. The joint definitions of forest and other wooded land in a country  $i$  can be analysed as a classification rule  $h_i: O \rightarrow C$ . These classification rules use variables  $V_j$  in  $V$ .

Land cover and land use are strongly related, but have different meanings and assessments. Land cover can be presented as the physical coverage of land, usually expressed in terms of vegetation cover or lack of it (Hassan et al. 2005). Land use is the total arrangement, activities, and inputs undertaken in a certain land cover type (a set of human actions); the social and economic purposes for which land is managed (e.g. grazing, timber extraction, conservation) (IPCC 2000).



AT: Austria; BE: Belgium (Walloon region only); CH: Switzerland; CY: Cyprus; CZ: Czech Republic; DE: Germany; DK: Denmark; EE: Estonia; ES: Spain; FI: Finland; FR: France; GR: Greece; HU: Hungary; IE: Ireland; IS: Iceland; IT: Italy; LT: Lithuania; LU: Luxembourg; LV: Latvia; NL: Netherlands; NO: Norway; PT: Portugal; RO: Romania; SE: Sweden; SI: Slovenia; SK: Slovak Republic; UK: United Kingdom  
 FAO: Food and Agriculture Organization

**Fig. 2.** 3D representation of the three main variables (and their threshold values) used in national forest definitions (Finland, Norway and Sweden taken into account in the FAO bubble). Volume of spheres is proportional to the total forest area already assessed using these threshold values. A “zero” value is used when a parameter is not considered. Length of axis is conventional because the influence of each parameter is still unknown and, most importantly, possibly vary country by country as a consequence of the variety of vegetation characteristics at the continental scale.

Land cover and land use can be analysed independently or one after the other but both of them are used in the definition. In this example, we only present the case of land cover decomposition.

### 3.3.2 Example of Land Cover Decomposition

Land cover variables consist of several aspects characterising the type and size of areas to be considered. To select variables that must be integrated in the reference definition of forest, we extract the

ones that are used in existing definitions. Then, we analyse their frequency (computed using GFRA 2005 results) and relevance (Table 1).

The most commonly used variables are the “minimum area” and the “minimum tree crown cover”. Switzerland is the only country in which no minimal area is defined. However, a minimum width of 25 m is used as well, which implies that the smallest piece of land that can be considered forest is a 0.049 ha circle. A “minimum area” variable must be integrated in the reference definition.

**Table 1.** Variables used in forest and other wooded land according to national definitions.

Variable	Use	Number of countries	Total country area (1 000 ha)	% of total country area	Forest area (1 000 ha)	% of forest area
Minimum area	Yes	26	433 339	99.1	152 200	99.2
	No	1	4 129	0.9	1 221	0.8
Minimum width	Yes	20	286 590	65.5	82 112	53.5
	No	7	150 878	34.5	71 309	46.5
Minimum tree crown cover	Yes	22	300 416	68.7	86 372	56.3
	No	5	137 052	31.3	67 049	43.7
Minimum tree height	Yes	16	204 546	46.8	63 919	41.7
	No	11	232 922	53.2	89 502	58.3
Total		27	437 468	100.0	153 421	100.0

Note: For the Scandinavian countries using both national and FAO definitions (Finland, Norway, Sweden), the national definition is considered.

In the European countries participating in COST Action E43, only five do not use a “minimum tree crown cover” variable in their forest and other wooded land national definitions: Finland, Norway, Sweden, Romania and Slovenia. Nevertheless, this lack of precision is more or less compensated with another variable: a “minimum productivity” ( $\text{m}^3/\text{ha}/\text{year}$ ) that implies a certain density of trees. Finland, Norway and Sweden also utilise the FAO definition that includes a “minimum tree crown cover” in a combined assessment. It is easier and more practicable in several countries to assess crown cover than productivity. As a result, we propose to take this variable as relevant in the reference definitions of forest and other wooded land.

