Chapter 2
Extent of forest resources

OVERVIEW

Extent of forest resources is the first of the thematic elements characterizing sustainable forest management. Generally speaking, it refers to the overall goal of maintaining adequate forest cover and stocking – of various forest types and characteristics including on 'other wooded land' and as 'trees outside forests' – to support the social, economic and environmental objectives related to forestry within a country or region. The ultimate aim of monitoring the extent and characteristics of forest resources is to reduce unplanned deforestation, restore and rehabilitate degraded forest landscapes, manage forests sustainably and evaluate the important function of carbon sequestration by forests, other wooded land and trees outside forests – thereby contributing to moderating the global climate (FAO, 2005d).

Information on the extent of forest resources has formed the backbone of all global forest resources assessments and continued to be a major topic in FRA 2005. Forest area is an easily understood baseline variable, which provides a first indication of the relative importance of forests in a country or region. Estimates of change in forest area over time provide an indication of the demand for land for forestry and other land uses, as well as of the impact of significant environmental disasters and disturbances on forest ecosystems. As mentioned previously, the proportion of land area under forests is also used in the Millennium Development Goals indicator process (United Nations, 2005a).

However, as was observed in FRA 2000 (FAO, 2001b), the significance of forest area as a single indicator of forest development has often been overemphasized, particularly in the public debate, where other aspects of forest resources feature less prominently. The most commonly quoted result from global forest resources assessments continues to be the global net loss of forest area. However, it is important to note that many other parameters and scales must be considered in determining the relevant trends in the extent of forest resources. Growing stock and carbon storage may be considered equally important parameters, as they indicate whether forests are degraded and to what extent they mitigate climate change. Further, the net loss of forest area is not in itself sufficient to describe land-use dynamics that include both loss of forests due to deforestation and natural disasters and gains in forest area from planting or natural expansion.

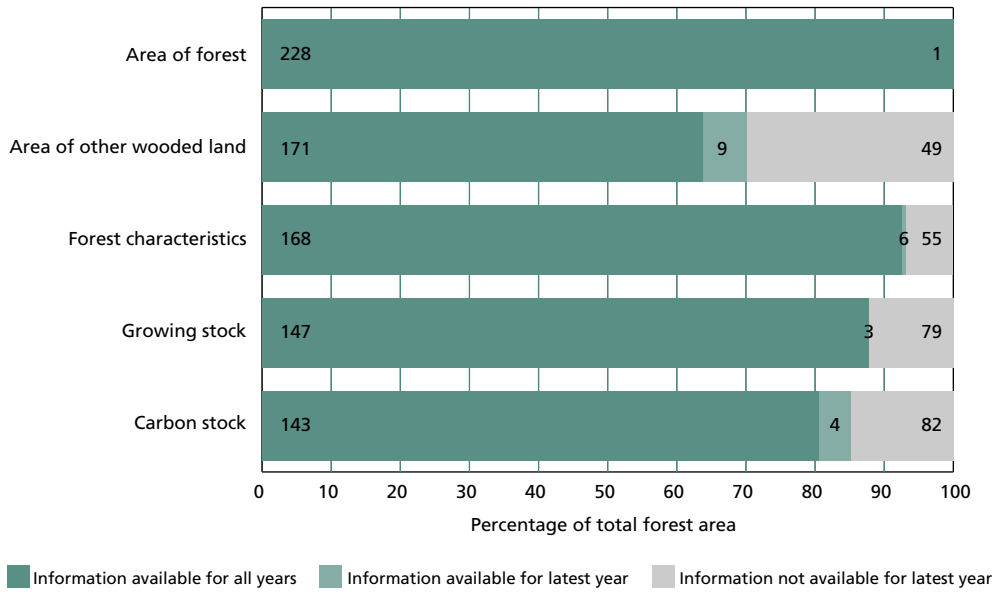
For FRA 2005, information was sought on the current status and changes over time of the following four variables:

- area of 'forest' and 'other wooded land'. Countries were also encouraged to provide information on 'other land with tree cover';[1]
- characteristics of forests and other wooded land according to five classes: primary, modified natural, semi-natural, protective forest plantations and productive forest plantations;
- standing volume of wood, i.e. the total growing stock in forests and other wooded land;
- carbon stock contained in woody biomass, dead wood, litter and forest soils.

