



Forestry Department

Food and Agriculture Organization of the United Nations

**GLOBAL FOREST RESOURCES
ASSESSMENT 2005**

**GLOBAL ASSESSMENT OF
GROWING STOCK, BIOMASS
AND CARBON STOCK**

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The Forest Resources Assessment Programme

Sustainably managed forests have multiple environmental and socio-economic functions important at the global, national and local scales, and play a vital part in sustainable development. Reliable and up-to-date information on the state of forest resources - not only on area and area change, but also on such variables as growing stock, wood and non-wood products, carbon, protected areas, use of forests for recreation and other services, biological diversity and forests' contribution to national economies - is crucial to support decision-making for policies and programmes in forestry and sustainable development at all levels.

FAO, at the request of its member countries, regularly monitors the world's forests and their management and uses through the Forest Resources Assessment Programme. The Global Forest Resources Assessment 2005 (FRA 2005) is the most comprehensive assessment to date. More than 800 people have been involved, including 172 national correspondents and their colleagues, an Advisory Group, international experts, FAO staff, consultants and volunteers. Information has been collated from 229 countries and territories for three points in time: 1990, 2000 and 2005.

The reporting framework for FRA 2005 is based on the thematic elements of sustainable forest management acknowledged in intergovernmental forest-related fora and includes more than 40 variables related to the extent, condition, uses and values of forest resources. More information on the FRA 2005 process and the results - including all the country reports - is available on the FRA 2005 Web site (www.fao.org/forestry/fra2005).

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Abbreviations

FAO	Food and Agriculture Organization of the United Nations
UNFCCC	United Nations Framework Convention on Climate Change
IPCC	Intergovernmental Panel on Climate Change
DBH	Diameter at breast height
SFM	Sustainable Forest Management
FRA	Global Forest Resources Assessment
BD	Basic Density
BEF	Biomass Expansion Factor
BCEF	Biomass Conversion and Expansion Factor

1 Introduction

In 2006, FAO published the main report of the Global Forest Resources Assessment 2005 (FRA 2005), in which the progress towards sustainable forest management (SFM) was described and analysed.

FRA 2005 covered a wide range of variables related to SFM, among them growing stock, biomass and carbon stock. The FRA 2005 main report (FAO, 2006) includes global estimates and analysis of growing stock and carbon stock, but does not provide detailed information on the methodology applied and the assumptions made in order to make these estimates. Neither does the main report include an in-depth analysis of the reliability of the global estimates.

The purpose of this working paper is to give a detailed explanation of the methods used for making the global estimates of growing stock, biomass and carbon stock based on the country submissions to FRA 2005. It includes all the assumptions and calculations made in order to make the estimates. It also includes a discussion on the reliability and plausibility of the estimates.

This working paper focuses on analysis and estimates at subregional, regional and global level. It does not include tables with data for individual countries. FRA 2005 data for individual countries are presented in the FRA 2005 main report and in the country tables and country reports available at the FRA Website at: <http://www.fao.org/forestry/fra2005>.

2 The FRA 2005 data set

The FRA 2005 data set is based on information submitted by the countries using a common methodology and reporting template for presenting the information. In total, 173 countries submitted reports to FRA 2005 while 56 reports were compiled by FAO as desk studies (primarily small island states and some dependent territories). The data from these 229 country reports constitutes the basis for the estimates of growing stock, biomass and carbon stock presented in this paper.

FRA 2005 requested countries to report on more than 40 variables for three points in time (1990, 2000 and 2005). Of the reported variables the following are related to growing stock, biomass and carbon stock:

- Growing stock
- Commercial growing stock
- Above-ground biomass
- Below-ground biomass
- Dead wood
- Carbon in above-ground biomass
- Carbon in below-ground biomass
- Carbon in dead wood
- Carbon in litter
- Carbon in soil

The FRA 2005 definitions of the above-mentioned variables are found in Appendix 2.

For some of the variables countries were requested to specify a number of threshold values (diameter, soil depth, etc.) in order to allow for a better interpretation of the reported values.

The FRA 2005 data set has several gaps, as many countries did not report data for all variables and all years. This working paper presents how countries have reported on growing stock, biomass and carbon stock, and how these data gaps were taken into account when making the estimates.

3 Methods

3.1 General

Since the FRA 2005 set of country data is not complete, appropriate methods had to be applied in order to make global and regional estimates. In FRA 2005 the world is divided into regions and subregions (see table 3.1). The general procedure was to first make subregional estimates and then aggregate these to regional and global estimates.

Table 3.1. The FRA 2005 set of regions and subregions.

Region / subregion
Africa
Eastern and Southern Africa
Northern Africa
Western and Central Africa
Asia
East Asia
South and Southeast Asia
Western and Central Asia
Europe
Europe
North and Central America
Caribbean
Central America
North America
Oceania
Oceania
South America
South America

3.2 Subregional and regional estimates of growing stock, biomass and carbon

The following formulae were applied for making estimates of the variables related to growing stock, biomass and carbon, with the exception of commercial growing stock. The term “Reporting countries” refers here to those countries that reported a complete time series (1990, 2000 and 2005) for a specific variable.

a) Estimates of subregional values per hectare

$$\text{Per hectare value for subregion} = \frac{\text{Sum of values for reporting countries in subregion}}{\text{Sum of forest area in hectares of reporting countries in subregion}}$$

b) Estimates of subregional totals

$$\text{Total value for subregion} = \text{Estimated per hectare value for subregion} * \text{Total forest area in subregion}$$

For carbon in litter and soil there are some subregions where no countries have reported (East Asia for carbon in litter and soil, Eastern and Southern Africa for soil carbon). In these cases, the following formula was used:

$$\text{Total value for subregion} = \text{Estimated per hectare value for region} * \text{Total forest area in subregion}$$

c) Estimates of regional per hectare values

Regions composed of only one subregion: the estimated subregional per hectare values was used directly.

Regions composed of more than one subregion: the regional per hectare value was estimated by adding all estimated subregional totals and then dividing this sum by the total forest area of the region.

3.3 Subregional and regional estimates of commercial growing stock

When making subregional and regional estimates of commercial growing stock, the following formulae were used. In this case the term “Reporting countries” refers to the countries which reported a complete time series on both commercial growing stock and total growing stock.

a) Estimates of subregional ratios between commercial growing stock and total growing stock

$$\text{Ratio for subregion} = \frac{\text{Sum of commercial growing stock for reporting countries in subregion}}{\text{Sum of total growing stock of reporting countries in subregion}}$$

b) Estimates of subregional totals

$$\text{Total value for subregion} = \text{Estimated ratio for subregion} * \text{Estimated total growing stock in subregion}$$

c) Estimates of regional ratios between commercial growing stock and growing stock

For regions composed of only one subregion, the estimated subregional ratios were used directly.

For regions composed of several subregions, the regional ratio was estimated by adding all subregional estimated totals of commercial growing stock and then dividing this sum by the total growing stock of the region.

3.4 Global estimates

For all variables related to growing stock, biomass and carbon, the global estimates were obtained by adding all regional estimates. The global per-hectare values were calculated by dividing the estimated global totals by the corresponding global forest area.

3.5 Country-specific estimates

In a few cases FAO made country-specific estimates to complement the data set before applying the general formulae above. This was only done in cases where no or incomplete information on a particular variable was given in the country report, and where complementary information on a closely correlated variable was available. Preference was here given to countries that had much influence on regional and sub-regional estimates, due to the size of their forest area (e.g. Australia that has large impact on estimates for Oceania).

4 Global assessment of growing stock

4.1 Total growing stock

4.1.1 Data availability

For FRA 2005, 147 countries, representing 87.7 percent of the world's forest area, reported a complete time series of data on growing stock (see Table 4.1 below).

Table 4.1. Countries reporting on growing stock

Region / Sub-region	Number of countries			Forest area (1000 ha)		
	All	reporting on growing stock	%	All	reporting on growing stock	%
Eastern and Southern Africa	20	16	80.0	226 534	226 434	100.0
Northern Africa	16	15	93.8	131 048	129 494	98.8
Western and Central Africa	22	17	77.3	277 829	272 184	98.0
Africa	58	48	82.8	635 412	628 112	98.9
East Asia	5	5	100.0	244 862	244 862	100.0
South and Southeast Asia	18	15	83.3	283 127	282 325	99.7
Western and Central Asia	25	17	68.0	43 588	42 190	96.8
Asia	48	37	77.1	571 577	569 377	99.6
Europe	47	37	78.7	1 001 394	988 013	98.7
Caribbean	25	8	32.0	5 974	5 692	95.3
Central America	7	6	85.7	22 411	22 113	98.7
North America	5	2	40.0	677 464	613 223	90.5
North and Central America	37	16	43.2	705 849	641 028	90.8
Oceania	24	3	12.5	206 254	30 172	14.6
South America	15	6	40.0	831 540	608 419	73.2
WORLD	229	147	64.2	3 952 025	3 465 121	87.7

4.1.2 Global estimates of total growing stock

By applying the methodology and formulae described in chapter 3, subregional, regional and global estimates of total growing stock were made for each of the three reporting years. The detailed tables are presented in Appendix 1.

Table 4.2 shows in consolidated form, the trends of total growing stock and growing stock per hectare for the period 1990-2005. Here, the results for Europe is presented in two different ways, one including and one excluding the Russian Federation. This was done as the Russian Federation, when included, completely dominates the estimates for Europe therefore some important trends, such as the increase in growing stock per hectare in the other European countries would not be possible to distinguish.

Table 4.2. Consolidated estimates of total growing stock for the period 1990-2005.

Region / Sub-region	Growing stock (million m3)			Growing stock (m3/ha)			Change rate (m3/ha/yr)
	1990	2000	2005	1990	2000	2005	90-05
Eastern and Southern Africa	11 035	10 346	10 015	43.7	44.0	44.2	n.s.
Northern Africa	2 771	2 607	2 523	19.0	19.2	19.2	n.s.
Western and Central Africa	55 566	53 218	52 420	184.7	187.0	188.7	0.3
Africa	69 373	66 171	64 957	99.2	100.9	102.2	0.2
East Asia	15 850	18 433	19 743	76.1	81.7	80.6	0.3
South and Southeast Asia	32 615	27 296	24 202	100.9	91.8	85.5	-1.0
Western and Central Asia	2 959	3 105	3 166	68.5	71.3	72.6	0.3
Asia	51 423	48 834	47 111	89.5	86.2	82.4	-0.5
Europe (incl. Russian Federation)	102 063	105 374	107 264	103.2	105.6	107.1	0.3
Europe (excl. Russian Federation)	22 024	25 103	26 785	123.6	135.0	141.5	1.2
Caribbean	328	403	441	61.4	70.6	73.8	0.8
Central America	3 585	3 097	2 906	129.7	129.9	129.7	n.s.
North America	72 542	74 227	75 235	107.0	109.5	111.1	0.3
North and Central America	76 455	77 727	78 582	107.6	109.9	111.3	0.3
Oceania	7 593	7 428	7 361	35.7	35.7	35.7	n.s.
South America	138 310	133 467	128 944	155.3	156.5	155.1	n.s.
WORLD	445 218	439 000	434 219	109.2	110.1	109.9	n.s.

n.s. = not significant, indicating a value < 0.05

4.1.3 Reliability of growing stock estimates

In general, the reporting countries represent a fairly high proportion of the forest area in each subregion. The exception is Oceania, where the figures are dominated by the estimates of Papua New Guinea (> 95% of reported growing stock in the region), as neither Australia, nor New Zealand provided any growing stock figures. Furthermore, the growing stock figures for Papua New Guinea are not very representative, as they only reported the volume of trees with a diameter at breast height (DBH) greater than or equal to 50 cm.

The quality of the growing stock estimates varies between countries. While a few countries have permanent national forest inventories in place, a majority of countries still lack good forest inventory data. Frequently the growing stock estimates are based on very old and often partial and non-representative forest inventories; this is particularly common in the developing countries.

Another important issue is the reliability of the trend data for growing stock. Figure 4.1 shows reported country data of growing stock change rate plotted against the forest area change rate.

The figure shows that most dots lie on the diagonal, indicating that changes in growing stock merely reflect the changes in forest area. This is often the case when countries only have inventory information on growing stock from one point in time, and then apply the growing stock per hectare from this single occasion to the forest area for the three reporting years. In the FRA 2005 data set, 93 out of 147 countries assumed no change in growing stock per hectare for the 1990-2005 period, while the remaining 54 countries estimated either an increase or a decrease of growing stock per hectare. As a consequence the growing stock trend estimates are weak, which also affect the reliability of the trend estimates of biomass and carbon stocks.

