RELIABILITY AND COMPARABILITY OF TBFRA-2000 RESULTS[1]

Introduction

At a very early stage of the preparation of the TBFRA-2000 a decision had to be made about the methods of data assessment. Forest resources assessments are regularly carried out at the national level in the majority of countries in the boreal and temperate region. The team of specialists (ToS) formed in 1994 to assist the UN-ECE/FAO Secretariat in preparing the TBFRA-2000 recommended at its first meeting to utilize the data assessed on the national level and combine them to provide information on boreal and temperate forests. A major reason for this decision was the desire to utilize the experience and investment put into forest inventory by countries to a maximum extent.

The systems of nomenclature applied in national forest resources assessments are characterized by tradition and by national information needs and are not standardized internationally. Even identically named attributes may mask different concepts and definitions. A major concern of the TBFRA-2000 was therefore the comparability of data between nations and the reliability of aggregated results. In close co-operation with the European Commission, DG VI (Agriculture, Forestry and Fisheries), Brussels, and the Joint Research Centre (JRC) of the European Commission, Forest Inventory by Remote Sensing (FIRS)-Project, Ispra, studies were conducted that aimed at the reliability of information obtained by the aggregation of data from national forest resources assessments. The results of these studies form the base for this analysis of the reliability and comparability of the TBFRA-2000 results.

Reliability, comparability and related terms

Problems of comparability of national data and the reliability of aggregated results arise mainly because of differences in (1) the national systems of nomenclature, i.e. measurement rules and definitions, and (2) the reference period. Differences in definitions and measurement rules can be made compatible in two different ways: (1) by harmonization and by (2) standardization.

Webster´s comprehensive dictionary, 1995, gives the following definitions related to harmonization and standardization:

- Harmonize: “to make or become harmonious or suitable, accommodate, adapt, agree”
- Harmony: “state of order, agreement or completeness in the relations of things or of parts of a whole to each other”
- Standardize: “to make to or regulate by a standard”
- Standard: “any established measure of extent, quantity, quality or value”

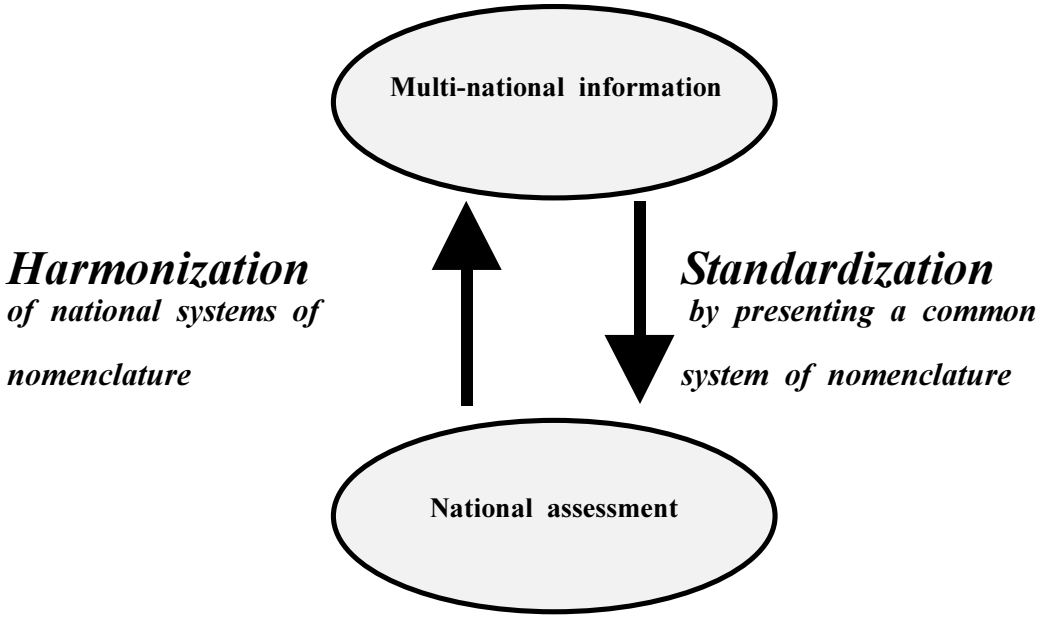
Understanding the distinction between harmonization and standardization is important. Harmonization is based on existing concepts which should be brought together in a way to be more easy to compare. It can be seen as a ‘bottom up approach’ starting from an existing divergence and ending in a state of comparability. Standardization is a totally different concept and does not necessarily consider existing conventions and definitions. Standardization is focusing on a common standard, i.e. a generally accepted and followed system of nomenclature, and can thus be interpreted as a ‘top-down approach’.

When both concepts are related to assessment and monitoring programmes, two approaches of bringing data closer together can be seen in Figure R.1. Harmonization relates to attributes that are already defined in different ways at the national level. The harmonization process seeks for a common agreement on how data can be converted to meet a harmonized definition, which is often the union of similarities of existing definitions, and does not necessarily eliminate all inconsistencies. Standardization introduces a new, common definition or standard that is applied in all national programmes. The standard eliminates all inconsistencies but can be quite different from individual, national approaches. Standardization can be seen as the process necessary for definitions of attributes that are not yet assessed but have to be introduced in national programmes. Harmonization is related to using already existing national systems of definitions but endeavouring to bring the definitions into alignment through incorporating “adjustments” for the known differences.

[1] This chapter was prepared by Mr. Michael Köhl (see Appendix V).

FIGURE R.1

Harmonization and standardization process



In the TBFRA-2000 a harmonization approach was utilized. An expert consultation on the TBFRA-2000 was held in Kotka, Finland, in June 1996 (Kotka III), where national systems of nomenclature were presented and methods for harmonizing these systems were discussed. As a result of those discussions a set of terms and definitions was developed and recommendations for the adjustment of national data were issued (Metla, 1996)[2]. The main objective of these recommendations was to make national data comparable and thus provide reliable information at the multi-national level.

According to the Oxford English Dictionary comparability is the quality of being comparable. Making data comparable means increasing the similarities and eliminating the differences as much as possible. The success in making data comparable affects directly the reliability of the results. Reliability is a term that is used to describe the closeness of obtained results (figures, maps, etc.) to the real situation. It is not a statistical term.

From a statistical point of view the reliability of results can be quantified by giving their precision, accuracy, mean square error or bias. As there is considerable confusion in the use of those terms a short description of the terms as they are used throughout this chapter is given below:

Precision

Precision refers to the size of deviations from the estimated mean, $\hat{\mu}$ obtained by repeated application of a sampling procedure. It is quantified by the standard error or confidence intervals. The precision of a statistical estimate can be increased by increasing the number of observations.

Accuracy

Accuracy refers to the size of deviations from the true mean, μ. Increasing the number of observations does not necessarily increase accuracy.

[2] Metla 1996: Expert Consultation on Global Forest Resources Assessment 2000 (Kotka III), Finnish Forest Research Institute, Research Report No. 620, Helsinki, 369 p.