In many definitions a “minimum width” for linear formations like windrows, and shelterbelts is mentioned. Even if not always used, it seems to be relevant to avoid considering single tree rows or hedges as forest. Even if the value of the “current use” term of the weighting function is moderate, the relevance of the term is high. Consequently, this variable will be integrated in the reference definitions.

Finally, minimum tree height is often mentioned. It clarifies which type of woody plants must be taken into account for applying the definition and especially when estimating the crown coverage. This variable is often not mentioned. It is sometimes shifted to a tree definition that frequently includes a species list rather than a minimum height. We propose to use this variable in the forest definition because this minimum

height is related to the species growth in the specific stand conditions.

We propose to use the following variables: minimum area, minimum tree crown cover and minimum width. These choices are coherent with the majority of national definitions and also with international definitions (FAO 2000, UNECE/FAO 2000, IPCC 2003).

The same method is used for selecting land use variables.

### 3.3.3 Determination of the Threshold Values: Example of Minimum Tree Crown Cover

Many different tree crown cover threshold values are applied in forest definitions. The threshold is also one of the major criteria that differentiate forest from other wooded land.

Following the analytical decomposition approach, we collect all existing threshold values. The crown cover rate is in the set  $[0, 1]$  (or  $[0\%, 100\%]$ ). We create a partition of this set using the collected threshold values as subset limits. These values are the following: 5%, 10%, 20%, 30%, 50%. The subsets are then:  $[0\%, 5\%]$ ,  $(5\%, 10\%]$ ,  $(10\%, 20\%]$ ,  $(20\%, 30\%]$ ,  $(30\%, 50\%]$  and  $(50\%, 100\%]$ .

It is possible to classify any piece of land in one of those subsets. All definitions clearly mention if it includes or excludes a piece of land classified in one of those subsets. It is then possible to distinguish the places determined as forest

**Table 2.** Tree crown cover classes considered as forest according to national definitions.

Tree crown cover threshold	Number of countries	Total country area (1 000 ha)	% of country area	Forest area (1 000 ha)	% of forest area
5%	1	50 599	11.6	17 915	11.7
10%	10	130 677	29.9	34 907	22.8
20%	6	54 695	12.5	12 253	8.0
30%	3	19 439	4.4	8 245	5.4
50%	2	45 006	10.3	13 052	8.5
Variable not used	5	137 052	31.3	67 049	43.7
Total	27	437 468	100.0	153 421	100.0

Note: For the Scandinavian countries using both national and FAO definitions (Finland, Norway, Sweden), the national definition is considered.

**Table 3.** Countries where a land can be considered as forest depending on the measured tree crown cover.

Tree crown cover	Cumulative number of countries	Cumulative country area (1 000 ha)	Possible forest in		Cumulative % of forest area
			Cumulative % of country area	Cumulative forest area (1 000 ha)	
[5%;10%]	1	50 599	11.6	17 915	11.7
(10%;20%]	14	292 462	66.9	112 237	73.2
(20%;30%]	20	347 157	79.4	124 490	81.1
(30%;50%]	23	366 596	83.8	132 735	86.5
(50%;100%]	25	411 602	94.1	145 787	95.0
Variable not used	2	25 866	5.9	7 634	5.0

Note: For the Scandinavian countries having both national and FAO definitions (Finland, Norway, Sweden) the FAO definition is considered.

according to all or almost all definitions and that consequently have to be recognised as forest using the reference definition.

In all countries using the tree crown cover variable, the threshold value is below 50%, except for two countries in which the threshold value is exactly 50%. More than one third of these countries, 30% of the total area of the COST E43 countries, consider land with more than 10% of tree crown cover as forest. If the Scandinavian countries are included in the statistic, the percentage of country area rises to 55% and the percentage of the total forest area, to 62%.

Table 3 highlights that data are available for two-thirds of the total country area if the minimal tree crown cover class is set to 10%. As this is the most frequently used threshold, we propose to use it in our reference definition.

The result of the analytical decomposition approach for this variable is a component of the *f* classification function. It can be phrased as follows: Forest is a land with a tree crown coverage of more than 10%.