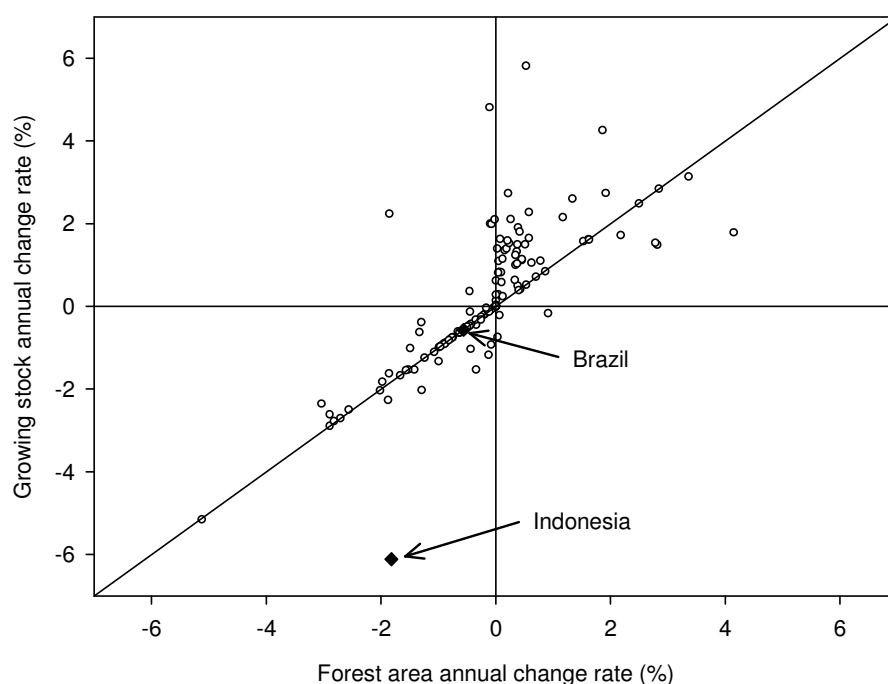


Figure 4.1. Change rates in growing stock plotted against change rates in forest area. Data points falling on the diagonal represent countries where the same per-hectare values of growing stock (and presumably also biomass and carbon) were applied to the forest area for all reporting years.

Data from Brazil and Indonesia can be used to illustrate the growing stock trend data. The data point for Brazil lies on the diagonal, indicating that growing stock per hectare was assumed to be constant over time. Indonesia, on the other hand, show a decrease in growing stock that is larger than the corresponding decrease in forest area, indicating that the growing stock per hectare is decreasing.

Figure 4.1 also shows that the reliable information on trends in growing stock is less available in countries that show a general decrease in growing stock and forest area (lower left quartile of the figure); here is where we find most of the developing countries. On the other hand, most of the countries that have reported a general increase (upper right quartile) have also reported a growing stock change rate that is different from the forest area change rate, indicating that the reliable growing stock trend information from these countries is more available.

4.1.4 Threshold values for growing stock estimates

The definition of growing stock for FRA 2005 (see Appendix 2) does not establish any fixed values for parameter thresholds. Instead, it gives freedom to the countries to define several country-specific parameters related to the definition of growing stock. These parameters are:

- Minimum diameter at breast height (DBH) of trees included in the growing stock
- Minimum diameter at the top end of stem for estimation of growing stock
- Minimum diameter of branches if included in growing stock
- Whether growing stock data refers to volume above-ground or above-stump

Of these, the DBH threshold value is the parameter that most significantly influences the growing stock estimates. Of the 147 countries that reported on growing stock, 100 reported DBH threshold values while 47 countries did not report any DBH threshold value, among them several important countries in terms of forest area, such as Brazil, Canada, China and Malaysia. Table 4.3 shows the number of countries that applied different DBH thresholds.

Table 4.3. Application of different DBH thresholds for growing stock data

DBH threshold	Frequency	Comment	Growing stock (million m3)	Proportion of growing stock
Missing	47	Incl. Brazil, Canada, China and Malaysia	155 492	40.6%
0	7		6 896	1.8%
0.1 - 5	21		90 822	23.7%
5.1 - 10	45		67 074	17.5%
10.1 - 15	12		36 508	9.5%
15.1 - 20	8		16 868	4.4%
30	1	Congo (average of 20 and 40)	4 551	1.2%
35	1	Central African Republic (average)	3 801	1.0%
40	3	Burkina Faso, Sao Tome, New Caledonia	282	0.1%
50	1	Papua New Guinea	1 035	0.3%
60	1	Equatorial Guinea	107	0.0%
TOTAL	147		383 437	100.0%

Due to the variation in countries' application of DBH thresholds and the fact that 41 percent of the total reported growing stock are in countries that did not report any DBH threshold, no attempt was made to harmonize the growing stock estimates to a common DBH threshold value (e.g. 0 cm or 10 cm), although that would have been desirable, particularly when considering that in most countries the growing stock was used as the basis for carbon estimates

For FRA 2010, the issue of how to deal with missing DBH thresholds, the variety of DBH thresholds employed and the implications for global estimates of growing stock, biomass and carbon should be thoroughly analyzed and resolved.

4.2 Commercial growing stock

4.2.1 Data availability

In total, 106 countries, corresponding to 74.2 percent of the world's forest area reported a complete time series of data for both growing stock and commercial growing stock¹ (Table 4.4). Three subregions show particularly weak data (Northern Africa, Western and Central Africa and Oceania) as the reporting countries represent less than half of the subregions' total forest area.

¹ For definitions of growing stock and commercial growing stock, see Appendix 2.

Table 4.4. Countries reporting on commercial growing stock

Region / Sub-region	Number of countries			Forest area (1000 ha)		
	All	reporting on commercial growing stock	%	All	reporting on commercial growing stock	%
Eastern and Southern Africa	20	12	60.0	226 534	202 887	89.6
Northern Africa	16	8	50.0	131 048	47 809	36.5
Western and Central Africa	22	11	50.0	277 829	85 217	30.7
Africa	58	31	53.4	635 412	335 913	52.9
East Asia	5	3	60.0	244 862	213 807	87.3
South and Southeast Asia	18	13	72.2	283 127	172 940	61.1
Western and Central Asia	25	13	52.0	43 588	38 509	88.3
Asia	48	29	60.4	571 577	425 256	74.4
Europe	47	32	68.1	1 001 394	980 757	97.9
Caribbean	25	3	12.0	5 974	3 278	54.9
Central America	7	4	57.1	22 411	15 812	70.6
North America	5	2	40.0	677 464	613 223	90.5
North and Central America	37	9	24.3	705 849	632 313	89.6
Oceania	24	2	8.3	206 254	30 154	14.6
South America	15	3	20.0	831 540	526 840	63.4
WORLD	229	106	46.3	3 952 025	2 931 234	74.2

4.2.2 Estimates of the ratio between commercial growing stock and growing stock

The ratio between commercial growing stock and growing stock was calculated for each subregion, based on those countries that reported a complete time series of both growing stock and commercial growing stock (Table 4.4). The result of this calculation is shown in the Table 4.5:

Table 4.5. Ratio between commercial growing stock and growing stock. The subregional and regional totals refer to reporting countries only and were used to estimate the ratios.

Region / Sub-region	Growing stock (million m3)			Commercial growing stock (million m3)			Ratio between commercial growing stock and growing stock		
	1990	2000	2005	1990	2000	2005	1990	2000	2005
Eastern and Southern Africa	10 147	9 531	9 238	2 316	2 138	2 060	0.228	0.224	0.223
Northern Africa	1 405	1 339	1 303	382	391	396	0.272	0.292	0.304
Western and Central Africa	12 316	11 510	11 231	2 956	2 847	2 872	0.240	0.247	0.256
Africa	23 868	22 380	21 772	5 654	5 376	5 329	0.237	0.240	0.245
East Asia	12 235	14 151	15 099	10 817	12 265	13 051	0.884	0.867	0.864
South and Southeast Asia	14 112	13 987	13 675	5 497	4 979	4 611	0.390	0.356	0.337
Western and Central Asia	2 800	2 937	2 996	1 716	1 766	1 788	0.613	0.601	0.597
Asia	29 146	31 076	31 771	18 030	19 011	19 450	0.619	0.612	0.612
Europe	99 889	102 985	104 773	64 656	59 273	59 823	0.647	0.576	0.571
Caribbean	205	278	316	110	169	203	0.535	0.608	0.643
Central America	2 606	2 292	2 168	521	443	420	0.200	0.193	0.194
North America	65 155	67 051	68 101	58 216	59 959	60 618	0.894	0.894	0.890
North and Central America	67 966	69 621	70 585	58 847	60 571	61 242	0.866	0.870	0.868
Oceania	1 151	1 100	1 075	583	560	548	0.507	0.509	0.510
South America	92 176	88 434	84 947	18 695	17 669	17 123	0.203	0.200	0.202
WORLD	314 195	315 597	314 923	166 465	162 459	163 514	0.530	0.515	0.519

4.2.3 Global estimates of commercial growing stock

Multiplying the estimated ratios for each subregion from Table 4.5 by the estimated total growing stock in Table 4.2 gives the global estimates of commercial growing stock as shown in Table 4.6 below.

Table 4.6. Global estimates of commercial growing stock

Region / Sub-region	Commercial growing stock (million m ³)		
	1990	2000	2005
Eastern and Southern Africa	2 519	2 321	2 234
Northern Africa	754	762	767
Western and Central Africa	13 336	13 162	13 407
Africa	16 609	16 245	16 408
East Asia	14 013	15 976	17 065
South and Southeast Asia	12 705	9 717	8 160
Western and Central Asia	1 813	1 867	1 890
Asia	28 531	27 561	27 115
Europe	66 063	60 648	61 245
Caribbean	175	245	283
Central America	717	599	563
North America	64 816	66 376	66 968
North and Central America	65 709	67 220	67 815
Oceania	3 849	3 777	3 751
South America	28 052	26 666	25 992
WORLD	208 813	202 116	202 325

5 Global assessment of biomass stocks

5.1 Country-specific assumptions and FAO estimates

Country-specific estimates and assumptions were made for four countries where no or incomplete biomass information was reported but good auxiliary information was available, namely: Australia, Austria, Canada and New Zealand. The estimates for Australia and New Zealand were of particular importance as Oceania otherwise would have been represented by only a few small islands, making it difficult to make good estimates for that region.

The country-specific FAO estimates are presented in Table 5.1, where the shaded areas refer to the information available in the country report that was used as a basis for the estimation. The root-shoot ratios used for the estimates are from IPCC (2003).

Table 5.1. Country-specific biomass estimates made by FAO. Shaded numbers are the actually reported data that were used for the estimates.

Australia	1990	2000	2005
Forest Area	167 904	164 645	163 678
Above ground biomass	13 263	13 005	12 929
Below-ground biomass	5 725	5 614	5 581
Dead wood	5 036	4 938	4 909
Total biomass	18 988	18 619	18 510

The ratio between biomass and forest area for 2005 was applied to the forest area for 1990 and 2000.

Austria	1990	2000	2005
Above ground biomass	533	589	628
Below-ground biomass	122	135	145
Total biomass	655	724	773

A root-shoot ratio of 0.23 was applied to the total biomass reported.

Canada	1990	2000	2005
Growing stock	32 983	32 983	32 983
Above ground biomass	24 987	24 987	24 987
Below-ground biomass	7 996	7 996	7 996
Total biomass	32 983	32 983	32 983

It was assumed that 1 m³ of growing stock corresponds to 1 ton of total living biomass (FAO, 2006. Table 2.9). A root-shoot ratio of 0.32 was then applied in order to estimate above-ground and below-ground biomass.

New Zealand	1990	2000	2005
Forest Area	7 720	8 226	8 309
Above ground biomass	1 612	1 718	1 735
Below-ground biomass	420	447	452
Total biomass	2 032	2 165	2 187

The ratio between biomass and forest area for 1990 was applied to the forest area for 2000 and 2005.

5.2 Data availability for biomass and dead wood

Including the four countries above, 146 countries have a complete time series of data for biomass and its two components - above-ground and below-ground biomass. The response rate for biomass reporting by subregion is shown in Table 5.2.

Table 5.2. Countries reporting on biomass

Region / Sub-region	Number of countries reporting on			Forest area (1000 ha) reporting on		
	All	biomass	%	All	biomass	%
Eastern and Southern Africa	20	16	80.0	226 534	226 434	100.0
Northern Africa	16	15	93.8	131 048	129 494	98.8
Western and Central Africa	22	17	77.3	277 829	272 184	98.0
Africa	58	48	82.8	635 412	628 112	98.9
East Asia	5	5	100.0	244 862	244 862	100.0
South and Southeast Asia	18	15	83.3	283 127	282 325	99.7
Western and Central Asia	25	16	64.0	43 588	41 981	96.3
Asia	48	36	75.0	571 577	569 168	99.6
Europe	47	38	80.9	1 001 394	999 089	99.8
Caribbean	25	7	28.0	5 974	5 177	86.6
Central America	7	5	71.4	22 411	17 465	77.9
North America	5	2	40.0	677 464	613 223	90.5
North and Central America	37	14	37.8	705 849	635 865	90.1
Oceania	24	4	16.7	206 254	172 722	83.7
South America	15	6	40.0	831 540	661 084	79.5
WORLD	229	146	63.8	3 952 025	3 666 040	92.8

The reporting on dead wood was not quite as comprehensive as for living biomass, only 107 countries reported, corresponding to 80.3 percent of the world's total forest area. The reporting on dead wood by subregion is shown in Table 5.3.