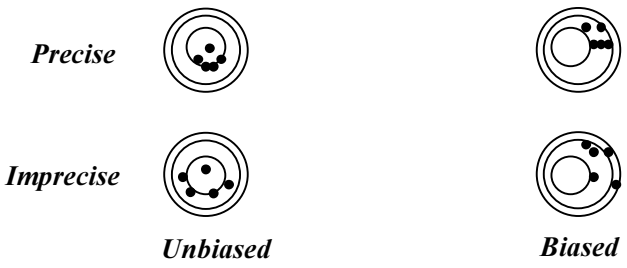
Bias

Bias, B, is directly related to the accuracy of an estimate, as $B=\hat{\mu}-\mu$. A problem in sample based surveys is that the presence of bias, i.e. the lack of accuracy, is often not known.

The effect of precision and bias can be seen in Figure R.2.

FIGURE R.2

Accuracy and precision (after Vanclay, 1994)[3]



Mean square error

A useful measure of reliability is the mean square error (MSE). It combines the precision of an estimate with its squared bias.

Sources of error in forest resources assessments

Environmental data for large units of reference are generally assessed by sample based methods, as full tallies are too time and cost intensive. The objective of a sample based survey is to select a sub-set–the sample–from the population of interest and to estimate population parameters based on probability theory. The parameter estimates differ from the true population value as they are subject to different sources of errors. Those error sources are:

- sampling errors
- assessment errors including measurement and classification errors
- prediction errors caused by models
- non-statistical errors

These types of errors occur in all assessment and monitoring programmes and have been studied intensively (e.g. Hansen et al. 1961, Cunia 1965, Bailar et al. 1977, Päivinen 1987, Groves 1989, Lessler and Kalsbeek 1992, Gertner and Köhl 1993)[4]. If independent surveys, for example national or regional assessments, are combined to calculate statistics for an enlarged unit of reference, another reason for deviations of estimated from true values might occur through differences in the individual definitions. We will refer to this type of error as **definition error.**

Especially in international statistics, the final results are affected by the fact that the nomenclature used for individual attributes varies from country to country. The differences in nomenclature lead to the unfavourable situation that attributes–even if identically named–reflect different concepts. While the different nomenclatures are not error sources in national estimates they may result in considerable bias if data from various nations are combined without

[3] J. Vanclay, 1994: "Modelling Forest Growth and Yield", CAB International, Oxon, U.K., 312 p.

[4] B. Bailar, L. Bailey and J. Stevens, 1977, "Measures of interviewer bias and variance", Journal of Marketing Research, 14, pp. 337-343.
T. Cunia, 1965: "Some Theory on Reliability of Volume Estimates in a Forest Inventory Sample", Forest Science, Vol. 11 (1).
G. Z. Gertner and M. Köhl,, 1992: "An Assessment of Some Non-sampling Errors in a National Survey Using an Error Budget", Forest Science, Vol. 38, No. 3, pp. 525-538.
M. H. Hansen, W. N. Hurwitz and M. Gurney, 1961: "Problems and methods of the sample survey of business", Journal of the American Stat. Association, 41, pp. 173-189.
R. Groves, 1989: "Survey errors and survey costs", John Wiley & Sons, New York, 590 p.
J. Lessler and W. Karlsbeek, 1992: "Non-sampling Error in Surveys", John Wiley & Sons, New York, 412 p.
R. Päivinen, 1987: "Metsän inventoinnin suunnitelumalli", A Planning Model for Forest Inventory, University of Joensuu, Publications in Science 11, 179 p.

adjustment for a common nomenclature. The recommendations given by the expert consultation in 1996 (Metla, 1996)[5] and the terms and definitions used in the TBFRA-2000 are intended to reduce definition errors.

Sampling errors are caused by the fact that the sample does not represent the whole population well enough and are caused by the variability of the observations. Sampling errors can be reduced by increasing the sample size and by introducing a more cost-efficient sampling design (Cochran, 1977, Särndal et al., 1992[6]).

Assessment errors are either measurement errors or classification errors. Measurement errors may be due to careless application of measurement rules or may be caused by measurement instruments. The wrong application of definitions of attributes result in classification errors, i.e. the incorrect assignment of classes to sample elements. Both assessment errors can either be random in nature or one-sided, i.e. biased. Some authors use the term "observer error" for this error source.

Many attributes in forest resources assessments are not directly assessed but are derived from models. Examples for derived attributes are diversity indices of stem volume of single trees. It is assumed that based on the input values the true population value is derived. Models and functions, however, are subject to errors, which are called **prediction errors**.

Non-statistical errors occur everywhere and can be the most serious ones. The origins are human errors in measurement, sampling and the calculation of results. Programming errors belong in this class as well as errors in defining the sampling frame, i.e. the target population is different from the sampling population. In the scope of TBFRA an important source for non-sampling errors is non-response. The results of TBFRA are valid only for the entity of those countries that replied to the questionnaire.

In national reports, sampling errors are usually the only error source that is published. Even if sampling errors are published, only a part of the reliability of figures can be judged. Especially attributes on nominal and ordinal scales may be subject to observer bias. Various error sources may cumulate in figures that are based on models. Gertner and Köhl (1992)[4] showed for standing timber volume estimates in the Swiss national forest survey that small biases in the input variables for timber volume models cause prediction errors that are larger than the corresponding sampling errors.

The reliability of results cannot be related to a single error source. In order to improve the interpretation of survey results and to review the benefit of the retrieved information the total error of estimates has to be quantified – an attempt that results in an '**error budget**' (Gertner and Köhl, 1992)[7] or the '**total sampling design**'[8] (Lessler and Karlsbeek, 1992)[9]. A study carried out in the scope of the implementation of a European Forest Information and Communication System (EFICS) showed that the data quality of national forest resource assessments is relatively high because at the national level the non-sampling errors are given much attention. In most countries of the TBFRA-region assessment procedures, models and analysis tools have been developed that reduce the non-sampling errors to a large extent.

The reliability of the TBFRA results are mainly affected by two error sources: (1) definition errors and (2) non-response. In addition the different national reference periods may add some imprecision to the results. Thus a study of the non-responses and reference periods and an analysis of the definition errors will be presented below.

Analysis of non-responses

Non-response refers to the failure to obtain data on some attributes or entire countries for the set of TBFRA attributes and nations. The non-response rate of the TBFRA can be measured exactly as reports are available that show the countries that did not respond to the questionnaire and attributes that could not be provided by individual countries. It has to be emphasized that many actions were undertaken by the UN-ECE/FAO secretariat to reduce non-responses as much as possible. The actions include the assignment of National Correspondents, meetings of National Correspondents, personal communication and assistance in filling out the questionnaire and converting data to the TBFRA terms and definitions as well as visits to some countries. Due to these efforts the non-response rate has been minimized.

Non-responses by nations

Due to the changes in the former USSR and former Yugoslavia the number of countries included in the TBFRA-2000 increased compared to the FRA 1990 (TZ). For the current TBFRA, 55 countries had to report. Out of these 55 countries five countries did not reply to the questionnaire, i.e. nine percent. Non responding countries were

[5] Metla 1996: Expert Consultation on Global Forest Resources Assessment 2000 (Kotka III), Finnish Forest Research Institute. Research Report No. 620, Helsinki, 369 p.