This is coherent with FAO (2000), UNECE/

FAO (2000), IPCC (2003) and FAO (2004) definitions. Using it as a reference should be possible, because most countries are already able to provide data according to this variable and threshold value.

This variable is measurable in the field and in remote sensing. An accurate tool is required, but not more specific than the common forest inventory tools already in use.

Some points must be clarified. For example, the definitions of tree and crown are required for a common understanding of tree crown cover. These definitions must be considered separately, because they will also be used for other purposes.

This part of the definition was discussed in the COST Action E43 working group 1 and approved. It fulfils the “reference definition principles”.

Similar analyses are conducted for all variables, e.g. the minimum area was established at 0.5 ha, and a width threshold of 20 m for linear formations, corridors and windbreaks was fixed. Repeating the selection procedure for all variables, it is possible to develop a reference definition.

The reference definition resulting from the decision process is presented as follows:

*“Forest is a land spanning more than 0.5 ha with trees higher than 5 metres and a crown cover of more than 10%, or trees able to reach these thresholds in situ. For tree rows or shelterbelts, a minimum width of 20 m is required. It does not include land that is predominantly under agricultural or urban land use.”*

FAO (2004) gives the following explanatory notes which are relevant also for our definition:

1. Forest is determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 meters *in situ*. Areas under reforestation that have not yet reached but are expected to reach a canopy cover of 10 percent and a tree height of 5 m are included, as are temporarily unstocked areas, resulting from human intervention or natural causes, which are expected to regenerate.
2. Includes areas with bamboo and palms provided that height and canopy cover criteria are met.
3. Includes forest roads, firebreaks and other small open areas; forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest.
4. Includes windbreaks, shelterbelts and corridors of trees with an area of more than 0.5 ha and width of more than 20 m.
5. Includes plantations primarily used for forestry or protection purposes, such as rubberwood plantations and cork oak stands.
6. Excludes tree stands in agricultural production systems, for example in fruit plantations and agroforestry systems. The term also excludes trees in urban parks and gardens. The term is mainly related to FRA 2005 National Reporting Table T1.

### 3.4 Limits of the Reference Definition and Required Improvements

Due to the method, the reference definition that is built respects most requirements. However, in this definition, several specific terms are used. To follow the principle of clearness, these terms have to be explained. The most important one is “tree”. A reference definition for this term is required,

because the presence of trees is determinant in estimating several variables such as tree crown cover, minimum width and minimum area.

To define a minimum width and a minimum area, another concept is mandatory: “borderline”. This line separates forest from non-forest areas. It must be clearly described if the borderline follows tree stems, tree crowns or a fraction of tree crowns and the maximum distance between trees or tree crowns that are on the border of the forest. Once the line is defined, it is possible to measure the area of the wooded land and width in case of linear formations, windrow or shelter-belt.

Some room is still left for interpretation, and especially in the case of discontinuities. The information gathered by Cost Action E43 WG1 demonstrates that at the country level each NFI generally adopts an autonomously chosen threshold value (minimum width or minimum area) to assess if a discontinuity is excluded from forest or not. Moreover, the range of adopted values is wide (e.g. for forest road, the minimum width varies from 3 to 20 meters), also among countries using the FAO definition.

Hence, the reference definition cannot be considered exhaustive by itself. It must be completed by the reference definition of some terms it uses.

## 4 Growing Stock

### 4.1 Growing Stock: a Part of the Woody Biomass

Growing stock, living tree biomass and standing dead wood are important target variables in national forest inventories. They are part of the total woody biomass. Growing stock has an economic background and addresses the subject of wood production related to round-wood (timber and fibre-wood) and fuel-wood supply. Some growing stock definitions focus on the currently existing merchantable volume, whereas other definitions also imply trees potentially able to yield merchantable wood in the future. Both the status at a given point in time and the changes over time are of interest. With the increase in inter-

national reporting requirements, and the cross border information needs of European institutions and industrial stakeholders, a reference definition and harmonised data become more and more important.