Table 5.3. Countries reporting on dead wood

Region / Sub-region	Number of countries reporting on			Forest area (1000 ha) reporting on		
	All	dead wood	%	All	dead wood	%
Eastern and Southern Africa	20	12	60.0	226 534	210 508	92.9
Northern Africa	16	6	37.5	131 048	94 755	72.3
Western and Central Africa	22	15	68.2	277 829	249 629	89.8
Africa	58	33	56.9	635 412	554 892	87.3
East Asia	5	4	80.0	244 862	219 994	89.8
South and Southeast Asia	18	15	83.3	283 127	282 325	99.7
Western and Central Asia	25	12	48.0	43 588	29 826	68.4
Asia	48	31	64.6	571 577	532 145	93.1
Europe	47	24	51.1	1 001 394	935 508	93.4
Caribbean	25	5	20.0	5 974	4 759	79.7
Central America	7	5	71.4	22 411	17 465	77.9
North America	5	1	20.0	677 464	303 089	44.7
North and Central America	37	11	29.7	705 849	325 313	46.1
Oceania	24	2	8.3	206 254	164 395	79.7
South America	15	6	40.0	831 540	661 084	79.5
WORLD	229	107	46.7	3 952 025	3 173 338	80.3

5.3 Global estimates of biomass and dead wood

Global estimates of biomass and dead wood, by region and subregion were made for each of the three reporting years, based on the methodology and formulae presented in Chapter 3. The detailed tables are presented in Appendix 1. From these, two consolidated tables with the main results were derived (Tables 5.4 and 5.5)

Table 5.4. Global estimates of above-ground and below-ground biomass

Region / Subregion	Above-ground biomass (million t)			Below-ground biomass (million t)			Total biomass (million t)		
	1990	2000	2005	1990	2000	2005	1990	2000	2005
Eastern and Southern Africa	25 076	23 326	22 630	6 765	6 307	6 126	31 840	29 632	28 756
Northern Africa	5 793	5 394	5 193	1 805	1 681	1 620	7 598	7 076	6 813
Western and Central Africa	74 417	71 018	69 706	17 967	17 070	16 711	92 384	88 088	86 417
Africa	105 286	99 738	97 530	26 537	25 058	24 457	131 822	124 796	121 986
East Asia	11 030	12 920	13 915	3 364	3 912	4 188	14 395	16 832	18 103
South and Southeast Asia	50 250	40 072	34 442	14 727	11 448	9 635	64 977	51 520	44 077
Western and Central Asia	2 628	2 765	2 820	608	635	647	3 235	3 400	3 467
Asia	63 908	55 757	51 177	18 699	15 995	14 470	82 607	71 752	65 647
Europe	67 275	68 938	70 269	16 981	17 550	17 886	84 257	86 488	88 155
Caribbean	723	891	971	198	249	273	921	1 140	1 245
Central America	5 220	4 425	4 115	1 534	1 317	1 234	6 754	5 742	5 349
North America	59 247	61 494	62 574	15 150	15 565	15 767	74 397	77 059	78 341
North and Central America	65 191	66 810	67 660	16 881	17 131	17 275	82 072	83 941	84 935
Oceania	18 071	17 788	17 656	7 440	7 298	7 239	25 511	25 086	24 895
South America	152 796	148 004	143 489	46 022	43 835	42 699	198 818	191 839	186 187
WORLD	472 526	457 035	447 781	132 560	126 867	124 025	605 087	583 901	571 806

Table 5.5. Global estimates of total biomass and dead wood

Region / Subregion	Total biomass (million t)			Dead wood (million t)			Biomass and dead wood (million t)		
	1990	2000	2005	1990	2000	2005	1990	2000	2005
Eastern and Southern Africa	31 840	29 632	28 756	3 791	3 498	3 380	35 631	33 130	32 137
Northern Africa	7 598	7 076	6 813	988	911	867	8 585	7 987	7 680
Western and Central Africa	92 384	88 088	86 417	6 060	5 680	5 513	98 444	93 768	91 930
Africa	131 822	124 796	121 986	10 838	10 090	9 760	142 660	134 886	131 747
East Asia	14 395	16 832	18 103	2 061	2 326	2 438	16 456	19 158	20 541
South and Southeast Asia	64 977	51 520	44 077	7 460	5 994	5 170	72 437	57 514	49 247
Western and Central Asia	3 235	3 400	3 467	301	311	319	3 536	3 710	3 786
Asia	82 607	71 752	65 647	9 822	8 630	7 927	92 429	80 382	73 574
Europe	84 257	86 488	88 155	27 809	27 953	28 051	112 066	114 441	116 206
Caribbean	921	1 140	1 245	99	104	109	1 020	1 245	1 354
Central America	6 754	5 742	5 349	820	696	647	7 574	6 438	5 996
North America	74 397	77 059	78 341	11 094	11 721	11 958	85 490	88 779	90 299
North and Central America	82 072	83 941	84 935	12 012	12 521	12 714	94 084	96 462	97 649
Oceania	25 511	25 086	24 895	6 363	6 229	6 175	31 874	31 315	31 070
South America	198 818	191 839	186 187	16 340	15 909	15 658	215 159	207 748	201 845
WORLD	605 087	583 901	571 806	83 186	81 332	80 286	688 272	665 233	652 092

5.4 Conversion factors and ratios

Most countries do not have inventory data expressed directly in terms of biomass. Instead, they estimate biomass stocks by applying a set of conversion and/or expansion factors to the growing stock data. Table 5.6 show the conversion factors used and their definitions.

Table 5.6. Definition of conversion factors used for biomass estimation. The definitions are based on the IPCC 2006 Guidelines.

Term	Definition
Basic wood density (BD)	Ratio between oven-dry weight and green volume of wood
Biomass conversion and expansion factor (BCEF)	Ratio between above-ground biomass in tonnes and growing stock in m ³
Biomass expansion factor (BEF)	Ratio between above-ground biomass and biomass of growing stock
Root-shoot ratio	Ratio between below-ground and above-ground biomass
Dead-live ratio	Ratio between dead wood biomass and total living biomass

For FRA 2005, countries were given the default factors from the IPCC (2003) to use when no better information was available.

In order to check the plausibility of reported biomass data, implied conversion factors were derived from the reported values on growing stock and biomass and then compared with IPCC default values (IPCC, 2003) and a few other sources. The plausibility check does not focus on values for individual countries, but on the range of implied parameter values to see if it is likely that there is any bias in the estimates.

Table 5.7 show the biomass conversion and expansion factor (BCEF) derived from reported country data on growing stock and above-ground biomass. BCEF can be converted to biomass expansion factors (BEF) by dividing by the basic wood density. Assuming an average basic wood density of 0.6 tonnes of dry matter per m³ wood, the global figures in Table 5.7 correspond to a BEF of 0.7 (min), 2.2 (average) and 6.6 (max). This should then be compared with IPCC (2003) that gives a BEF interval of 1.15-9.0 and an average of approximately 2. The correspondence is fairly good, which also could be expected as many countries used the IPCC (2003) factors for making their biomass estimates.

Table 5.7. Biomass conversion and expansion factor² (BCEF) derived from the country reports.

Region / Subregion	Minimum	Average	Maximum
Eastern and Southern Africa	0.693	1.835	3.320
Northern Africa	0.540	1.811	3.974
Western and Central Africa	0.853	1.649	3.039
Africa	0.540	1.762	3.974
East Asia	0.648	0.736	0.860
South and Southeast Asia	0.810	1.574	2.448
Western and Central Asia	0.522	0.925	1.603
Asia	0.522	1.170	2.448
Europe	0.416	0.662	1.250
Caribbean	1.037	1.953	3.339
Central America	0.593	1.197	1.953
North America	0.758	0.825	0.901
North and Central America	0.593	1.522	3.339
Oceania	1.700	2.339	2.978
South America	0.973	2.039	3.617
WORLD	0.416	1.319	3.974

² The derived biomass conversion and expansion factors are presented for the plausibility analysis only and should not be used as regional and subregional conversion and expansion factors.

The BCEF tends to decrease with increasing growing stock per hectare. Figure 5.1 shows the BCEFs derived from reported country data plotted against growing stock per hectare. For comparison, the figure also shows three typical functions for different forest types that were used for the preparation of the IPCC 2006 Guidelines (Schoene, pers. comm.) Except for a few outliers (Suriname, Madagascar and Congo), the observed data are within the expected range and appear plausible as a whole.

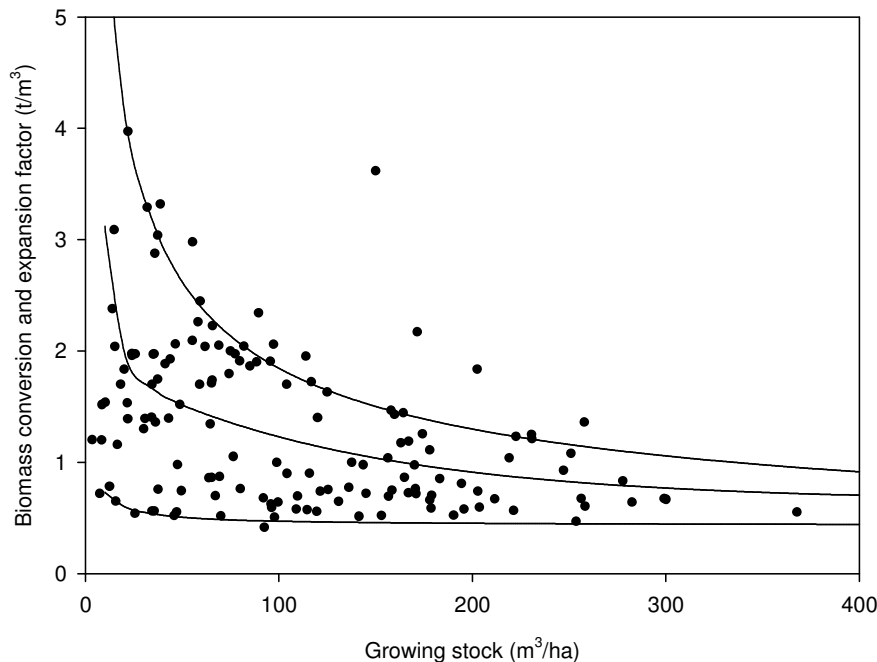


Figure 5.1. BCEFs derived from reported country data plotted against growing stock per hectare. The curves show three BCEF functions for different forest types: Norway spruce (lower curve), temperate broadleaved forest (middle curve) and tropical broadleaved forest (upper curve).

Root-shoot ratios are used to expand above-ground biomass to total biomass. Root-shoot ratios derived from reported country data are in the range between 0.1 and 0.99 with an average of 0.29. The derived values fall well within the ranges provided by IPCC (2003) that reports a global average root-shoot ratio of about 0.3 and an interval between 0.1 and 1.2.

When below-ground biomass per hectare reported by countries is plotted against above-ground biomass per hectare (Figure 5.2), the observations match a function of these variables established by Cairns (1997). It is important to keep in mind that rather than new scientific information, the observations plotted in Figure 5.2 in most cases merely reflect the IPCC default values, which were based on Cairns (1997). However, the figure indicates that most countries have applied plausible root-shoot ratios.

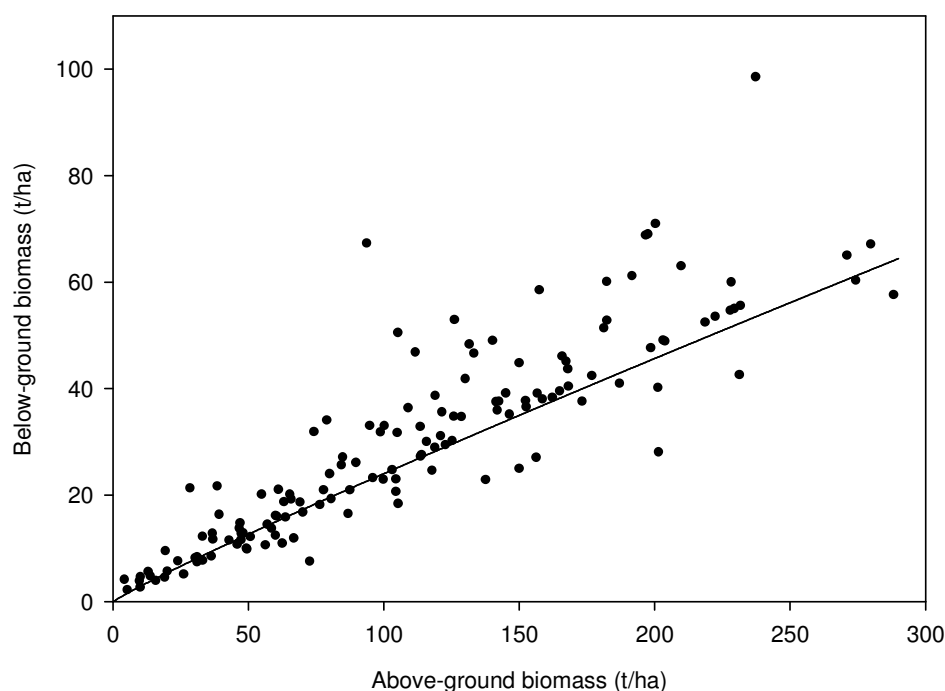


Figure 5.2. Reported values of below-ground biomass per ha used by countries plotted against above-ground biomass per ha. The curve shows a function established by Cairns (1997) and serves as reference for comparison.

Dead-live ratios derived from data reported by countries are in the range between 0 and 0.38 with an average of 0.12. For comparison, IPCC (2003) reports dead-live ratios in the range between 0.11 and 0.20.

IPCC (2003) gives two approaches for estimating dead wood, one based on dead-live ratios and the other as average per hectare stocks of dead wood, but they also explicitly warn against using its dead-live ratios or average dead wood stocks as these averages have very large standard errors and are based only on semi-natural or near-natural forests. Taking this uncertainty into account, the IPCC (2006) Guidelines no longer provide any default values for dead-live ratios or dead wood stocks.