[6] W. G. Cochran, 1977: "Sampling Techniques", John Wiley & Sons, New York, 428 p.

C. E. Särndal, B. Swenson and J. Wretman, 1992: "Model Assisted Survey Sampling", Springer Verlag, Heidelberg, 694 p.

[7] G. Z. Gertner and M. Köhl, 1995: "Correlated Observer Errors and their Effects on Survey Estimates of Needle-Leaf Loss", Forest Science, Vol. 41, No. 4, pp. 758-776.

[8] In the following both terms are used synonymously.

[9] J. Lessler and W. Karlsbeek, 1992: "Nonsampling Error in Surveys", John Wiley & Sons, New York, 412 p.

Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Kyrgyzstan, Turkmenistan and Uzbekistan. These countries comprise a total land area of 1,210,810 km^2 or 2.2 per cent of the total land area covered by TBFRA. The three countries in Central Asia have a rather small proportion of forest land. Von Maydell (1983)[10] reports forest area proportions of 5.3 per cent for Uzbekistan, 3.3 per cent for Kyrgyzstan and 6.6 per cent for Turkmenistan. Main Table 1 presents figures for forest land of those countries. Given these figures the non-response rate in terms of forest area is 9.57 million ha out of 1,682 million ha or 0.57 per cent.

Non-response by attributes

The terms and definitions utilized in TBFRA are listed in Appendix I. Among those attributes a core set was defined that is regarded as the essential, must-have data. These attributes address the main topics of forest area, other wooded land, growing stock of trees, total woody biomass, net annual increment, annual fellings, annual removals and average annual change. These eight groups are split up in several subgroups resulting in 25 attributes. Out of these 25 attributes further requests were made for nine attributes by specifying figures for coniferous, broadleaved and mixed species forest types for the total forested area and forests available for wood supply. Table R.1 lists the essential TBFRA data together with the number of non-responses. Not included in the non-responses are the five countries that did not return the TBFRA enquiry.

Table R.1 indicates that all nations provided data for forest area and all its subsets. Only Luxembourg representing 0.005 per cent of the forest area covered by TBFRA could not provide information on the area of semi-natural forests and plantations. The area of other wooded land as well as growing stock of trees on total forest land are also attributes for which each nation could provide data. Australia (9.3 per cent of TBFRA's forest area and 83 per cent of the forest area of the "Other TBFRA" countries, i.e. Australia, Japan and New Zealand) is the only country that did not provide information on average annual change of forest area. Attributes related to forest area show an excellent response rate. The same holds with some reservations in the "Other TBFRA" group for changes in forest area.

Attributes related to annual removals show the lowest response rates. Five countries were not able to provide any information, eight countries could not provide information on removals on other wooded land. This reflects problems in the methodology applied to assess removals. Removals cannot be quantified by field assessments but have to be recorded via timber sale statistics or input by wood-processing industries.

Poor response rates were found for annual fellings, removals, growing stock, annual change and net annual increment when these attributes are related to other wooded land. In some countries assessments are carried out only on forest area but not on other wooded land. Those countries had difficulties in providing information for other wooded land.

Four countries could not provide information on biomass, five countries could not give the biomass of stumps and roots. As biomass is strongly related to growing stock any interpretation of biomass figures can be cross-checked with information on growing stock.

Up to six countries had problems to provide information for the species group breakdown of attributes. One reason is that in those countries the percentage of broadleaved, coniferous or mixed species stands is so low that there is no need for separate figures at the national level. Another reason is that there is no distinction made between forests and forests available for wood supply.

Summary (Non-responses)

- The response rates to the TBFRA enquiry are comparatively high, and with respect to non-response rates there is no reason to doubt the reliability of the TBFRA results.
- 5 countries, representing approximately 0.57 per cent of the forest area covered by TBFRA did not respond to the enquiry.
- Attributes related to forest area show an excellent response rate (in terms of forest area 99.5 per cent). The same holds with some reservations in the "Other TBFRA" group for changes in forest area.
- Lowest response rates are observed for annual removals.
- Information on attributes for the unit of reference "other wooded land" could not be provided by up to eight nations out of those which replied to the enquiry.
- Biomass figures were not provided by four countries out of those which replied to the enquiry. As biomass is strongly related to wood volume, any interpretation of biomass figures can be cross-checked by information on growing stock.

[10] H.-J. von Maydell, 1983: "Forst- und Holzwirtschaft der Sowjetunion", Teil 4: Kasachstan und die mittelasiatischen Republiken, Mitteilungen der Bundesforschungsanstalt für Forst- und Holzwirtschaft, No. 140, Hamburg, 313 p.

TABLE R.1

TBFRA essential data and the number of countries not responding

Parameter	Total:	of which:			Forest available for wood supply			
		Coniferous	Broadleaved	Mixed	Total	Coniferous	Broadleaved	Mixed
Forest area	-	-	-	-	-		-	-
Undisturbed by man	-							
Semi-natural	1							
Plantations	1							
Other wooded land	-	3	4	4				
Undisturbed by man	2							
Semi-natural	2							
Growing stock of trees	2							
On forest, total	-	2	2		2	5	5	
other trees (OWL)	4							
Total woody biomass	4							
Trees on forest, total	4	4	4		5			
Stumps and roots	5							
Net annual increment	3							
On forest, total	2	3	3		3	4	4	
On OWL	6							
Annual fellings, total	5							
On forest, total	3	6	6		5	6	6	
On OWL	5							
Annual removals, total	6							
On forest, total	5	6	6		4	6	6	
On OWL	8							
Average annual change								
Forest, total	1				1			
Other wooded land	4							
In growing stock	4				4	5	6	

Shaded: data not regarded as essential.

Reliability of attributes

In national forest resources assessments several hundred attributes are utilized. Some of these attributes such as tree species, stem diameters or tree heights can be directly assessed, but most attributes are derived by models and functions taking directly assessed attributes as input, e.g. single tree volume as a function of stem diameters and tree height.

Each country provides a system of nomenclature including measurement rules, definitions and algorithms for all the attributes that are treated in their national assessments. National systems of nomenclature reflect the national objectives of resource assessment programmes. Many measurement rules are compatible between nations; this is partly due to the activities of the International Union of Forest Research Organisations (IUFRO), which has been looking after standardized assessment rules for more than 100 years and provides guidelines for assessments (e.g. IUFRO, 1959)[11]. Most nomenclatures for attributes show, however, differences between nations. The TBFRA concentrates on 77 attributes, for which definitions have been developed with the objective of uniting national definitions to the maximum extent. Assistance in converting figures based on national definitions to figures according to TBFRA-2000 definitions was provided by the secretariat. The success of converting national figures to the common TBFRA terms and definitions is decisive for the reliability of the TBFRA results.

[11] UFRO, 1959: "The Standardization of Symbols in Forest Mensuration", IUFRO, Wien.

The worst-case scenario: no adjustments

Many of the TBFRA attributes are based on estimates of forest area or single tree volume. Single tree volume is aggregated in different ways to obtain information on growing stock, removals, fellings or changes in growing stock. Forest area is used to relate many attributes to a unit area, e.g. average volume in m^3/ha. The reliability of single tree volume and forest area figures is driving the reliability of many related attributes. Therefore national differences between those two attributes will be investigated in detail below. In order to provide the worst case scenario the investigation is based on national definitions and on no conversions towards the TBFRA terms and definitions being made.