Figure 2.1 illustrates the availability of information for these variables at the global level.

[1] See Annex 2 for exact definitions.

FIGURE 2.1
Information availability – extent of forest resources



Note: Figures present number of countries in each category.

In regional and ecoregional criteria and indicator processes, as well as in national reports, more-detailed classifications of the forest area are often used, e.g. according to forest or vegetation type, age structure or diameter distribution classes. Because of the varying conditions and classification systems among countries and regions, it was not feasible to report on such classifications at the global level. However, country reports for FRA 2005 contain considerably more detail than is shown in the global tables. Moreover, thematic studies have been prepared on planted forests, mangroves and bamboo that provide in-depth knowledge on these forest types and groups of species.

In FRA 2000, an independent remote sensing survey was carried out to supplement country reporting for the pan-tropical region. The results constituted an important ingredient in the analysis of global and regional trends, leading, for example, to a calibration of reported changes in forest area for Africa. The survey also provided considerable insight into change processes in land use, including the documentation of different patterns of land-use change in tropical regions. The results have been widely acknowledged and used (e.g. Mayaux *et al.*, 2005). While no similar project was carried out for FRA 2005 owing to lack of resources, preparations have been made for a more ambitious approach (FAO, 2003d) that takes a broader range of information requirements into account. This approach is being considered for the next global forest resources assessment (FRA 2010).

KEY FINDINGS

Based on the information provided, total forest area in 2005 is estimated to be just under 4 billion hectares (ha) or 30 percent of total land area. This corresponds to an average of 0.62 ha of forest per capita.

However, area of forest is unevenly distributed. For example, 64 countries with a combined population of 2.0 billion have less than 0.1 ha of forest per capita. Often described as low forest cover countries (LFCCs), they include a number of fairly large countries in arid zones, as well as many small island developing states (SIDS)

and dependent territories. The ten most forest-rich countries account for two-thirds of total forest area, while seven countries or territories have no forest at all, and an additional 57 have forest on less than 10 percent of their total land area.

Deforestation, mainly due to conversion of forests to agricultural land, continues at an alarmingly high rate – some 13 million hectares per year. At the same time, forest planting, landscape restoration and natural expansion of forests have significantly reduced the net loss of forest area.

Net global change in forest area in the period 2000–2005 is estimated at -7.3 million hectares per year (an area about the size of Panama or Sierra Leone), down from -8.9 million hectares per year in the period 1990–2000.

South America suffered the largest net loss of forests from 2000 to 2005 – about 4.3 million hectares per year – followed by Africa, which lost 4.0 million hectares annually.

North and Central America and Oceania each had a net loss of about 350 000 ha, while Asia, which had a net loss of some 800 000 ha per year in the 1990s, reported a net gain of 1 million hectares per year from 2000 to 2005, primarily as a result of large-scale afforestation reported by China. Forest areas in Europe continued to expand, although at a slower rate than in the 1990s.

Total area of other wooded land is estimated to be at least 1 376 million hectares – about one-third the size of total forest area. Total area of other land with tree cover was reported to be 76 million hectares, but is undoubtedly much higher as information availability was limited.

An estimated 36 percent of total forest area is classified as primary forests, i.e. forests of native species, in which there are no clearly visible indications of human activity and ecological processes are not significantly disturbed. About 6 million hectares of these forests were lost or modified each year since 1990, and there is no indication that the rate of change is slowing down. This rapid decrease stems not only from deforestation, but also from modification of forests due to selective logging and other human interventions through which primary forests move into the category of modified natural forests.

The global area of modified natural forests (forests of naturally regenerated native species in which there are clearly visible indications of human activity) is about 2 billion hectares (53 percent of all forests). An estimated 7 percent of the world's forests are semi-natural forests – i.e. forests comprising native species, established through planting, seeding or assisted natural regeneration.