6 Global assessment of carbon stocks

6.1 Country-specific assumptions and FAO estimates

Country-specific carbon estimates were made by FAO for the same four countries as for the biomass estimates. These estimates are presented in Table 6.1, where the shaded areas refer to the auxiliary information available in the country report that was used as a basis for the estimation. The root-shoot and dead-live ratios used are from IPCC (2003).

Table 6.1. Country-specific carbon estimates made by FAO. Shaded numbers are the actually reported data that were used for the estimates.

Australia	1990	2000	2005
Forest Area	167 904	164 645	163 678
Carbon in above ground biomass	5 974	5 858	5 824
Carbon in below-ground biomass	2 580	2 530	2 515
Carbon in dead wood	1 283	1 258	1 251
Carbon in litter	983	964	958
Carbon in dead wood and litter	2 266	2 222	2 209

The ratio between carbon in biomass and forest area for 2005 was applied to the forest area for 1990 and 2000.

*A dead-live ratio of 0.15 was applied to estimate carbon in dead wood
Carbon in litter was then estimated as the remaining difference*

Austria	1990	2000	2005
Carbon in above ground biomass	260.2	287.8	308.1
Carbon in below-ground biomass	59.8	66.2	70.9
Carbon in biomass	320	354	379

A root-shoot ratio of 0.23 was applied to the total carbon in biomass reported.

Canada	1990	2000	2005
Growing stock	32 983	32 983	32 983
Carbon in above ground biomass	12 494	12 494	12 494
Carbon in below-ground biomass	3 998	3 998	3 998
Carbon in biomass	16 492	16 492	16 492

It was assumed that one m³ of growing stock corresponds to 1 ton of total living biomass. A root-shoot ratio of 0.32 and a carbon content of 50% was then applied in order to estimate carbon in above-ground and below-ground biomass.

New Zealand	1990	2000	2005
Forest Area	7 720	8 226	8 309
Carbon in above ground biomass	806	859	868
Carbon in below-ground biomass	210	224	226
Carbon in dead wood	203	217	219
Carbon in litter	385	410	414
Carbon in dead wood and litter	588	627	633
Carbon in soil	781	832	841

*The ratios to forest area for 1990 was applied to the forest area for 2000 and 2005. A dead-live ratio of 0.20 was applied to estimate carbon in dead wood.
Carbon in litter was then estimated as the remaining difference*

Furthermore, Comoros was the only country from the subregion Eastern and Southern Africa that reported on soil carbon. They reported very high values of soil carbon per hectare and a highly inconsistent time series and were therefore not considered suitable to use as a basis for making the subregional soil carbon estimates. Instead, and in the absence of a subregional estimate, the regional per hectare values were applied to the countries in this subregion.

6.2 Adjustment of soil carbon data due to different soil depths

Most countries reported soil carbon to the common soil depth of 30 cm; however a few countries used other soil depths in their carbon reporting. In order to standardize the soil carbon estimates to a common soil depth, correction factors were applied as shown in Table 6.2.

Table 6.2. Factors used to adjust reported figures on soil carbon to a standard soil depth of 30 cm.

Soil depth (cm)	Correction factor
20	1.291
50	0.797
80	0.710
100	0.684

These correction factors were derived from data on generalized soil carbon profiles in natural ecosystems (Bouwman, 1990). They represent average values of soil carbon percentage by depth of all soil types from forest ecosystems. Original and adjusted country data on soil carbon are presented in Table 6.3 below.

Table 6.3. Countries with non-standard soil depth. Soil carbon before and after standardization to a soil depth of 30 cm.

Country	Soil depth (cm)	Correction factor	Soil C - original figures (million tonnes)			Soil C - adjusted figures (million tonnes)		
			1990	2000	2005	1990	2000	2005
Algeria	50	0.797	68	82	87	54	65	69
Austria	50	0.797	463	471	474	369	375	378
Belgium	20	1.293	47	47	47	61	61	61
Brazil	100	0.684	55 939	52 284	50 289	38 262	35 762	34 398
Czech Republic	20	1.293	189	190	190	245	246	246
India	100	0.684	6 782	7 166	7 181	4 639	4 902	4 912
Nepal	100	0.684	432	350	326	295	239	223
Netherlands	80	0.710	37	39	40	26	28	28
Romania	50	0.797	723	723	723	576	576	576
Russian Federation	100	0.684	137 000	137 000	137 000	93 708	93 708	93 708
Slovakia	100	0.684	271	271	271	185	185	185
Slovenia	20	1.293	83	87	89	108	112	114
United Kingdom	100	0.684	656	702	719	449	480	492
United States of America	100	0.684	15 640	15 749	15 732	10 698	10 772	10 761

6.3 Availability of carbon stock data

Including the four countries for which carbon estimates were made by FAO, carbon in biomass and dead wood was reported upon by 146 and 107 countries respectively; the same countries that reported on biomass and dead wood (see tables 5.2 and 5.3). The reporting on carbon in litter and soil are shown in the tables 6.4 and 6.5 below.

Table 6.4. Countries reporting on carbon in litter

Region / Sub-region	Number of countries reporting on C in			Forest area (1000 ha) reporting on C in		
	All	litter	%	All	litter	%
Eastern and Southern Africa	20	2	10.0	226 534	59 109	26.1
Northern Africa	16	6	37.5	131 048	27 098	20.7
Western and Central Africa	22	3	13.6	277 829	144 495	52.0
Africa	58	11	19.0	635 412	230 702	36.3
East Asia	5	0	0	244 862	0	0
South and Southeast Asia	18	13	72.2	283 127	246 915	87.2
Western and Central Asia	25	5	20.0	43 588	6 166	14.1
Asia	48	18	37.5	571 577	253 081	44.3
Europe	47	16	34.0	1 001 394	866 118	86.5
Caribbean	25	1	4.0	5 974	339	5.7
Central America	7	1	14.3	22 411	4 294	19.2
North America	5	1	20.0	677 464	303 089	44.7
North and Central America	37	3	8.1	705 849	307 722	43.6
Oceania	24	3	12.5	206 254	172 704	83.7
South America	15	3	20.0	831 540	526 840	63.4
WORLD	229	54	23.6	3 952 025	2 357 168	59.6

Table 6.5. Countries reporting on soil carbon

Region / Sub-region	Number of countries reporting on C in			Forest area (1000 ha) reporting on C in		
	All	soil	%	All	soil	%
Eastern and Southern Africa	20	0	0	226 534	0	0
Northern Africa	16	4	25.0	131 048	4 666	3.6
Western and Central Africa	22	3	13.6	277 829	144 495	52.0
Africa	58	7	12.1	635 412	149 160	23.5
East Asia	5	0	0	244 862	0	0
South and Southeast Asia	18	4	22.2	283 127	87 463	30.9
Western and Central Asia	25	5	20.0	43 588	7 755	17.8
Asia	48	9	18.8	571 577	95 218	16.7
Europe	47	19	40.4	1 001 394	882 320	88.1
Caribbean	25	2	8.0	5 974	3 052	51.1
Central America	7	1	14.3	22 411	4 294	19.2
North America	5	1	20.0	677 464	303 089	44.7
North and Central America	37	4	10.8	705 849	310 435	44.0
Oceania	24	1	4.2	206 254	8 309	4.0
South America	15	3	20.0	831 540	526 840	63.4
WORLD	229	43	18.8	3 952 025	1 972 282	49.9

Figure 6.1 shows the carbon stock reporting response rate in terms of the number of countries reported on carbon stocks and the forest area these countries represent. The difference between the two curves is because most of the countries with large forest area have reported on carbon stocks, while the countries not reporting on carbon stocks are mainly countries with small forest area.

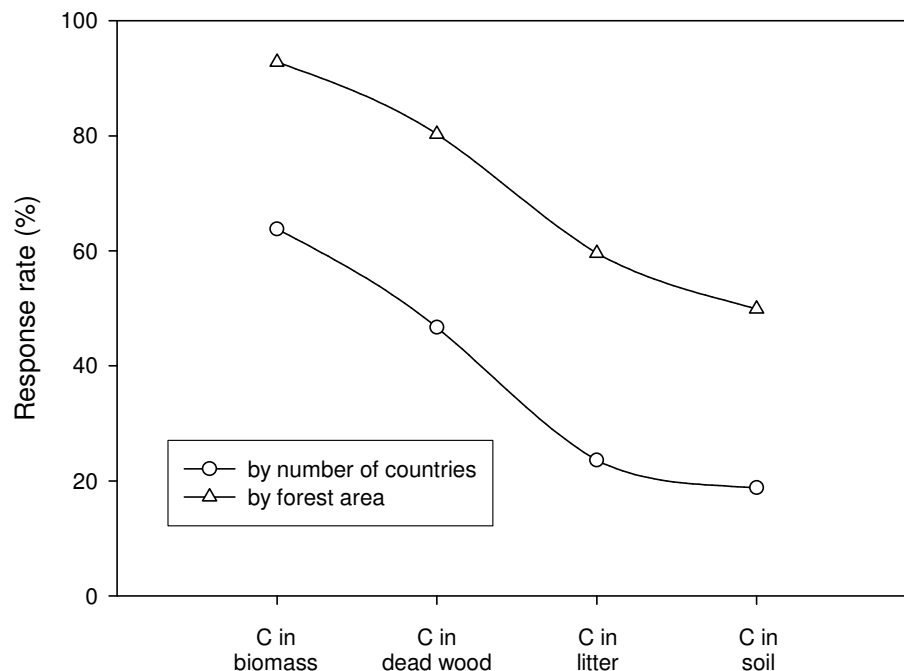


Figure 6.1. Response rates in percent for carbon reporting by countries.

6.4 Estimates of carbon in biomass, dead wood, litter and soil

Global estimates of carbon in biomass, dead wood, litter and soil were made for each of the three reporting years. The detailed tables are presented in Appendix 1. From these, the following consolidated tables (Table 6.6 to 6.10) were derived in which the main results are presented.

Table 6.6. Global estimates of carbon in biomass (million tonnes)

Region / Subregion	Carbon in above-ground biomass (million t)			Carbon in below-ground biomass (million t)			Carbon in total forest biomass (million t)		
	1990	2000	2005	1990	2000	2005	1990	2000	2005
Eastern and Southern Africa	12 539	11 662	11 316	3 383	3 154	3 064	15 922	14 816	14 379
Northern Africa	2 896	2 697	2 598	902	840	810	3 798	3 537	3 408
Western and Central Africa	37 061	35 360	34 704	8 984	8 536	8 358	46 045	43 896	43 063
Africa	52 496	49 719	48 618	13 269	12 530	12 232	65 765	62 249	60 850
East Asia	5 516	6 459	6 959	1 682	1 957	2 094	7 198	8 415	9 052
South and Southeast Asia	24 944	19 841	17 027	7 313	5 672	4 766	32 258	25 513	21 793
Western and Central Asia	1 314	1 382	1 410	302	317	323	1 616	1 700	1 733
Asia	31 774	27 682	25 395	9 297	7 946	7 182	41 072	35 628	32 578
Europe	33 541	34 360	35 018	8 463	8 743	8 910	42 004	43 102	43 929
Caribbean	349	428	465	95	119	131	444	548	596
Central America	2 610	2 213	2 057	766	659	619	3 376	2 872	2 676
North America	29 624	30 747	31 286	7 574	7 782	7 884	37 198	38 529	39 170
North and Central America	32 583	33 388	33 809	8 436	8 561	8 633	41 019	41 949	42 442
Oceania	8 244	8 122	8 063	3 379	3 317	3 291	11 623	11 439	11 354
South America	74 883	72 515	70 338	22 816	21 723	21 160	97 699	94 239	91 498
WORLD	233 521	225 786	221 242	65 660	62 821	61 409	299 181	288 607	282 650

Table 6.7. Global estimates of carbon in biomass (tonnes per hectare)

Region / Subregion	Carbon in above-ground biomass (tonnes/ha)			Carbon in below-ground biomass (tonnes/ha)			Carbon in total forest biomass (tonnes/ha)		
	1990	2000	2005	1990	2000	2005	1990	2000	2005
Eastern and Southern Africa	49.7	49.6	50.0	13.4	13.4	13.5	63.1	63.0	63.5
Northern Africa	19.8	19.8	19.8	6.2	6.2	6.2	26.0	26.0	26.0
Western and Central Africa	123.2	124.2	124.9	29.9	30.0	30.1	153.0	154.2	155.0
Africa	75.1	75.8	76.5	19.0	19.1	19.3	94.0	94.9	95.8
East Asia	26.5	28.6	28.4	8.1	8.7	8.5	34.6	37.3	37.0
South and Southeast Asia	77.2	66.7	60.1	22.6	19.1	16.8	99.8	85.8	77.0
Western and Central Asia	30.4	31.8	32.4	7.0	7.3	7.4	37.4	39.1	39.8
Asia	55.3	48.9	44.4	16.2	14.0	12.6	71.5	62.9	57.0
Europe	33.9	34.4	35.0	8.6	8.8	8.9	42.5	43.2	43.9
Caribbean	65.2	75.1	77.8	17.8	20.9	21.9	83.1	96.0	99.7
Central America	94.4	92.8	91.8	27.7	27.7	27.6	122.2	120.5	119.4
North America	43.7	45.4	46.2	11.2	11.5	11.6	54.9	56.8	57.8
North and Central America	45.8	47.2	47.9	11.9	12.1	12.2	57.7	59.3	60.1
Oceania	38.8	39.0	39.1	15.9	15.9	16.0	54.7	55.0	55.0
South America	84.1	85.0	84.6	25.6	25.5	25.4	109.7	110.5	110.0
WORLD	57.3	56.6	56.0	16.1	15.8	15.5	73.4	72.4	71.5