The findings presented below are based on a study carried out in the framework of EFICS (European Forest Information and Communication System). The study was funded by EC-DG VI and carried out in close co-operation with the UN/ECE Timber Section and the European Forest Institute (EFI). The impact of national definitions were studied for the 19 EU and EFTA countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Iceland, Liechtenstein, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom), but the results allow a generalization to the region covered by TBFRA. A detailed description of the study can be found in Traub et al. (1997) and in EU (1997)[12].

Forest area

The definition of forest area as used in the TBFRA was agreed upon during the expert consultation held in Kotka, Finland in 1996 and reads as follows:

> *Land with tree crown cover (or equivalent stocking level) of more than 10 percent and area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. May consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground; or of open forest formations with a continuous vegetation cover in which tree crown cover exceeds 10 per cent. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10 per cent or tree height of 5m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest.*
>
> ***Includes**: Forest nurseries and seed orchards that constitute an integral part of the forest; forest roads, cleared tracts, firebreaks and other small open areas within the forest; forest in national parks, nature reserves and other protected areas such as those of special environmental, scientific, historical, cultural or spiritual interest; windbreaks and shelterbelts of trees with an area of more than 0.5 ha and a width of more than 20 m. Rubberwood plantations and cork oak stands are included.*
>
> ***Excludes**: Land predominantly used for agricultural practices.*

This definition can be seen as the lowest common denominator of all national definitions of forest area applied in the TBFRA region. Table R.2 summarizes the quantitative criteria that are used in selected countries to assess their forest area. The quantitative criteria found in definitions for forest area are crown cover[13] (5 per cent to 30 per cent), width of the stand (9 to 50 m) and minimum area (0,01 ha to 2 ha). These quantitative criteria are measured either on aerial photographs or in sample plots on the ground. The Scandinavian countries require a minimum potential increment (at least 1 m^3/ha/year) for the site to be considered as forest area. In many national forest area definitions no specific minimum height is specified, which trees should be able to reach at maturity in situ.

In order to investigate the effect of different national forest area definitions on the estimated extent of forest area a simulation study was carried out. Differences in the spatial distribution of trees and forested patches—as they can be found in the Mediterranean, the Central and the Nordic regions of Europe—were simulated in computer generated forest/non-forest maps. The computer generated forests, representing forest cover patterns in different parts of Europe, were used to simulate the impact of individual national forest area definitions applied in EU and EFTA countries. Only the criteria minimum width, minimum crown cover and minimum area were considered in the simulation study but not the minimum tree height to be reached at maturity. For the given criteria this approach results in a worst-case scenario and can quantify the maximum effect of different national forest area definitions in absolute terms.

Table R.3 displays the effects of applying individual national forest area definitions to other countries and provides results for two different approaches: (1) the forest area differences resulting from the application of an individual national forest area definition with respect to other nations; and (2) differences in forest area estimates for individual nations when other national forest area definitions are applied. The rows in Table R.3 provide information

[12] European Commission 1997: Study on European Forest Information and Communication System (EFICS), Report on Forest Inventory and Survey Systems, European Commission, Luxembourg (2 volumes), 1328 p.

B. Traub, M. Köhl and R. Päivinen, 1997: Simulation Study, in: European Commission, Study on European Forest Information and Communication System (EFICS), Report on Forest Inventory and Survey Systems, Luxembourg.

[13] Proportion of area covered by the vertical projection of tree crowns.

TABLE R.2

Forest area definitions of some selected countries

Country	Minimum width	Minimum crown cover	Minimum area	Minimum production
Australia	-	20 per cent	-	-
Austria	10 m	30 per cent	0.05 ha	-
Belgium[1]	9 m /25 m	-/20 per cent	0.01/ 0.05 ha	-
Denmark	20m	30 per cent	0.5 ha	
Finland	-	-	0.25 ha	1m^3/ha/yr
France	15	500 stems/ha or 10 per cent	0.05 ha	-
Germany	10 m	-	0.1 ha	-
Greece	30 m	10 per cent	0.5 ha	-
Iceland	-	-	0.25 ha	
Ireland	40 m	20 per cent	0.5 ha	4 m^3/ha/yr
Italy	20 m	20 per cent	0.2 ha	-
Japan	-	30 per cent	0.3 ha	-
Liechtenstein	25 m to 50 m^2	100 per cent to 20 per cent	-	-
Luxembourg	-	-	-	-
Netherlands	30	20 per cent	0.5 ha	-
New Zealand[2]	-	20 per cent	0.5 ha	-
Norway	-	-	0.1 ha	1 m^3/ha/yr
Portugal	15 m	10 per cent	0.2 ha	-
Spain	20 m	5 per cent	0.2 ha	-
Sweden	-	-	0.25 ha	1 m^3/ha/yr
Switzerland	25 m to 50 m^2	100 per cent to 20 per cent	-	-
United Kingdom	20 m	20 per cent	0.25 ha	
United States	40 m	10 per cent	0.4 ha	1.4 m^3/ha/yr

[1] Belgium uses separate definitions for the Walloon and Flemish regions.

[2] depending on crown cover.

for the first approach, i.e. differences in estimates of 19 national forest areas if the definition of the country given in the first column would be applied in other countries (e.g. the Austrian forest area definition would overestimate the Danish forest area as assessed according to the Danish forest area definition by 107 km^2). The columns provide information on the second alternative, i.e. the differences of national forest area estimates with respect to the application of other individual national forest area definitions (e.g. the forest area of Austria would be underestimated by 57.5 km^2, if the Danish forest area definition would be applied in Austria and overestimated by 18.4 km^2, if the Finnish forest area definition would be applied).

Applying other countries' forest area definitions to national data results in an overestimation of the national forest area of up to 10 per cent or an underestimation of up to – 6 per cent. The forest area definition of Luxembourg, which does not apply threshold values for the width, minimum area and crown closure of forest patches, leads to the largest forest area figures compared to other national definitions. The forest area definition of Ireland results in the lowest forest area figures, as it incorporates comparatively large threshold values for minimum width (40 m) and minimum area (0.5 ha).

The differences between forest area estimates based on different national forest area definitions are small for central Europe (± 3.6 per cent), as here mainly closed, large forest patches can be found, which are not sensitive to the specified threshold values for crown cover, area and width. In countries close to a natural timberline the differences in estimates forest area are larger, as here threshold values play a decisive role.

If the forest area definition of Ireland would be applied in Western Europe the total forested area would be roughly 5 per cent less. The application of the forest area definition used in Luxembourg would increase the reported Western European forest area by approximately 3 per cent. The definitions of Belgium (Flemish region), Switzerland, Denmark, France, Liechtenstein, Greece, Italy, Ireland, the Netherlands, Portugal, Spain and the UK would lead to a smaller total forest area, while the definitions of Austria, Belgium (Walloon region), Germany, Finland, Iceland, Luxembourg, Norway and Sweden would report a higher total forest area than currently reported. These figures are

based on national forest area definitions without any adjustment to the TBFRA definition of forest area. After adjustment the range of bias will be smaller than the one presented above.