## 4.2 Review of Woody Biomass Definitions

The terms tree, growing stock and biomass are defined several times in the international reporting procedures. FAO (1998), UNECE/FAO (2000), IPCC (2003) and FAO (2004) define growing stock. In addition FAO (1998, 2004) defines commercial growing stock. The mentioned sources also provide biomass definitions, but follow different approaches. UNECE/FAO (2000) defines above-stump woody biomass whereas FAO (1998) mentions above-ground woody biomass. Contrarily, IPCC (2003) and FAO (2004) define biomass and further distinguish between above-ground, below-ground and dead wood biomass. For standing dead wood, no definitions are available. Nevertheless, it is covered by the definitions for dead wood biomass (FAO 2004), dead wood (IPCC 2003), and standing volume (UNECE/FAO 2000, IPCC 2003). Summarising, the listed definitions refer to:

- ‘living’ or ‘living and dead trees’;
- ‘standing’ or ‘standing and lying trees’.

Growing stock definitions specify a minimum value for the diameter of the trees at breast height. On the contrary, biomass definitions usually do not specify a lower diameter limit, except UNECE/FAO (2000). Furthermore, biomass definitions may additionally include shrubs, crops, grasses, moss and other non-woody plants.

The basic units for growing stock and tree biomass definitions are the tree elements that they include. Existing international definitions are more or less clear in this concern. However, the elements of a tree are not defined in international sources, except “stump and roots” in UNECE/FAO (2000).

The existing international definitions for growing stock and biomass reveal shortcomings, such as the missing specifications of tree characteristics like living, dead, standing and lying.

The definitions of growing stock in national

forest inventories have a similar structure. Two types of variables are used to determine if a tree (or a part of a tree) is taken into account:

- quantitative variables for which a threshold value is fixed (e.g. DBH);
- qualitative variables for which a decision is made for each value (e.g. tree elements).

## 4.3 Analytical Decomposition

For the establishment of the growing stock reference definition, we first identify the space of objects that have to be classified. Then, we distinguish the relevant variables and select the adequate threshold values or qualitative values.

### 4.3.1 Definition of the Space of Woody Biomass Definitions

Based on the analytical decomposition approach, a broad range of reference definitions can be developed depending on their purpose. Our concern in this part is the space  $O$  of woody biomass. Many classes’ spaces  $C$  can be defined for the classification of an object  $o$ . We identify the classes that are the target of the classification function: for this example, we are interested in  $C_1$ : growing stock;  $C_2$ : tree volume apart from growing stock  $C_3$ : other biomass. The number of classes can be enlarged for further definitions. Each  $C_i$  category is disjoint and independent. It is possible to prepare a new and more general classification by gathering two or more categories into a new one. For example, the total tree volume  $C_1'$  can be obtained by adding  $C_1$  and  $C_2$ .

### 4.3.2 Identification of the Variables

In the definition, two types of variables  $V_i$  are required: variables to determine which ligneous plants are included in the definition and variables to define which parts of these plants are taken into account. We analyse all national growing stock definitions to explore all the variable possibilities (Table 4). The review of this list aims at selecting all mandatory variables for creating reference definitions for each part of the woody biomass.

**Table 4.** List of variables used in growing stock national definitions.

Variable	Number of countries	Forest area (1 000 ha)	% of total forest area	Growing stock (1 000 000 m <sup>3</sup> )	% of total growing stock
Woody plant manner of growth (tree, shrub, liana)	18	94 308	61.5	11 758	53.5
Life status (alive or dead)	23	128 287	83.6	17 747	80.8
Shape (normal or abnormal)	2	4 227	2.8	1 224	5.6
Standing or lying	12	54 069	35.2	8 306	37.8
Entire or broken	1	1 976	1.3	337	1.5
Size (DBH, height)	26	150 576	98.1	21 624	98.5
Tree elements (above or below ground)	24	149 711	97.6	21 483	97.8
Merchantability (saw timber, pulp wood, fuel wood, not merchantable)	0	0	0	0	0
Information not available	1	2 845	1.9	340	1.5

Note: Forest area and growing stock in the categories are computed using GFRA 2005 results. For Germany, growing stock was not published in the GFRA 2005 report. We used the result published since then (BMELV 2007).