Table 6.8. Global estimates of carbon in dead wood, litter and soil (million tonnes)

Region / Subregion	Carbon in dead wood (million t)			Carbon in litter (million t)			Carbon in soil (million t)		
	1990	2000	2005	1990	2000	2005	1990	2000	2005
Eastern and Southern Africa	1 895	1 749	1 690	532	495	477	13 964	12 997	12 522
Northern Africa	493	456	433	309	284	273	4 838	4 488	4 392
Western and Central Africa	3 009	2 819	2 736	633	599	585	16 847	15 933	15 553
Africa	5 396	5 023	4 860	1 473	1 378	1 335	35 649	33 418	32 466
East Asia	1 031	1 164	1 218	579	648	711	13 857	15 009	16 203
South and Southeast Asia	3 707	2 972	2 556	839	793	762	22 289	20 446	19 360
Western and Central Asia	150	156	159	485	496	500	1 796	1 810	1 798
Asia	4 888	4 292	3 933	1 903	1 938	1 973	37 942	37 266	37 361
Europe	13 902	13 972	14 022	6 123	6 078	6 109	111 917	112 687	113 075
Caribbean	49	51	53	11	12	13	381	403	421
Central America	410	348	323	57	50	47	1 358	1 190	971
North America	5 547	5 860	5 979	10 204	10 364	10 409	24 279	24 160	24 052
North and Central America	6 006	6 260	6 355	10 272	10 426	10 469	26 018	25 752	25 444
Oceania	1 882	1 863	1 852	1 650	1 649	1 641	21 499	21 046	20 866
South America	8 008	7 799	7 675	3 683	3 569	3 501	63 297	59 520	57 518
WORLD	40 082	39 209	38 697	25 104	25 037	25 028	296 321	289 690	286 729

Table 6.9. Global estimates of carbon in dead wood, litter and soil (tonnes per hectare)

Region / Subregion	Carbon in dead wood (tonnes/ha)			Carbon in litter (tonnes/ha)			Carbon in soil (tonnes/ha)		
	1990	2000	2005	1990	2000	2005	1990	2000	2005
Eastern and Southern Africa	7.5	7.4	7.5	2.1	2.1	2.1	55.3	55.3	55.3
Northern Africa	3.4	3.4	3.3	2.1	2.1	2.1	33.1	33.0	33.5
Western and Central Africa	10.0	9.9	9.8	2.1	2.1	2.1	56.0	56.0	56.0
Africa	7.7	7.7	7.6	2.1	2.1	2.1	51.0	51.0	51.1
East Asia	5.0	5.2	5.0	2.8	2.9	2.9	66.6	66.5	66.2
South and Southeast Asia	11.5	10.0	9.0	2.6	2.7	2.7	69.0	68.8	68.4
Western and Central Asia	3.5	3.6	3.6	11.2	11.4	11.5	41.6	41.6	41.2
Asia	8.5	7.6	6.9	3.3	3.4	3.5	66.0	65.8	65.4
Europe	14.1	14.0	14.0	6.2	6.1	6.1	113.1	112.9	112.9
Caribbean	9.2	8.9	8.8	2.1	2.1	2.2	71.2	70.6	70.4
Central America	14.8	14.6	14.4	2.1	2.1	2.1	49.1	49.9	43.3
North America	8.2	8.6	8.8	15.1	15.3	15.4	35.8	35.6	35.5
North and Central America	8.5	8.8	9.0	14.5	14.7	14.8	36.6	36.4	36.0
Oceania	8.9	9.0	9.0	7.8	7.9	8.0	101.2	101.2	101.2
South America	9.0	9.1	9.2	4.1	4.2	4.2	71.1	69.8	69.2
WORLD	9.8	9.8	9.8	6.2	6.3	6.3	72.7	72.6	72.6

Table 6.10. Global estimates of total carbon in forest

Region / Subregion	Total carbon in forest (million t)			Total carbon in forest (tonnes/ha)		
	1990	2000	2005	1990	2000	2005
Eastern and Southern Africa	32 312	30 057	29 069	128.0	127.9	128.3
Northern Africa	9 438	8 765	8 505	64.6	64.5	64.9
Western and Central Africa	66 534	63 248	61 937	221.1	222.2	222.9
Africa	108 284	102 069	99 511	154.8	155.7	156.6
East Asia	22 664	25 236	27 184	108.9	111.8	111.0
South and Southeast Asia	59 093	49 726	44 471	182.9	167.2	157.1
Western and Central Asia	4 048	4 162	4 189	93.7	95.6	96.1
Asia	85 805	79 124	75 845	149.4	139.7	132.7
Europe	173 945	175 840	177 134	175.8	176.2	176.9
Caribbean	886	1 014	1 082	165.6	177.7	181.2
Central America	5 201	4 460	4 017	188.2	187.1	179.3
North America	77 228	78 913	79 611	113.9	116.4	117.5
North and Central America	83 316	84 387	84 710	117.2	119.3	120.0
Oceania	36 654	35 997	35 713	172.5	173.0	173.1
South America	172 686	165 126	160 192	193.9	193.6	192.6
WORLD	660 688	642 544	633 105	162.0	161.1	160.2

6.5 Plausibility of carbon estimates

The plausibility of country data on **carbon in above- and below-ground biomass** mirrors the analysis for biomass (see Chapter 5.4). The only additional parameter is the **carbon fraction** which is used to convert biomass to carbon. Values used by countries vary from 0.45 to 0.53 but, overwhelmingly, countries used the default value of 50%. The average weighted by forest area is 0.49.

Apart from carbon in above-ground and below-ground biomass, forest soils contain very large amounts of carbon while dead wood and litter contribute smaller, but nevertheless globally significant amounts.

Reporting rates for **soil carbon** were the lowest of all carbon pools, perhaps indicating scarcity of country data or problems in applying the IPCC (2003) default values. However, with few exceptions, reported values as presented in Figure 6.2 fall within the range given by IPCC (2003). The IPCC 2006 Guidelines provides a range from 20 to 300 t C per hectare. The global average soil carbon content to a depth of 30 cm estimated from the FRA 2005 data set was 73 t C per hectare.

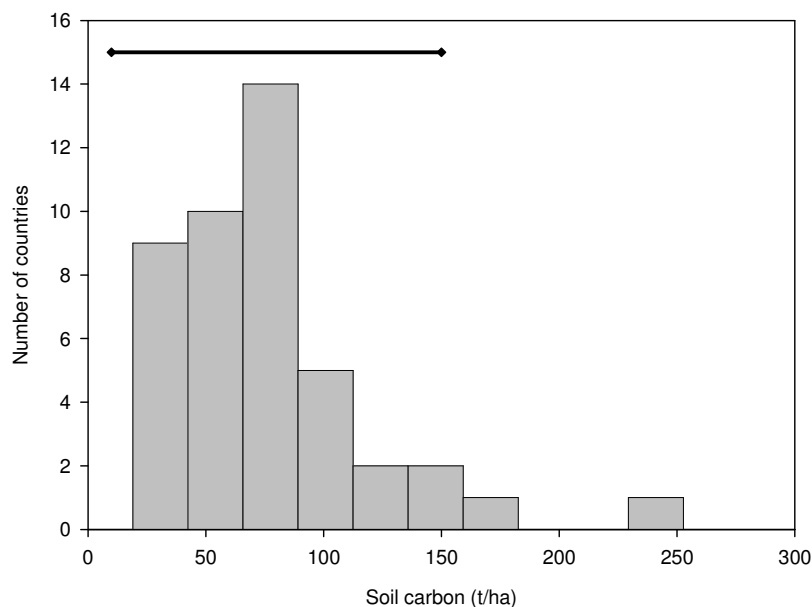


Figure 6.2. Histogram of reported values of soil carbon per hectare. The horizontal line denotes the range of default values given by IPCC (2003).

Regional default values for **carbon in dead wood** are scarce in the literature and highly uncertain. IPCC (2003) provides average defaults of 9-22 t C per hectare (assuming a carbon fraction of 0.5) for semi-natural and near natural forests and with a very large uncertainty range. Brown (1997) cites a range for deadwood of at least 10 percent to more than 40 percent of above-ground biomass carbon, which would amount here to 6 to 23 t C per hectare. The global average carbon content in dead wood as reported to FRA 2005 is 10 t C per hectare which falls in the lowest quartile of the IPCC range (Figure 6.3). Regional and global averages might therefore be underestimated. Globally, carbon in dead wood amounts to only 5 percent of the total carbon stock in forests; yet dead wood represents a very uncertain component in carbon assessments.

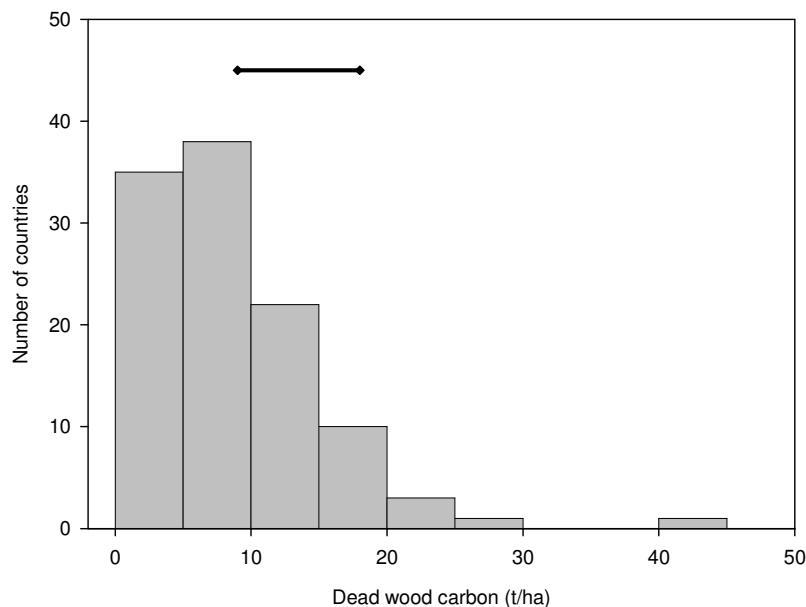


Figure 6.3. Histogram of reported values of carbon in dead wood. The horizontal line denotes the range of mean values given by IPCC (2003).

Similarly, **carbon in litter** (Figure 6.4) reported by countries does not appear plausible when compared to estimates in the literature (Waring, 1998; Pritchett, 1987) and IPCC (2003) default values that give a range from 2 t C per hectare in the tropics to 55 t C per hectare for boreal conifer forests. While reported values for tropical forests appear representative, low values or missing data for many boreal countries with typically deep litter layers may have produced a bias leading to underestimation in the global average of only 6 t C per hectare, a value more typical for tropical forests that usually have a very thin litter layer (Brown, 1997).

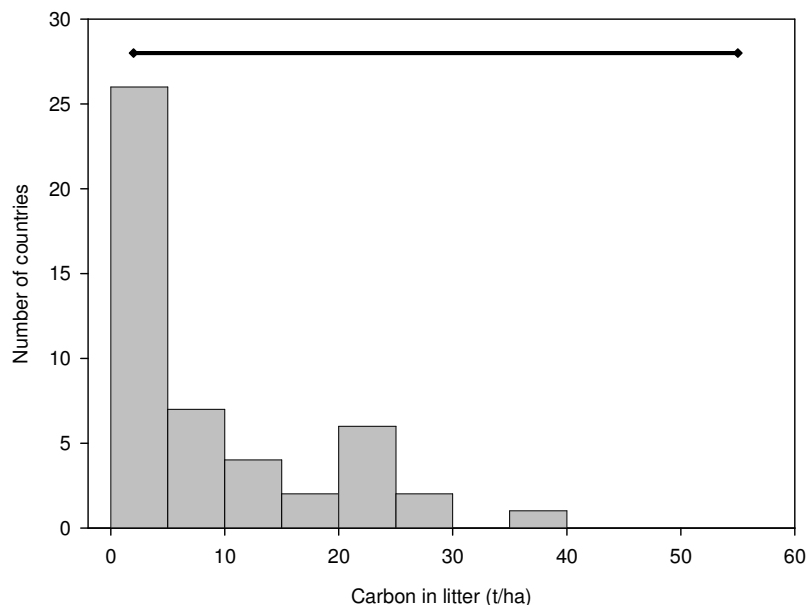


Figure 6.4. Histogram of reported values of carbon in litter. The horizontal line denotes the range of default values given by IPCC (2003).

7 Comparison with other global estimates

7.1 Earlier Forest Resources Assessments

FRA 2000 reported on growing stock and biomass for year 2000 (FAO, 2001), while FRA 2005 reports on growing stock, biomass and carbon stock for three reference years; 1990, 2000 and 2005.

The data reported to FRA 2005 for all three reference years are based on best available country estimates and furthermore, the countries were asked to use the IPCC (2003) default factors if no better information was available (Tier 1 approach). In contrast, the data reported five years earlier to FRA 2000 on growing stock and biomass were based on weaker country information and very rough biomass conversion factors.

As estimation methods and country data have improved considerably in FRA 2005 compared to FRA 2000, it is not meaningful to perform any direct comparison of the estimates.

7.2 Global estimates by IPCC

According to the estimates presented in this working paper, the global forest vegetation stores 283 Gt C³ in its biomass, and an additional 39 Gt C as deadwood, for a total of 322 Gt C. This is slightly less than the prior estimate by IPCC (2000) of 359 Gt C in these pools.