The minimum crown cover specified in the TBFRA forest area definition is 10 per cent. In many European countries higher crown cover thresholds are defined. In areas where forests are growing close to a timber line due to temperature, e.g. in northernmost Europe and in the Alps, or due to rainfall, e.g. in the Mediterranean area, scattered forests types with gradual transitions to other land cover categories occur naturally. Here, a change in the required minimum crown cover might cause a change in the amount of forested area. Crown coverage thresholds have only a minor effect in closed forests, which are typical for the temperate region. Many countries located areas where open forests are widely spread, e.g. in the Mediterranean area or the northern boreal region, have specified a threshold value for crown density of 10 per cent, e.g. France, Portugal, Greece or Alaska, or even less, e.g. 5 per cent in Spain, and thus match the TBFRA definition.

TABLE R.3

Per cent differences of forest area estimates according to national forest area definitions

	A	B1	B2	CH	D	DK	F	FIN	FL	GR	I	IRL	IS	L	N	NL	P	S	SP
A	**0.00**	-0.07	1.69	2.03	-0.00	2.31	0.94	-0.65	2.03	7.73	3.64	2.94	-0.65	-0.69	-0.96	2.41	2.43	-0.04	3.72
B1	0.07	**0.00**	1.76	2.09	0.06	2.43	1.01	-0.54	2.09	8.04	3.95	3.00	-0.54	-0.62	-0.84	2.47	2.50	0.02	4.03
B2	-1.69	-1.76	**0.00**	0.34	-1.69	-0.14	-0.75	-3.11	0.34	2.84	-1.25	1.25	-3.11	-2.38	-3.41	0.72	0.74	-1.73	-1.17
CH	-2.03	-2.09	-0.34	**0.00**	-2.03	-0.83	-1.08	-3.79	0.00	0.97	-3.12	0.91	-3.79	-2.72	-4.10	0.38	0.40	-2.07	-3.04
D	0.00	-0.06	1.69	2.03	**0.00**	2.31	0.95	-0.65	2.03	7.83	3.75	2.94	-0.65	-0.69	-0.96	2.41	2.43	-0.04	3.83
DK	-1.49	-1.55	0.20	0.54	-1.49	**0.00**	-0.54	-2.96	0.54	3.34	-0.75	1.45	-2.96	-2.17	-3.27	0.92	0.95	-1.53	-0.67
F	-0.94	-1.01	0.75	1.08	-0.95	0.98	**0.00**	-1.97	1.08	5.23	1.15	1.99	-1.99	-1.63	-2.29	1.46	1.49	-0.99	1.23
FIN	0.47	0.41	2.16	2.50	0.47	2.96	1.42	**0.00**	2.50	9.29	5.21	3.41	0.00	-0.21	-0.31	2.88	2.90	0.43	5.29
FL	-2.03	-2.09	-0.34	0.00	-2.03	-0.83	-1.08	-3.79	**0.00**	0.97	-3.12	0.91	-3.79	-2.72	-4.10	0.38	0.40	-2.07	-3.04
GR	-2.40	-2.47	-0.71	-0.37	-2.40	-1.44	-1.46	-4.40	-0.37	**0.00**	-4.09	0.53	-4.40	-3.09	-4.70	0.00	0.03	-2.44	-4.01
I	-1.30	-1.36	0.39	0.73	-1.30	0.41	-0.36	-2.55	0.73	4.09	**0.00**	1.64	-2.55	-1.99	-2.86	1.11	1.13	-1.34	0.08
IRL	-2.94	-3.00	-1.25	-0.91	-2.94	-2.31	-1.99	-5.27	-0.91	-2.01	-6.10	**0.00**	-5.27	-3.62	-5.58	-0.53	-0.51	-2.98	-6.02
IS	0.47	0.41	2.16	2.50	0.47	2.96	1.42	0.00	2.50	9.29	5.21	3.41	**0.00**	-0.22	-0.31	2.88	2.90	0.43	5.29
L	0.69	0.62	2.38	2.72	0.69	3.42	1.63	0.46	2.72	10.10	6.02	3.62	0.46	**0.00**	0.16	3.09	3.12	0.65	6.10
N	0.61	0.55	2.30	2.64	0.61	3.27	1.56	0.31	2.64	9.81	5.73	3.55	0.31	-0.08	**0.00**	3.02	3.04	0.57	5.81
NL	-2.40	-2.47	-0.72	-0.38	-2.41	-1.44	-1.46	-4.40	-0.38	-0.02	-4.10	0.53	-4.40	-3.09	-4.71	**0.00**	0.03	-2.45	-4.02
P	-1.03	-1.09	0.66	1.00	-1.03	0.81	-0.08	-2.15	1.00	4.92	0.84	1.91	-2.15	-1.72	-2.46	1.38	**0.00**	-1.07	0.92
S	0.47	0.41	2.16	2.50	0.47	2.96	1.42	0.00	2.50	9.29	5.21	3.41	0.00	-0.21	-0.31	2.88	2.90	**0.00**	5.29
SP	-1.32	-1.39	0.37	0.71	-1.32	0.35	-0.38	-2.61	0.71	4.01	-0.08	1.61	-2.61	-2.01	-2.91	1.08	1.11	-1.36	**0.00**

The forest area definition of Portugal matches the minimum crown cover of 10 per cent specified by the TBFRA definition. If the Portuguese forest area definition would be applied for all EU and EFTA countries, the total forest area as assessed according to national forest area definitions, i.e. without adjustment, would be overestimated by less than 1 per cent. This proves that even without adjustment the national forest area definitions provide reliable figures for the reported units of reference according to the TBFRA definitions.

Volume of standing trees

Single tree volume is a basic input value for the calculation of the volume of growing stock, increment, fellings and removals and can be transformed into woody biomass. The national definitions of wood volume show differences. The volume figures depend on three factors: (1) how small trees are taken into account (minimum threshold value for the diameter at breast height, d.b.h.), (2) starting point of the stem volume included (ground or stump) and (3) end point of the stem volume included (minimum top diameter).

Among the 19 western European countries Switzerland uses the highest d.b.h. threshold value (12 cm) and Finland, Sweden and UK the lowest (0 cm). The minimum top diameter varies from 0 cm (9 countries) to 7.5 cm (Spain). The starting point of the volume is at stump level in 7 countries, the others are using ground level (Table R.4).

Traub et al. (1997)[14] showed that the volume of trees below 12 cm d.b.h. comprises 2-3 per cent of the total volume of the Swiss forests. If the Swiss threshold value (12 cm) is applied in Finnish forests, 13 per cent of the total

[14] B. Traub, M. Köhl and R. Päivinen, 1997: Simulation Study, in: European Commission, Study on European Forest Information and Communication System (EFICS), Report on Forest Inventory and Survey Systems, Luxembourg.

volume reported according to the Finnish definition would be lost. This result shows that threshold values have more importance in those areas where trees with relatively small dimensions cover a high proportion of forest, like in the Nordic and Mediterranean regions. In the UK the volume of the stump is included in the stem volume, in Finland and Sweden stump volume is not included. If UK definitions are used in Finland and Sweden, both countries would gain 5 per cent in volume in their forests.