Table 4 shows that some of the listed variables are used in almost all definitions. Others are rare, for example the shape, broken/unbroken and merchantability. Regarding the size threshold, two variables are used: minimum height and minimum DBH. Minimum height is rarely used, but fixing a DBH threshold implies the exclusion of stems that are below 1.3 m in height (e.g. young regeneration). DBH thresholds are more common in growing stock definitions.

Most growing stock definitions clearly refer to aboveground tree elements. The merchantability aspect is rare in definitions and not used in any reviewed growing stock definition (Table 4). Consequently, it should not be part of the reference definition.

As a conclusion, the growing stock reference definition should contain statements for the following variables: type of woody plants (manner of growth), life status, statement (standing/lying), size expressed as minimum DBH and a list of tree elements.

#### 4.3.3 Selection of the Variable Values: Example of Tree Elements

For each variable  $V_i$ , the classes (qualitative variable) or the threshold value (quantitative variable) used in the reference definition must be selected. Therefore, we decompose the value space of each variable into subsets following the decomposition approach.

Let us consider the example of elements of trees. First, a list of tree element terms is established (see Fig. 3). This list is then modified to avoid redundancies and double counting, i.e. each part  $P_j$  of the thinnest division of the tree is called by a unique term. For each tree element, the prospect of including it in the definition is evaluated using the weighting function (Table 5).

The woody part of the bole is always included in the definitions. The bark of the tree elements is taken into account in almost all definitions. It is excluded from the definition in three countries, but two of them (Czech Republic and Slovakia), can compute growing stock including this element. As a result, the bole and bark must be in the growing stock reference definition.

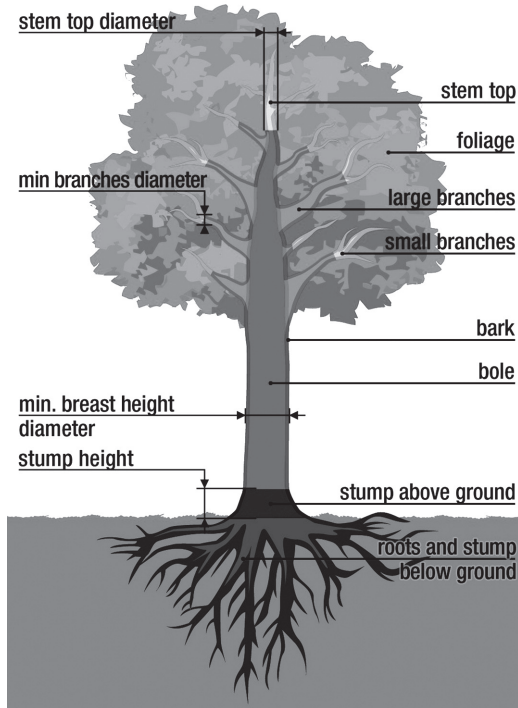
Also stem top is included in most national definitions. Nearly 81% of the total growing stock now available is computed taking into account the



**Table 5.** List of tree elements and weighting functions used in national growing stock definitions of 24 Cost E43 member countries.

Included tree elements	Number of countries	Forest area (1 000 ha)	% of total forest area	Growing stock (1 000 000 m <sup>3</sup> )	% of total growing stock
Bole	24	149 711	100.0	21 483	100.0
Bark	21	141 382	94.4	20 076	93.5
Stem top	16	109 629	73.2	17 325	80.6
Stump above ground	12	55 239	36.9	11 485	53.5
Large branches	4	19 589	13.1	3 488	16.2
Small branches	0	0	0.0	0	0.0
Foliage (leaves / needles, fruits, flowers, buds)	0	0	0.0	0	0.0
Stump below ground	0	0	0.0	0	0.0
Roots	0	0	0.0	0	0.0
Total	24	149 711	100.0	21 483	100.0

Information is not available for Denmark, Netherlands and the United Kingdom.