Soils to a depth of 30 cm and litter contain 312 Gt C according to the estimates in this report. Thus, even to a depth of only 30 cm, they store about the same amount of carbon as the forest vegetation. Expanding carbon content in soils to a depth of 1m by applying the correction factor in Table 6.3, litter and soil together contain 448 Gt C. This is considerably less than the 787 Gt C that IPCC (2000) estimated in forest soils and litter. Large data gaps in this report for countries with large areas of boreal forests and peat soils with typically large amounts of C and likely underestimates of litter by countries could, at least partially, explain the difference.

The total carbon content of forests including soils to a depth of 30 cm for year 1990 is in this report estimated at 661 Gt C (table 6.10), and if soils to a depth of 1m are included, the estimate is 798 Gt C. The corresponding estimate by IPCC, adjusted for a slightly larger forest area is 1085 Gt C.

³ Gt C = Giga-tonnes (10⁹ tonnes) of carbon

8 Discussion

The FRA 2005 data set is the most comprehensive global data set to date with country estimates of growing stock, biomass and carbon stocks for three points in time. The quality and reliability of individual figures reported by the countries vary considerably, as many countries do not have good inventory data and therefore must rely partly or entirely on the use of conversion factors and default values. As the errors in country data are unknown, and sometimes large, it was not meaningful to perform a formal statistical error analysis of the estimates presented in this working paper.

The main weakness of the data set is related to the trend estimates. Most of the countries do not have inventory data at two or more points in time, instead one single estimate of stock per hectare has been applied to the forest area for the three reporting years. Reported trends in stocks therefore often reflect the trends in forest area. This applies particularly to the developing countries.

Another weakness in the data set is the generally weak reporting on carbon in litter and soil; however this is a known information gap. The estimates of carbon in dead wood, litter and soil are also uncertain due to the fact that the default values given by IPCC (2003) are uncertain.

The considerable variation in countries' application of diameter thresholds for growing stock estimates is also a source of uncertainty, and growing stock, biomass and carbon stocks in biomass might therefore be underestimated.

However, and despite the above-mentioned limitations in data availability, the conversion and expansion factors applied by countries for transforming growing stock into stocks of biomass and carbon appears plausible, although there are indications that some pools might be underestimated.

The information presented in this report has the potential to contribute to or substantiate estimates of the magnitude of carbon stocks and flows by scientific bodies, such as the Intergovernmental Panel on Climate Change. In the future, such information provided by the Global Forest Resources Assessment could facilitate streamlined international reporting and monitoring of greenhouse gas emissions and removals under the United Nations Framework Convention on Climate Change.

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APPENDIX 1

Detailed tables for subregional, regional and global estimates of total growing stock

Detailed tables for subregional, regional and global estimates of biomass and dead wood

Detailed tables for subregional, regional and global estimates of carbon stock

Estimation of growing stock 1990

Region / Subregion	Countries that reported on growing stock			All countries and territories	
	Growing stock (million m3)	Forest area (1000 ha)	Growing stock m3/ha	Forest area (1000 ha)	Growing stock (million m3)
Eastern and Southern Africa	11 031	252 253	43.7	252 354	11 035
Northern Africa	2 741	144 472	19.0	146 093	2 771
Western and Central Africa	54 211	293 572	184.7	300 914	55 566
Africa	67 982	690 297	99.2	699 361	69 373
East Asia	15 850	208 155	76.1	208 155	15 850
South and Southeast Asia	32 517	322 187	100.9	323 156	32 615
Western and Central Asia	2 869	41 864	68.5	43 176	2 959
Asia	51 235	572 206	89.5	574 487	51 423
Europe	100 730	976 396	103.2	989 320	102 063
Caribbean	311	5 061	61.4	5 350	328
Central America	3 537	27 264	129.7	27 639	3 585
North America	65 155	608 782	107.0	677 801	72 542
North and Central America	69 002	641 107	107.6	710 790	76 455
Oceania	1 153	32 258	35.7	212 514	7 593
South America	101 885	656 214	155.3	890 818	138 310
WORLD	391 987	3 568 478	109.2	4 077 291	445 218

Estimation of growing stock 2000

Region / Subregion	Countries that reported on growing stock			All countries and territories	
	Growing stock (million m3)	Forest area (1000 ha)	Growing stock m3/ha	Forest area (1000 ha)	Growing stock (million m3)
Eastern and Southern Africa	10 341	234 945	44.0	235 047	10 346
Northern Africa	2 577	134 382	19.2	135 958	2 607
Western and Central Africa	52 056	278 396	187.0	284 608	53 218
Africa	64 975	647 723	100.9	655 613	66 171
East Asia	18 433	225 663	81.7	225 663	18 433
South and Southeast Asia	27 217	296 523	91.8	297 380	27 296
Western and Central Asia	3 006	42 122	71.4	43 519	3 105
Asia	48 656	564 308	86.2	566 562	48 834
Europe	103 965	984 752	105.6	998 091	105 374
Caribbean	383	5 421	70.6	5 706	403
Central America	3 055	23 513	129.9	23 837	3 097
North America	67 051	612 428	109.5	677 971	74 227
North and Central America	70 489	641 362	109.9	707 514	77 727
Oceania	1 102	30 868	35.7	208 034	7 428
South America	97 932	625 747	156.5	852 796	133 467
WORLD	387 119	3 494 759	110.1	3 988 610	439 000

Estimation of growing stock 2005

Region / Subregion	Countries that reported on growing stock			All countries and territories	
	Growing stock (million m3)	Forest area (1000 ha)	Growing stock m3/ha	Forest area (1000 ha)	Growing stock (million m3)
Eastern and Southern Africa	10 011	226 434	44.2	226 534	10 015
Northern Africa	2 493	129 494	19.2	131 048	2 523
Western and Central Africa	51 354	272 184	188.7	277 829	52 420
Africa	63 858	628 112	102.2	635 412	64 957
East Asia	19 743	244 862	80.6	244 862	19 743
South and Southeast Asia	24 133	282 325	85.5	283 127	24 202
Western and Central Asia	3 062	42 152	72.6	43 588	3 166
Asia	46 938	569 339	82.4	571 577	47 111
Europe	105 831	988 013	107.1	1 001 394	107 264
Caribbean	420	5 692	73.8	5 974	441
Central America	2 867	22 113	129.7	22 411	2 906
North America	68 101	613 223	111.1	677 464	75 235
North and Central America	71 388	641 028	111.3	705 849	78 582
Oceania	1 077	30 172	35.7	206 254	7 361
South America	94 345	608 419	155.1	831 540	128 944
WORLD	383 437	3 465 083	109.9	3 952 025	434 219

Estimation of above-ground biomass 1990

Region / Subregion	Countries that reported on above-ground biomass			All countries and territories	
	Above-ground	Forest area	Above-ground	Forest area	Above-ground
	biomass		biomass		biomass
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	25 066	252 253	99.4	252 354	25 076
Northern Africa	5 728	144 472	39.6	146 093	5 793
Western and Central Africa	72 602	293 572	247.3	300 914	74 417
Africa	103 395	690 297	150.5	699 361	105 286
East Asia	11 030	208 155	53.0	208 155	11 030
South and Southeast Asia	50 099	322 187	155.5	323 156	50 250
Western and Central Asia	2 538	41 710	60.9	43 176	2 628
Asia	63 668	572 052	111.2	574 487	63 908
Europe	67 127	987 137	68.0	989 320	67 275
Caribbean	615	4 546	135.2	5 350	723
Central America	3 755	19 879	188.9	27 639	5 220
North America	53 214	608 782	87.4	677 801	59 247
North and Central America	57 583	633 207	91.7	710 790	65 191
Oceania	14 997	176 359	85.0	212 514	18 071
South America	121 706	709 562	171.5	890 818	152 796
WORLD	428 477	3 768 614	115.9	4 077 291	472 526

Estimation of above-ground biomass 2000

Region / Subregion	Countries that reported on above-ground biomass			All countries and territories	
	Above-ground	Forest area	Above-ground	Forest area	Above-ground
	biomass		biomass		biomass
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	23 315	234 945	99.2	235 047	23 326
Northern Africa	5 332	134 382	39.7	135 958	5 394
Western and Central Africa	69 468	278 396	249.5	284 608	71 018
Africa	98 115	647 723	152.1	655 613	99 738
East Asia	12 920	225 663	57.3	225 663	12 920
South and Southeast Asia	39 957	296 523	134.8	297 380	40 072
Western and Central Asia	2 666	41 958	63.5	43 519	2 765
Asia	55 542	564 144	98.4	566 562	55 757
Europe	68 782	995 828	69.1	998 091	68 938
Caribbean	766	4 906	156.2	5 706	891
Central America	3 357	18 083	185.6	23 837	4 425
North America	55 549	612 428	90.7	677 971	61 494
North and Central America	59 672	635 417	94.4	707 514	66 810
Oceania	14 844	173 606	85.5	208 034	17 788
South America	117 780	678 647	173.6	852 796	148 004
WORLD	414 736	3 695 365	114.6	3 988 610	457 035

Estimation of above-ground biomass 2005

Region / Subregion	Countries that reported on above-ground biomass			All countries and territories	
	Above-ground	Forest area	Above-ground	Forest area	Above-ground
	biomass		biomass		biomass
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	22 620	226 434	99.9	226 534	22 630
Northern Africa	5 132	129 494	39.6	131 048	5 193
Western and Central Africa	68 290	272 184	250.9	277 829	69 706
Africa	96 042	628 112	153.5	635 412	97 530
East Asia	13 915	244 862	56.8	244 862	13 915
South and Southeast Asia	34 345	282 325	121.6	283 127	34 442
Western and Central Asia	2 716	41 981	64.7	43 588	2 820
Asia	50 976	569 168	89.5	571 577	51 177
Europe	70 108	999 089	70.2	1 001 394	70 269
Caribbean	842	5 177	162.6	5 974	971
Central America	3 207	17 465	183.6	22 411	4 115
North America	56 640	613 223	92.4	677 464	62 574
North and Central America	60 689	635 865	95.9	705 849	67 660
Oceania	14 785	172 722	85.6	206 254	17 656
South America	114 075	661 084	172.6	831 540	143 489
WORLD	406 674	3 666 040	113.3	3 952 025	447 781

Estimation of below-ground biomass 1990

Region / Subregion	Countries that reported on below-ground biomass			All countries and territories	
	Below-ground biomass	Forest area	Below-ground biomass	Forest area	Below-ground biomass
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	6 762	252 253	26.8	252 354	6 765
Northern Africa	1 785	144 472	12.4	146 093	1 805
Western and Central Africa	17 528	293 572	59.7	300 914	17 967
Africa	26 075	690 297	37.9	699 361	26 537
East Asia	3 364	208 155	16.2	208 155	3 364
South and Southeast Asia	14 683	322 187	45.6	323 156	14 727
Western and Central Asia	587	41 710	14.1	43 176	608
Asia	18 634	572 052	32.5	574 487	18 699
Europe	16 944	987 137	17.2	989 320	16 981
Caribbean	168	4 546	36.9	5 350	198
Central America	1 103	19 879	55.5	27 639	1 534
North America	13 607	608 782	22.4	677 801	15 150
North and Central America	14 878	633 207	23.7	710 790	16 881
Oceania	6 174	176 359	35.0	212 514	7 440
South America	36 658	709 562	51.7	890 818	46 022
WORLD	119 364	3 768 614	32.5	4 077 291	132 560

Estimation of below-ground biomass 2000

Region / Subregion	Countries that reported on below-ground biomass			All countries and territories	
	Below-ground biomass	Forest area	Below-ground biomass	Forest area	Below-ground biomass
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	6 304	234 945	26.8	235 047	6 307
Northern Africa	1 662	134 382	12.4	135 958	1 681
Western and Central Africa	16 697	278 396	60.0	284 608	17 070
Africa	24 663	647 723	38.2	655 613	25 058
East Asia	3 912	225 663	17.3	225 663	3 912
South and Southeast Asia	11 415	296 523	38.5	297 380	11 448
Western and Central Asia	612	41 958	14.6	43 519	635
Asia	15 939	564 144	28.2	566 562	15 995
Europe	17 510	995 828	17.6	998 091	17 550
Caribbean	214	4 906	43.7	5 706	249
Central America	999	18 083	55.3	23 837	1 317
North America	14 060	612 428	23.0	677 971	15 565
North and Central America	15 274	635 417	24.2	707 514	17 131
Oceania	6 090	173 606	35.1	208 034	7 298
South America	34 884	678 647	51.4	852 796	43 835
WORLD	114 359	3 695 365	31.8	3 988 610	126 867

Estimation of below-ground biomass 2005

Region / Subregion	Countries that reported on below-ground biomass			All countries and territories	
	Below-ground biomass	Forest area	Below-ground biomass	Forest area	Below-ground biomass
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	6 123	226 434	27.0	226 534	6 126
Northern Africa	1 601	129 494	12.4	131 048	1 620
Western and Central Africa	16 371	272 184	60.1	277 829	16 711
Africa	24 095	628 112	38.5	635 412	24 457
East Asia	4 188	244 862	17.1	244 862	4 188
South and Southeast Asia	9 607	282 325	34.0	283 127	9 635
Western and Central Asia	623	41 981	14.8	43 588	647
Asia	14 419	569 168	25.3	571 577	14 470
Europe	17 845	999 089	17.9	1 001 394	17 886
Caribbean	237	5 177	45.8	5 974	273
Central America	962	17 465	55.1	22 411	1 234
North America	14 272	613 223	23.3	677 464	15 767
North and Central America	15 471	635 865	24.5	705 849	17 275
Oceania	6 062	172 722	35.1	206 254	7 239
South America	33 946	661 084	51.3	831 540	42 699
WORLD	111 838	3 666 040	31.4	3 952 025	124 025