TABLE R.4

Examples of stem volume definitions (after Traub et al., 1997)[15]

Country	Minimum d.b.h., cm	Minimum top stem diameter, cm	Starting point of volume
Finland[1], Sweden[1], New Zealand	0	0	Stump
Iceland	0[1]	0	Ground
Austria, Netherlands, Portugal	5	0	Ground
Italy	3	0/3	Stump
Norway	5	0	Stump
Germany, Ireland, the United Kingdom	7	7	Ground
France	7.5	7	Ground
Belgium	7	7	stump
Greece	10	0	stump
Liechtenstein	12	0	ground
Spain	7.5	7.5	stump
Switzerland	12	7	ground
Australia	-	-	-
Japan	4	0	ground
Canada			
USA	2.5 - 12	0	stump
	> 12	4 inch	stump

[1] definition for “Forest and other wooded land”.

The TBFRA definition specifies standing volume as follows:

Volume of standing trees, living or dead, above-stump measured overbark to top (0 cm). Includes all trees with diameter over 0 cm (d.b.h.)

***Includes**: Tops of stems, large branches; dead trees lying on the ground which can still be used for fibre or fuel.*

***Excludes**: Small branches, twigs and foliage.*

This definition corresponds with the definitions of Sweden and Finland. In countries specifying a minimum threshold value for d.b.h larger than 0 cm the reported values underestimate standing volume according to the TBFRA definition. The example from Switzerland, where the highest d.b.h.-threshold throughout Europe is applied shows, however, that only a small bias will result, if no adjustments towards the TBFRA definition are made.

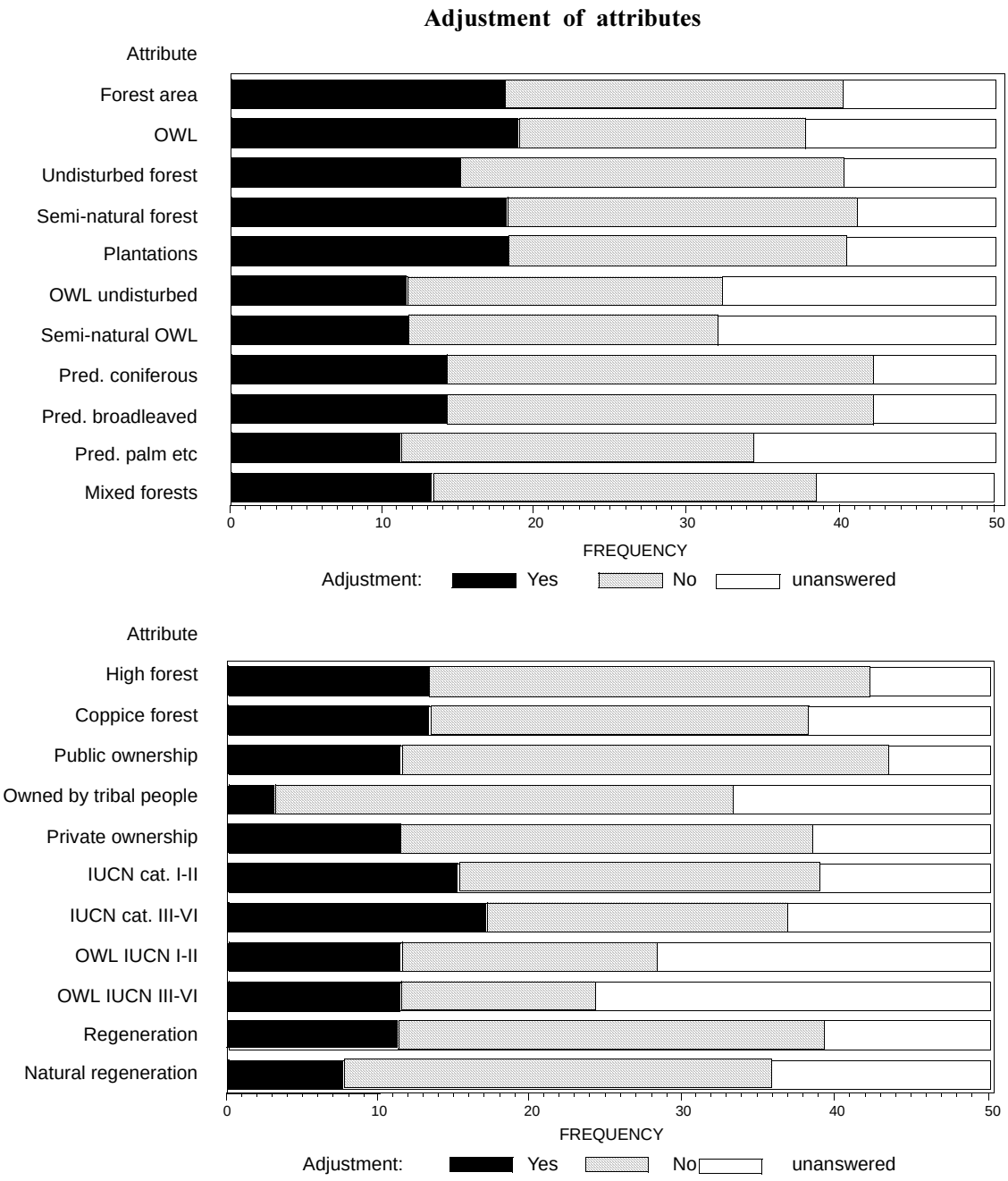
Adjustment of attributes

The reporting countries were asked to apply adjustments, if the national nomenclature diverged from the TBFRA definition. Countries were asked to specify the adjustments applied for 32 out of the 77 attributes assessed by the TBFRA enquiry. Figure R.3 presents information on the adjustment of attributes for the 50 responding countries. More than 30 per cent of those 50 countries applied adjustments for the attributes forest area, other wooded land, forest undisturbed by man, semi-natural forest, plantations, forest in IUCN-categories, total growing stock of forest, growing stock available for wood supply, total above-stump growing stock, and net annual increment on forest available for wood supply. The methods for applying adjustments were discussed in a meeting of the National Correspondents in Geneva in spring 1997. The methods applied to adjust national data to the TBFRA-definitions were reported to and cross-checked by the secretariat. Among the adjustment methods were reference to scientific reports or statistics other

[15] B. Traub, M. Köhl and R. Päivinen, 1997: Simulation Study, in: European Commission, Study on European Forest Information and Communication System (EFICS), Report on Forest Inventory and Survey Systems, Luxembourg.

than results of national forest resource assessments, the application of models or special investigations. In few cases expert opinion was used to adjust figures. The Finnish forest area estimate was for example adjusted to the TBFRA definition by applying a model that utilizes stand density and other parameters assessed in the Finnish national forest resources assessment. In Switzerland a special survey of aerial photographs was conducted to fit the national forest area definition to the TBFRA definition.

FIGURE R.3



For some attributes only a small number of countries applied adjustments. This was mainly due to the fact that national definitions meet the TBFRA definitions (e.g. ownership, regeneration, coppice sprouting, planting or seeding) or the attribute under consideration is matter of concern only in a few countries (e.g. forest owned by tribal peoples).