**Fig. 3.** Partition of a tree into elements.

stem top. In TBFRA 2000, the results presented include the stem top. In other international processes, the inclusion of stem top and its distinction from the bole remains unclear or undefined. So, we propose to include the stem top in the definition, avoiding the problem of differences in the definitions of the countries that exclude it from their national growing stock.

Stump above ground is included in half of the national definitions, evaluating growing stock in 37% of the forest area, and comprising 54% of the growing stock. So the harmonisation burden is nearly equal if our reference definition for growing stock would include or exclude the stump. However, this element is not included in TBFRA 2000, FRA 2000, and IPCC definitions. For consistency with these international reporting definitions, we propose to exclude it from the reference definition.

Large branches are included in the growing stock estimates of only four countries, thus we propose to exclude them from our reference definition.

All other elements (small branches, foliage and below ground parts) are never taken into account in growing stock definition. So we will not include them in the reference definition.

Finally, the reference definition of growing stock states that the “above ground volume of trees includes the wood from the base of the bole to the top of the stem, including bark and excluding stump, branches and foliage”.

The reference definition for growing stock was established by COST Action E43 – Working group 1 as follows:

*“Growing stock is the volume of living and standing stems over a specified land area. Included are stem volumes from the stump height to the stem top and the bark. Branches are excluded.”*

#### 4.4 Limits of the Reference Definition

Based on the analytical decomposition approach, we elaborated the reference definition for growing stock. This definition complies with the reference definition principles: it should be acceptable, because it is in line with international definitions and was approved by the COST Action E43 NFI representatives. The objectivity and the neutrality are ensured through the analytical methodology that refers to impartial arguments.

The reference definition clearly refers to the defined set of woody biomass definitions. All possibilities were screened using the analytical approach. So, the reference definition is sufficient and clear.

Variables used in the reference definition are the same as the ones that are usually in the national definitions. These values can be measured and assessed. As a result, the reference definition is practicable.

The variables used in the reference definition do not impose the use of any tool. Results can be obtained using remote sensing or field measurements and volume functions. So, it complies with the measurement device independency principle.

The reference definition is clear, because precise terms and values are used for each variable. However, some of these terms, for example tree elements, are differently defined in countries. Further investigation is required on such terms to find an agreed common definition.

The reference definition is useful on its own for international reporting, but is also the basis for precise further reference definitions. For example, we can define commercial growing stock as a sub-set of the growing stock, referring to “commercial” species and “commercial” minimum DBH. Commercial growing stock is used by

FAO (1998, 2004). Since international definitions for fellings and increment (FAO 1998 and 2004, UNECE/FAO 2000, IPCC 2003) do not mention the tree elements they refer to, we additionally propose to use growing stock definitions as the basis for estimating fellings and increment.

## 5 Conclusion

We have presented methods to establish reference definitions for forest and forestry related concepts. The described methodology can be applied to many different concepts and terms employed in international reporting when using national or international input data, for example pasture and grassland. The methodology is also applicable outside of land use and land cover related applications. The methods were developed using data and information from the participating countries of COST Action E43. The methods could also be applicable and efficient in other large processes, for example, in the harmonisation of reporting at the European or global level.

The presented definitions are very near those given in TBFRA 2000. We have analysed the differences between our reference definitions and the national definitions and evaluated the changes necessary to obtain common definitions. We have also argued why the presented definitions should be adopted. Growing stock has, however, been defined directly following TBFRA 2000 where it is defined as ‘The living tree component of the standing volume’ (UNECE/FAO 2000).

These reference definitions are a good starting point to make the forest resource information from different countries comparable. It allows creating tools, called bridge building, to obtain comparable results if nations apply different definitions in the data collection. These tools are for example conversion functions which convert estimates derived with national definitions to correspond reference definition.

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