Estimation of dead wood 1990

Region / Subregion	Countries that reported on dead wood			All countries and territories	
	Dead wood (million t)	Forest area (1000 ha)	Dead wood (t/ha)	Forest area (1000 ha)	Dead wood (million t)
Eastern and Southern Africa	3 517	234 127	15.0	252 354	3 791
Northern Africa	725	107 193	6.8	146 093	988
Western and Central Africa	5 453	270 787	20.1	300 914	6 060
Africa	9 695	612 107	15.5	699 361	10 838
East Asia	1 814	183 205	9.9	208 155	2 061
South and Southeast Asia	7 438	322 187	23.1	323 156	7 460
Western and Central Asia	210	30 097	7.0	43 176	301
Asia	9 461	535 489	17.1	574 487	9 822
Europe	26 167	930 905	28.1	989 320	27 809
Caribbean	76	4 130	18.5	5 350	99
Central America	590	19 879	29.7	27 639	820
North America	4 888	298 648	16.4	677 801	11 094
North and Central America	5 554	322 657	16.9	710 790	12 012
Oceania	5 049	168 621	29.9	212 514	6 363
South America	13 016	709 562	18.3	890 818	16 340
WORLD	68 942	3 279 341	20.4	4 077 291	83 186

Estimation of dead wood 2000

Region / Subregion	Countries that reported on dead wood			All countries and territories	
	Dead wood (million t)	Forest area (1000 ha)	Dead wood (t/ha)	Forest area (1000 ha)	Dead wood (million t)
Eastern and Southern Africa	3 249	218 285	14.9	235 047	3 498
Northern Africa	663	98 901	6.7	135 958	911
Western and Central Africa	5 105	255 758	20.0	284 608	5 680
Africa	9 016	572 944	15.4	655 613	10 090
East Asia	2 070	200 787	10.3	225 663	2 326
South and Southeast Asia	5 976	296 523	20.2	297 380	5 994
Western and Central Asia	214	29 939	7.1	43 519	311
Asia	8 260	527 249	15.2	566 562	8 630
Europe	26 174	934 571	28.0	998 091	27 953
Caribbean	82	4 489	18.3	5 706	104
Central America	528	18 083	29.2	23 837	696
North America	5 226	302 294	17.3	677 971	11 721
North and Central America	5 836	324 866	17.7	707 514	12 521
Oceania	4 951	165 362	29.9	208 034	6 229
South America	12 660	678 647	18.7	852 796	15 909
WORLD	66 897	3 203 638	20.4	3 988 610	81 332

Estimation of dead wood 2005

Region / Subregion	Countries that reported on dead wood			All countries and territories	
	Dead wood (million t)	Forest area (1000 ha)	Dead wood (t/ha)	Forest area (1000 ha)	Dead wood (million t)
Eastern and Southern Africa	3 141	210 508	14.9	226 534	3 380
Northern Africa	627	94 755	6.6	131 048	867
Western and Central Africa	4 953	249 629	19.8	277 829	5 513
Africa	8 722	554 892	15.4	635 412	9 760
East Asia	2 191	219 994	10.0	244 862	2 438
South and Southeast Asia	5 156	282 325	18.3	283 127	5 170
Western and Central Asia	218	29 826	7.3	43 588	319
Asia	7 564	532 145	13.9	571 577	7 927
Europe	26 205	935 508	28.0	1 001 394	28 051
Caribbean	87	4 759	18.3	5 974	109
Central America	504	17 465	28.9	22 411	647
North America	5 350	303 089	17.7	677 464	11 958
North and Central America	5 941	325 313	18.0	705 849	12 714
Oceania	4 922	164 395	29.9	206 254	6 175
South America	12 448	661 084	18.8	831 540	15 658
WORLD	65 802	3 173 338	20.3	3 952 025	80 286

Estimation of carbon in above-ground biomass 1990

Region / Subregion	Countries that reported on carbon in above-ground biomass (AGB)			All countries and territories	
	Carbon in AGB	Forest area	Carbon in AGB	Forest area	Carbon in AGB
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	12 534	252 253	49.7	252 354	12 539
Northern Africa	2 864	144 472	19.8	146 093	2 896
Western and Central Africa	36 157	293 572	123.2	300 914	37 061
Africa	51 555	690 297	75.1	699 361	52 496
East Asia	5 516	208 155	26.5	208 155	5 516
South and Southeast Asia	24 870	322 187	77.2	323 156	24 944
Western and Central Asia	1 269	41 710	30.4	43 176	1 314
Asia	31 655	572 052	55.3	574 487	31 774
Europe	33 467	987 137	33.9	989 320	33 541
Caribbean	297	4 546	65.2	5 350	349
Central America	1 877	19 879	94.4	27 639	2 610
North America	26 608	608 782	43.7	677 801	29 624
North and Central America	28 781	633 207	45.8	710 790	32 583
Oceania	6 841	176 359	38.8	212 514	8 244
South America	59 646	709 562	84.1	890 818	74 883
WORLD	211 945	3 768 614	57.3	4 077 291	233 521

Estimation of carbon in above-ground biomass 2000

Region / Subregion	Countries that reported on carbon in above-ground biomass (AGB)			All countries and territories	
	Carbon in AGB	Forest area	Carbon in AGB	Forest area	Carbon in AGB
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	11 657	234 945	49.6	235 047	11 662
Northern Africa	2 666	134 382	19.8	135 958	2 697
Western and Central Africa	34 588	278 396	124.2	284 608	35 360
Africa	48 911	647 723	75.8	655 613	49 719
East Asia	6 459	225 663	28.6	225 663	6 459
South and Southeast Asia	19 784	296 523	66.7	297 380	19 841
Western and Central Asia	1 333	41 958	31.8	43 519	1 382
Asia	27 575	564 144	48.9	566 562	27 682
Europe	34 282	995 828	34.4	998 091	34 360
Caribbean	368	4 906	75.1	5 706	428
Central America	1 679	18 083	92.8	23 837	2 213
North America	27 775	612 428	45.4	677 971	30 747
North and Central America	29 821	635 417	47.2	707 514	33 388
Oceania	6 778	173 606	39.0	208 034	8 122
South America	57 707	678 647	85.0	852 796	72 515
WORLD	205 075	3 695 365	56.6	3 988 610	225 786

Estimation of carbon in above-ground biomass 2005

Region / Subregion	Countries that reported on carbon in above-ground biomass (AGB)			All countries and territories	
	Carbon in AGB	Forest area	Carbon in AGB	Forest area	Carbon in AGB
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	11 311	226 434	50.0	226 534	11 316
Northern Africa	2 567	129 494	19.8	131 048	2 598
Western and Central Africa	33 999	272 184	124.9	277 829	34 704
Africa	47 877	628 112	76.5	635 412	48 618
East Asia	6 959	244 862	28.4	244 862	6 959
South and Southeast Asia	16 979	282 325	60.1	283 127	17 027
Western and Central Asia	1 358	41 981	32.4	43 588	1 410
Asia	25 295	569 168	44.4	571 577	25 395
Europe	34 938	999 089	35.0	1 001 394	35 018
Caribbean	403	5 177	77.8	5 974	465
Central America	1 603	17 465	91.8	22 411	2 057
North America	28 320	613 223	46.2	677 464	31 286
North and Central America	30 326	635 865	47.9	705 849	33 809
Oceania	6 752	172 722	39.1	206 254	8 063
South America	55 920	661 084	84.6	831 540	70 338
WORLD	201 108	3 666 040	56.0	3 952 025	221 242

Estimation of carbon in below-ground biomass 1990

Region / Subregion	Countries that reported on carbon in below-ground biomass (BGB)			All countries and territories	
	Carbon in BGB	Forest area	Carbon in BGB	Forest area	Carbon in BGB
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	3 382	252 253	13.4	252 354	3 383
Northern Africa	892	144 472	6.2	146 093	902
Western and Central Africa	8 765	293 572	29.9	300 914	8 984
Africa	13 039	690 297	19.0	699 361	13 269
East Asia	1 682	208 155	8.1	208 155	1 682
South and Southeast Asia	7 292	322 187	22.6	323 156	7 313
Western and Central Asia	292	41 710	7.0	43 176	302
Asia	9 265	572 052	16.2	574 487	9 297
Europe	8 444	987 137	8.6	989 320	8 463
Caribbean	81	4 546	17.8	5 350	95
Central America	551	19 879	27.7	27 639	766
North America	6 803	608 782	11.2	677 801	7 574
North and Central America	7 435	633 207	11.9	710 790	8 436
Oceania	2 804	176 359	15.9	212 514	3 379
South America	18 174	709 562	25.6	890 818	22 816
WORLD	59 161	3 768 614	16.1	4 077 291	65 660

Estimation of carbon in below-ground biomass 2000

Region / Subregion	Countries that reported on carbon in below-ground biomass (BGB)			All countries and territories	
	Carbon in BGB	Forest area	Carbon in BGB	Forest area	Carbon in BGB
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	3 152	234 945	13.4	235 047	3 154
Northern Africa	831	134 382	6.2	135 958	840
Western and Central Africa	8 350	278 396	30.0	284 608	8 536
Africa	12 333	647 723	19.1	655 613	12 530
East Asia	1 957	225 663	8.7	225 663	1 957
South and Southeast Asia	5 656	296 523	19.1	297 380	5 672
Western and Central Asia	306	41 958	7.3	43 519	317
Asia	7 919	564 144	14.0	566 562	7 946
Europe	8 723	995 828	8.8	998 091	8 743
Caribbean	103	4 906	20.9	5 706	119
Central America	500	18 083	27.7	23 837	659
North America	7 030	612 428	11.5	677 971	7 782
North and Central America	7 633	635 417	12.1	707 514	8 561
Oceania	2 768	173 606	15.9	208 034	3 317
South America	17 287	678 647	25.5	852 796	21 723
WORLD	56 662	3 695 365	15.8	3 988 610	62 821

Estimation of carbon in below-ground biomass 2005

Region / Subregion	Countries that reported on carbon in below-ground biomass (BGB)			All countries and territories	
	Carbon in BGB	Forest area	Carbon in BGB	Forest area	Carbon in BGB
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	3 062	226 434	13.5	226 534	3 064
Northern Africa	800	129 494	6.2	131 048	810
Western and Central Africa	8 189	272 184	30.1	277 829	8 358
Africa	12 051	628 112	19.3	635 412	12 232
East Asia	2 094	244 862	8.5	244 862	2 094
South and Southeast Asia	4 752	282 325	16.8	283 127	4 766
Western and Central Asia	311	41 981	7.4	43 588	323
Asia	7 157	569 168	12.6	571 577	7 182
Europe	8 890	999 089	8.9	1 001 394	8 910
Caribbean	113	5 177	21.9	5 974	131
Central America	482	17 465	27.6	22 411	619
North America	7 136	613 223	11.6	677 464	7 884
North and Central America	7 732	635 865	12.2	705 849	8 633
Oceania	2 756	172 722	16.0	206 254	3 291
South America	16 823	661 084	25.4	831 540	21 160
WORLD	55 408	3 666 040	15.5	3 952 025	61 409

Estimation of carbon in dead wood 1990

Region / Subregion	Countries that reported on carbon in dead wood (DW)			All countries and territories	
	Carbon in DW	Forest area	Carbon in DW	Forest area	Carbon in DW
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	1 758	234 127	7.5	252 354	1 895
Northern Africa	362	107 193	3.4	146 093	493
Western and Central Africa	2 707	270 787	10.0	300 914	3 009
Africa	4 827	612 107	7.7	699 361	5 396
East Asia	907	183 205	5.0	208 155	1 031
South and Southeast Asia	3 696	322 187	11.5	323 156	3 707
Western and Central Asia	105	30 097	3.5	43 176	150
Asia	4 708	535 489	8.5	574 487	4 888
Europe	13 081	930 905	14.1	989 320	13 902
Caribbean	38	4 130	9.2	5 350	49
Central America	295	19 879	14.8	27 639	410
North America	2 444	298 648	8.2	677 801	5 547
North and Central America	2 777	322 657	8.5	710 790	6 006
Oceania	1 493	168 621	8.9	212 514	1 882
South America	6 378	709 562	9.0	890 818	8 008
WORLD	33 264	3 279 341	9.8	4 077 291	40 082

Estimation of carbon in dead wood 2000

Region / Subregion	Countries that reported on carbon in dead wood (DW)			All countries and territories	
	Carbon in DW	Forest area	Carbon in DW	Forest area	Carbon in DW
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	1 624	218 285	7.4	235 047	1 749
Northern Africa	332	98 901	3.4	135 958	456
Western and Central Africa	2 533	255 758	9.9	284 608	2 819
Africa	4 489	572 944	7.7	655 613	5 023
East Asia	1 035	200 787	5.2	225 663	1 164
South and Southeast Asia	2 964	296 523	10.0	297 380	2 972
Western and Central Asia	107	29 939	3.6	43 519	156
Asia	4 106	527 249	7.6	566 562	4 292
Europe	13 083	934 571	14.0	998 091	13 972
Caribbean	40	4 489	8.9	5 706	51
Central America	264	18 083	14.6	23 837	348
North America	2 613	302 294	8.6	677 971	5 860
North and Central America	2 917	324 866	8.8	707 514	6 260
Oceania	1 481	165 362	9.0	208 034	1 863
South America	6 206	678 647	9.1	852 796	7 799
WORLD	32 283	3 203 638	9.8	3 988 610	39 209