Data quality in terms of likely range

The reporting countries were asked to give the likely range of values for 32 selected attributes, which were assessed in the enquiry. The range should incorporate errors due to measurement, sampling and adjustment. Table R.5 lists the 32 attributes and the number of countries that provided information on the likely range.

FIGURE R.3 *(continued)*

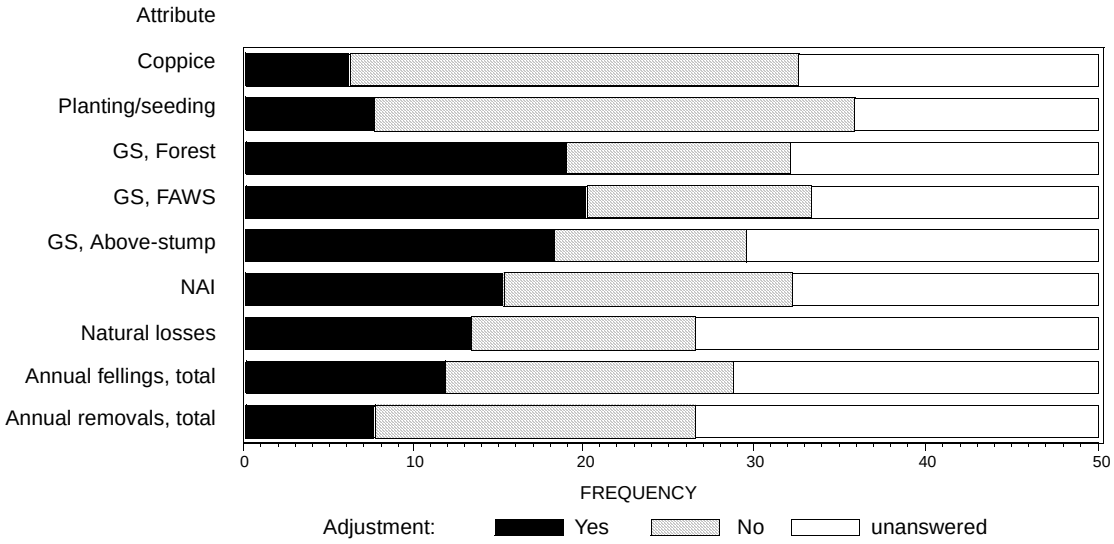


TABLE R.5

Attributes for which likely range was assessed and number of reporting countries

Attribute	Number of countries	Attribute	Number of countries
Forest area [ha]	31	Other wooded land [ha]	21
Forest undisturbed by man [ha]	22	Semi-natural forest [ha]	26
Plantations [ha]	26	Other wooded land undisturbed by man [ha]	14
Semi-natural other wooded land [ha]	16	Predominantly coniferous [ha]	24
Predominantly broadleaved [ha]	27	Predominantly palms, bamboos etc [ha]	-
Mixed forests [ha]	24	High forest available for wood supply [ha]	23
Coppice forest available for wood supply [ha]	18	In public ownership [ha]	24
Owned by tribal peoples [ha]	2	In private ownership [ha]	21
Forest in IUCN categories I-II [ha]	21	Forest in IUCN categories III-VI [ha]	22
OWL in IUCN categories I-II [ha]	7	OWL in IUCN categories III-VI [ha]	8
Regeneration of forest, total [ha]	23	Natural regeneration [ha]	17
Natural regeneration enhanced by planting [ha]	9	Coppice sprouting [ha]	8
Planting or seeding [ha]	18	Growing stock of trees, total [m^3 o.b.]	26
Growing stock of trees on forest available for wood supply [m^3 o.b.]	28	Total above-stump woody biomass [m^3 o.b.]	21
NAI on forests available for wood supply [m^3 o.b.]	24	Natural losses on forests available for wood supply [m^3 o.b.]	18
Annual fellings, total [m^3 o.b.]	19	Annual removals, total [m^3 u.b.]	14

Table R.6 shows that depending on the considered attribute between 2 (Forest owned by indigenous or tribal people) and 35 (Forest Area) countries out of fifty provided information on the likely ranges. For the majority of attributes more than 50 per cent of the reporting countries specified the likely range. The fact that only 3 countries reported values for the attribute “forest owned by indigenous or tribal people” explains the low response for this attribute.

For 7 out of 32 attributes (22 per cent), among which are key attributes such as “forest area”, “other wooded land” or “area of semi-natural forest”, a likely range within ± 5 per cent around the reported value was found. For 19 attributes (56 per cent) the likely range was found to be between ± 10 per cent and 80 per cent of the attributes cover a range of ± 15 per cent within which the reported value is located. The widest range was found for the attribute “total above stump growing stock”, where Australia and the Russian Federation gave very conservative estimates. If those two countries are omitted from the calculations, the likely range shrinks to ± 5 per cent .

TABLE R.6

Likely range for selected attributes

Variable	From (per cent)	To (per cent)	Number of countries
Forest area	97.32	102.79	35
Other wooded land	95.23	105.16	24
Forest undisturbed by man	93.45	106.77	22
Semi-natural forest	95.06	104.50	26
Plantations	97.09	102.80	28
Other wooded land undisturbed by man	94.44	105.57	12
Semi-natural other wooded land	95.18	104.73	18
Predominantly coniferous	88.99	105.89	29
Predominantly broadleaved	89.00	108.49	29
Mixed forests	81.66	118.04	26
High forest available for wood supply	98.29	101.74	26
Coppice forest available for wood supply	91.40	111.20	20
In public ownership	97.00	103.12	26
Owned by tribal peoples	90.85	109.06	2
In private ownership	93.47	106.34	22
Forest in IUCN categories I-II	88.30	105.00	25
Forest in IUCN categories III-VII	84.73	115.79	26
OWL in IUCN categories I-II	89.99	110.03	9
OWL in IUCN categories III-VII	80.07	119.94	9
Regeneration of forest, total	92.78	106.52	25
Natural regeneration	93.81	105.67	20
Natural regeneration enhanced by planting	90.72	107.52	13
Coppice sprouting	91.34	110.28	9
Planting or seeding	94.56	106.15	20
Growing stock of forest, total	88.85	117.46	26
Growing stock of forest available for wood supply	92.12	107.99	28
Total above-stump growing stock	90.57	132.06	21
NAI on forest available for wood supply	94.37	106.31	25
Natural losses on forest available for wood supply	84.81	115.39	19
Annual fellings, total	87.83	112.29	21
Annual removals total, u.b.	88.53	113.47	17

It has to be emphasized that the likely range presented by the TBFRA-2000 includes different sources of errors and is thus not directly comparable to confidence intervals specified in many national forest resource assessments. Confidence intervals include only sampling errors and are therefore narrower than the likely ranges presented in Table R.6. Taking also into account the large unit of reference covered by the TBFRA and the primary use of the information provided by the TBFRA the reliability of the results is more than sufficient.