Estimation of carbon in dead wood 2005

Region / Subregion	Countries that reported on carbon in dead wood (DW)			All countries and territories	
	Carbon in DW	Forest area	Carbon in DW	Forest area	Carbon in DW
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	1 571	210 508	7.5	226 534	1 690
Northern Africa	313	94 755	3.3	131 048	433
Western and Central Africa	2 458	249 629	9.8	277 829	2 736
Africa	4 342	554 892	7.6	635 412	4 860
East Asia	1 095	219 994	5.0	244 862	1 218
South and Southeast Asia	2 549	282 325	9.0	283 127	2 556
Western and Central Asia	109	29 826	3.6	43 588	159
Asia	3 752	532 145	6.9	571 577	3 933
Europe	13 100	935 508	14.0	1 001 394	14 022
Caribbean	42	4 759	8.8	5 974	53
Central America	252	17 465	14.4	22 411	323
North America	2 675	303 089	8.8	677 464	5 979
North and Central America	2 969	325 313	9.0	705 849	6 355
Oceania	1 476	164 395	9.0	206 254	1 852
South America	6 102	661 084	9.2	831 540	7 675
WORLD	31 741	3 173 338	9.8	3 952 025	38 697

Estimation of carbon in litter 1990

Region / Subregion	Countries that reported on carbon in litter			All countries and territories	
	Carbon in litter	Forest area	Carbon in litter	Forest area	Carbon in litter
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	129	60 988	2.1	252 354	532
Northern Africa	63	30 030	2.1	146 093	309
Western and Central Africa	318	151 071	2.1	300 914	633
Africa	510	242 089	2.1	699 361	1 473
East Asia				208 155	579
South and Southeast Asia	737	283 846	2.6	323 156	839
Western and Central Asia	69	6 162	11.2	43 176	485
Asia	806	290 008	2.8	574 487	1 903
Europe	5 336	862 293	6.2	989 320	6 123
Caribbean	1	345	2.1	5 350	11
Central America	9	4 376	2.1	27 639	57
North America	4 496	298 648	15.1	677 801	10 204
North and Central America	4 506	303 369	14.5	710 790	10 272
Oceania	1 369	176 341	7.8	212 514	1 650
South America	2 359	570 552	4.1	890 818	3 683
WORLD	14 886	2 444 651	6.2	4 077 291	25 104

Estimation of carbon in litter 2000

Region / Subregion	Countries that reported on carbon in litter			All countries and territories	
	Carbon in litter	Forest area	Carbon in litter	Forest area	Carbon in litter
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	126	59 736	2.1	235 047	495
Northern Africa	58	27 952	2.1	135 958	284
Western and Central Africa	307	145 879	2.1	284 608	599
Africa	491	233 566	2.1	655 613	1 378
East Asia				225 663	648
South and Southeast Asia	694	260 118	2.7	297 380	793
Western and Central Asia	71	6 186	11.4	43 519	496
Asia	765	266 304	2.9	566 562	1 938
Europe	5 271	865 477	6.1	998 091	6 078
Caribbean	1	341	2.1	5 706	12
Central America	9	4 307	2.1	23 837	50
North America	4 621	302 294	15.3	677 971	10 364
North and Central America	4 631	306 942	14.7	707 514	10 426
Oceania	1 376	173 588	7.9	208 034	1 649
South America	2 272	542 817	4.2	852 796	3 569
WORLD	14 805	2 388 693	6.3	3 988 610	25 037

Estimation of carbon in litter 2005

Region / Subregion	Countries that reported on carbon in litter			All countries and territories	
	Carbon in litter	Forest area	Carbon in litter	Forest area	Carbon in litter
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa	125	59 109	2.1	226 534	477
Northern Africa	56	27 098	2.1	131 048	273
Western and Central Africa	304	144 495	2.1	277 829	585
Africa	485	230 702	2.1	635 412	1 335
East Asia				244 862	711
South and Southeast Asia	664	246 915	2.7	283 127	762
Western and Central Asia	71	6 166	11.5	43 588	500
Asia	735	253 081	2.9	571 577	1 973
Europe	5 283	866 118	6.1	1 001 394	6 109
Caribbean	1	339	2.2	5 974	13
Central America	9	4 294	2.1	22 411	47
North America	4 657	303 089	15.4	677 464	10 409
North and Central America	4 667	307 722	14.8	705 849	10 469
Oceania	1 374	172 704	8.0	206 254	1 641
South America	2 218	526 840	4.2	831 540	3 501
WORLD	14 763	2 357 168	6.3	3 952 025	25 028

Estimation of carbon in soil 1990

Region / Subregion	Countries that reported on carbon in soil			All countries and territories	
	Carbon in soil	Forest area	Carbon in soil	Forest area	Carbon in soil
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa				252 354	13 964
Northern Africa	146	4 422	33.1	146 093	4 838
Western and Central Africa	8 458	151 071	56.0	300 914	16 847
Africa	8 604	155 492	55.3	699 361	35 649
East Asia				208 155	13 857
South and Southeast Asia	5 597	81 154	69.0	323 156	22 289
Western and Central Asia	325	7 802	41.6	43 176	1 796
Asia	5 922	88 956	66.6	574 487	37 942
Europe	99 324	877 998	113.1	989 320	111 917
Caribbean	171	2 403	71.2	5 350	381
Central America	215	4 376	49.1	27 639	1 358
North America	10 698	298 648	35.8	677 801	24 279
North and Central America	11 084	305 427	36.6	710 790	26 018
Oceania	781	7 720	101.2	212 514	21 499
South America	40 540	570 552	71.1	890 818	63 297
WORLD	166 255	2 006 146	72.7	4 077 291	296 321

Estimation of carbon in soil 2000

Region / Subregion	Countries that reported on carbon in soil			All countries and territories	
	Carbon in soil	Forest area	Carbon in soil	Forest area	Carbon in soil
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa				235 047	12 997
Northern Africa	148	4 490	33.0	135 958	4 488
Western and Central Africa	8 167	145 879	56.0	284 608	15 933
Africa	8 315	150 369	55.3	655 613	33 418
East Asia				225 663	15 009
South and Southeast Asia	5 935	86 320	68.8	297 380	20 446
Western and Central Asia	323	7 775	41.6	43 519	1 810
Asia	6 258	94 095	66.5	566 562	37 266
Europe	99 538	881 630	112.9	998 091	112 687
Caribbean	196	2 776	70.6	5 706	403
Central America	215	4 307	49.9	23 837	1 190
North America	10 772	302 294	35.6	677 971	24 160
North and Central America	11 183	309 377	36.4	707 514	25 752
Oceania	832	8 226	101.2	208 034	21 046
South America	37 885	542 817	69.8	852 796	59 520
WORLD	164 012	1 986 513	72.6	3 988 610	289 690

Estimation of carbon in soil 2005

Region / Subregion	Countries that reported on carbon in soil			All countries and territories	
	Carbon in soil	Forest area	Carbon in soil	Forest area	Carbon in soil
	(million t)	(1000 ha)	(t/ha)	(1000 ha)	(million t)
Eastern and Southern Africa				226 534	12 522
Northern Africa	156	4 666	33.5	131 048	4 392
Western and Central Africa	8 089	144 495	56.0	277 829	15 553
Africa	8 245	149 160	55.3	635 412	32 466
East Asia				244 862	16 203
South and Southeast Asia	5 981	87 463	68.4	283 127	19 360
Western and Central Asia	320	7 755	41.2	43 588	1 798
Asia	6 301	95 218	66.2	571 577	37 361
Europe	99 629	882 320	112.9	1 001 394	113 075
Caribbean	215	3 052	70.4	5 974	421
Central America	186	4 294	43.3	22 411	971
North America	10 761	303 089	35.5	677 464	24 052
North and Central America	11 162	310 435	36.0	705 849	25 444
Oceania	841	8 309	101.2	206 254	20 866
South America	36 442	526 840	69.2	831 540	57 518
WORLD	162 619	1 972 282	72.6	3 952 025	286 729

APPENDIX 2

TERMS AND DEFINITIONS USED IN FRA 2005

This Appendix presents the terms and definitions used for FRA 2005 that are related to the reporting on growing stock, biomass and carbon. It is an extract of the complete set of terms and definitions for FRA 2005 (FAO, 2004c)

Forest

Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use.

Explanatory notes

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 rubber-wood 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.

Growing stock

Volume over bark of all living trees more than X cm in diameter at breast height. Includes the stem from ground level or stump height up to a top diameter of Y cm, and may also include branches to a minimum diameter of W cm.

Explanatory notes

1. The countries must indicate the three thresholds (X, Y, W in cm) and the parts of the tree that are not included in the volume. The countries must also indicate whether the reported figures refer to volume above ground or above stump.
2. The diameter is measured at 30 cm above the end of the buttresses if these are higher than 1 meter.
3. Includes windfallen living trees.
4. Excludes: Smaller branches, twigs, foliage, flowers, seeds, and roots.

Commercial growing stock

The part of the growing stock that is considered as commercial or potentially commercial under current market conditions (and with a diameter at breast height of Z cm or more).

Explanatory notes

1. Includes all commercial and potentially commercial (merchantable) species for domestic and international markets.
2. Excludes growing stock on areas where legal, economic or other specific restrictions prevent felling and removal of wood.
3. The countries must indicate the minimum diameter at breast height (Z cm) applied for considering a tree as being commercial.
4. When most species are commercial, i.e. in the temperate and boreal zone, the commercial growing stock can be close to the total growing stock. On the other hand, when only a small fraction of all species is merchantable, it can be considerably smaller.

Biomass

Organic material both above-ground and below-ground, and both living and dead, e.g., trees, crops, grasses, tree litter, roots etc. Biomass includes the pool definition for above - and below - ground biomass.

Above-ground biomass

All living biomass above the soil including stem, stump, branches, bark, seeds and foliage.

Explanatory note

1. Where the forest understorey is a relatively small component of the above-ground biomass, it is acceptable to exclude it, provided this is done in a consistent manner throughout the inventory time series.

Below-ground biomass

All living biomass of live roots. Fine roots of less than (suggested) 2mm diameter are sometimes excluded because these often cannot be distinguished empirically from soil organic matter or litter.

Explanatory notes

1. May include the below-ground part of the stump.
2. The country may use another threshold value than 2 mm for fine roots, but in such a case the threshold value used must be documented.

The term is mainly related to FRA 2005 National Reporting Table T6.

Dead wood biomass

All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country.

Explanatory note

1. The country may use another threshold value than 10 cm, but in such a case the threshold value used must be documented.

Carbon stock

The quantity of carbon in a “pool”, meaning a reservoir or system which has the capacity to accumulate or release carbon.

Explanatory note

1. For FRA 2005 purposes, examples of carbon pools are Living biomass (including Above and below-ground biomass); Dead organic matter (including dead wood and litter); Soils (soils organic matter). The units are mass.

Carbon in above-ground biomass

Carbon in all living biomass above the soil, including stem, stump, branches, bark, seeds, and foliage.

Explanatory note

1. Where the forest under-storey is a relatively small component of the above ground biomass carbon pool, it is acceptable to exclude it, provided this is done in a consistent manner throughout the inventory time series.

Carbon in below-ground biomass

Carbon in all living biomass of live roots.

Explanatory notes

1. Includes the below-ground part of the stump.
2. The country may use another threshold value than 2 mm for fine roots, but in such a case the threshold value used must be documented.
3. Fine roots of less than 2 mm diameter are excluded, because these often cannot be distinguished empirically from soil organic matter or litter.

Carbon in dead wood biomass

Carbon in all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country.

Explanatory note

1. The country may use another threshold value than 10 cm, but in such a case the threshold value used must be documented.

Carbon in litter

Carbon in all non-living biomass with a diameter less than a minimum diameter chosen by the country in various states of decomposition above the mineral or organic soil. This includes the litter, fomic, and humic layers.

Explanatory note

1. Live fine roots of less than 2 mm (or other value chosen by the country as diameter limit for below-ground biomass) are included in the litter where they cannot be distinguished from it empirically.

Soil Carbon

Organic carbon in mineral and organic soils (including peat) to a specified depth chosen by the country and applied consistently through the time series.

Explanatory note

1. Live fine roots of less than 2 mm (or other value chosen by the country as diameter limit for below-ground biomass) are included with soil organic matter where they cannot be distinguished from it empirically.

Organic soil

A soil in “forest and “other wooded land” is an organic soil (*Histosol*) if it satisfies any one of the following conditions:

- a. If the soil is never saturated with water for more than a few days and contains more than 20 percent carbon (about 35 percent humus); or
- b. If the soil is subject to water saturation episodes and has either:
 - At least 12 percent organic carbon (about 21 percent humus) if it has no clay; or
 - At least 18 percent organic carbon (about 31 percent humus) if it has 60 percent or more clay
 - An intermediate, proportional amount of organic carbon for intermediate amounts of clay.

Explanatory note

1. Soils that do not satisfy the criteria for classification as organic soils are mineral soils.