Summary (Definition errors)

- At the national level forest area is assessed according to quantitative criteria, such as minimum crown cover, minimum area or minimum production.
- The minimum crown cover threshold of 10 per cent specified by the TBFRA definition is not critical in closed forests.
- In open forests close to natural timberlines the minimum crown cover is decisive for forest area estimates.
- Most countries that have forests close to natural timberlines utilize crown cover thresholds of 10 per cent or define forest area in a way that approximately matches the TBFRA definition.

- A study carried out in Europe and covering EU member states and EFTA countries showed that the total by the TBFRA definition is roughly 1 per cent higher than the European forest area assessed according to national definitions. The figures presented for forest area provide reliable results for TBFRA's units of reference.
- The figures presented for forest area provide reliable results for TBFRA's units of reference
- Single tree volume is a basic input value for the calculation of the volume of growing stock, increment, fellings and removals and can be transformed into woody biomass.
- According to the TBFRA definition for standing tree volume all trees with a diameter at breast height (d.b.h.) above 0 cm are included for volume estimates.
- Except for a few nations thresholds larger than 0 cm are defined for d.b.h. Even if the national figures are not converted towards the TBFRA definition only a small underestimation of standing volume will result.
- Taking also into account the large unit of reference covered by the TBFRA and the primary use of the information provided by the TBFRA the reliability of the results is more than sufficient.

Reference period

At the very beginning of the preparatory phase of TBFRA-2000 it was discussed if a common point in time should be specified to which all data should be related. A survey including all western European countries showed that in none of those countries inventory results are updated, even if the assessment periods cover several years. Only Germany specifies a single point in time to which data are related, the data are, however, assessed over a three-year period without any update.

The reference period of individual nations reporting to the TBFRA inquiry are presented in Figure R.4 and range from 1986 (Germany) to 1998 (Iceland). Eleven countries conduct national assessments over a period of several years; for those countries the mean of the reference period is presented in Figure R.4. Most countries (56 per cent) provided data assessed in 1995 and 1996. 80 per cent of the countries provided data for the reference period between 1994 and 1998. Ten countries delivered data that were assessed before 1994. Countries providing data before 1991 are Germany (1986), Azerbaijan (1988), Denmark (1990) and Spain (1990). Data from the North American region relate to 1994 (Canada) and 1992 (USA).

With the exception of two countries all national data presented in TBFRA-2000 were assessed during the 1990s. The differences in reference periods add some imprecision to the results. When the results of TBFRA-2000 are interpreted it has to be taken into account that the national data do not relate to a single point in time but to almost one decade. The reported changes in area and growing stock can be utilized as an indicator for potential differences of the status at the reference period and the time when the TBFRA-2000 results were issued. Given this background information the results of TBFRA-2000 can be regarded as reliable and comparable with respect to the reference period.

Summary (Reference period)

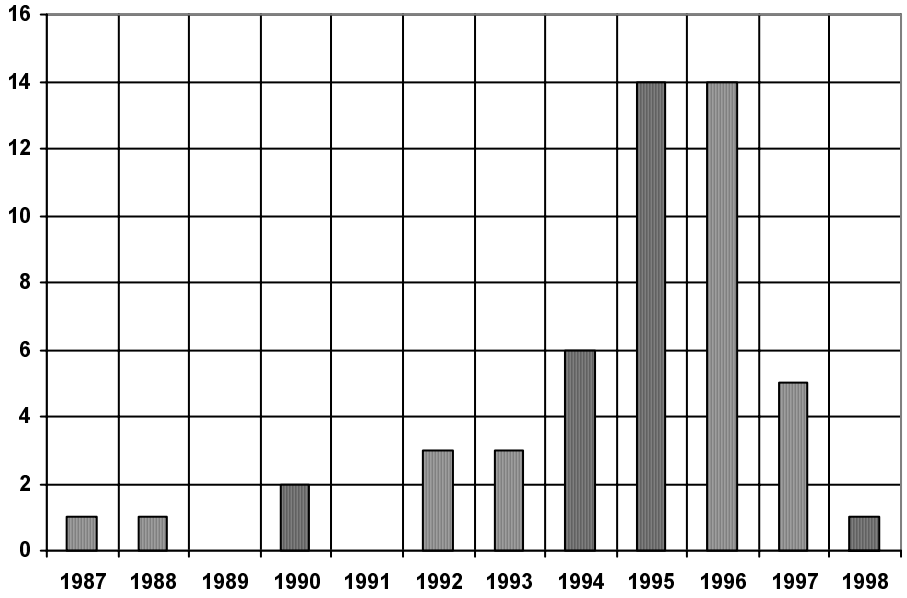
- The reference period of individual nations reporting to the TBFRA inquiry range from 1986 (Germany) to 1998 (Iceland).
- With the exception of two countries all national data presented in TBFRA-2000 were assessed during the 1990s.
- The reported changes in area and growing stock can be utilized as an indicator for potential differences of the status at the reference period and the time when the TBFRA-2000 results were issued.
- If TBFRA-2000 results for individual nations are cross-checked with the assessment period and the reported changes the information provided by TBFRA-2000 can be regarded as reliable and comparable with respect to the reference period.

Note on the results from the four largest forest countries

The above analysis has considered the reliability and comparability of the data provided by the fifty countries that responded to the TBFRA enquiry without considering the relative sizes of their forest resources and therefore the impact of the reliability and comparability of their data on the aggregate results. There is a very wide difference between the largest and smallest countries in terms of their forest resources; in fact four countries, the Russian Federation, Canada, the United States of America and Australia, account between them for the predominant share of the TBFRA region's total. Their share of the area of forest, for example, is over 85 per cent, that of other wooded land

FIGURE R.4

Number of countries per reference date



nearly 94 per cent, and of most of the other attributes discussed in this chapter more than three-fourths. Consequently, the reliability and comparability of their data have an important influence on the overall results of the TBFRA report.

The four countries were not amongst the nineteen (western European) countries covered by the EFICS study, which provided the basis for the analysis in this chapter. Given the very extensive nature of their forest resources, and the remoteness of and related difficulties of surveying a sizeable part of it, it is inevitable that they should have experienced certain difficulties in compiling as comprehensive and detailed a set of data as called for in the TBFRA enquiry. Without further analysis, which is beyond the reach of this report, it is impossible to assess whether there may be a number of areas where the data may possibly fall short of satisfactory reliability because of problems with definitions, sampling and survey methodologies, adjustment of national data, and so on. Generally speaking, there seems good reason to accept the figures in this report as the best available, and the National Correspondents in the four countries deserve full credit for the work they undertook to achieve this result. Nevertheless, in view of the importance of these countries at the TBFRA as well as global level, follow-up work to the TBFRA report could usefully take up this question in more detail.

Acknowledgement

This study was partly financed by the European Commission, DG VI, EFICS project. We thank Robert Flies and Louis du Breil de Pontbriand for the permission to publish results of the EFICS study. The simulation study on forest area was carried out by Dr. Berthold Traub, Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf, Switzerland, and Olaf Kügler, now Yale University, New Haven, USA. Special thanks to Christopher F.L. Prins and Alexander V. Korotkov, UN/ECE, and Dr. Matthias Scheuber, Dresden University of Technology, for helpful discussions and careful reviews of the manuscript.