Forests and trees are being planted for many purposes and at increasing rates, yet they still account for a fairly small proportion of total forest area. Forest plantations – a subset of planted forests consisting primarily of introduced species – make up an estimated 4 percent of total forest area. Productive forest plantations, primarily established for wood and fibre production, account for 78 percent of these, and protective forest plantations, primarily established for conservation of soil and water, account for 22 percent. The area of forest plantations increased by about 14 million hectares during 2000–2005, or 2.8 million hectares per year, 87 percent of which are productive forest plantations.

Total area of mangroves is estimated at 15.2 million hectares as of 2005, down from 18.8 million hectares in 1980. Close to half the total mangrove area (47 percent) is found in five countries: Indonesia, Australia, Brazil, Nigeria and Mexico.

The area of bamboo is difficult to assess, as these species often occur as patches within forests or as clusters outside them. Nevertheless, preliminary findings based on reports from 30 of the main bamboo-rich countries indicate that the total area is about 40 million hectares – or 1 percent of the global forest area – and is increasing.

In 2005 the total global growing stock of forests was estimated at 434 billion m^3, which corresponds to an average of 110 m^3 per hectare. The countries with the most growing stock per hectare were found in central Europe and some tropical areas.

Total growing stock shows a slight overall downward tendency – mainly owing to a decrease in forest area. However, some regions also show significant trends in growing stock per hectare, for example Europe shows an increase and Southeast Asia a decrease.

It is estimated that the world's forests store 283 gigatonnes (Gt) of carbon in their biomass alone and 638 Gt of carbon in the ecosystem as a whole (to a soil depth of 30 cm). Thus forests contain more carbon than the entire atmosphere. Roughly half of total carbon is found in forest biomass and dead wood combined and half in soils and litter combined.

Carbon in forest biomass decreased in Africa, Asia and South America in the period 1990–2005, but increased in all other regions. For the world as a whole, carbon stocks in forest biomass decreased by 1.1 Gt of carbon annually, owing to continued deforestation and forest degradation, partly offset by forest expansion (including planting) and an increase in growing stock per hectare in some regions.

In conclusion, considerable progress has been made towards reversing the overall trend of forest area loss, and several variables related to extent of forest resources show no significant negative trends or even a positive trend over time in some countries and regions. Yet deforestation, including conversion of forests to agricultural land, continues at an alarmingly high rate. Considerable efforts are needed before the overall trend in extent is positive or stable in all regions.

FOREST AREA AND FOREST AREA CHANGE

Forest area provides the first indication of the relative importance of forests in a country or region, while estimates of forest area change over time provide an indication of the demand for land for forestry and other land uses, and may also illustrate the impact of significant environmental disasters and disturbances on forest ecosystems. Forest area is relatively easy to measure, and this variable has therefore been selected as one of the 48 indicators for monitoring progress towards the Millennium Development Goals agreed by the United Nations (particularly Goal 7 – Ensuring environmental sustainability).

Data on the status of and trends in area of forest are crucial to decisions related to forest and land-use policies and resource allocations, but they need to be combined with information on the health and vitality of forests and their socio-economic and environmental functions and values. Other sections of this report deal with these aspects.

Information availability

Information on the extent of forests was provided by 228 of the 229 countries and areas reporting for FRA 2005 – the exception being the Marshall Islands, for which no quantitative information was available. Antarctica and some of the smaller dependent territories, which do not have, or have no significant, forest area were not included in the list of reporting units for FRA 2005.

Four countries or areas (Guam, Guyana, Lebanon and the Occupied Palestinian Territory) did not provide an estimate of forest area for 1990. All other countries and areas provided estimates for all three reporting years (1990, 2000 and 2005). For the purpose of analysis, the 1990 forest area for each of these four countries and areas was estimated by FAO based on a linear extrapolation of the figures provided for 2000 and 2005.

Since extent of forest resources is a key variable for decisions regarding forest policy and investments in the forestry sector, almost all countries and areas provided information on this variable. However, some countries had comprehensive information from only one point in time (see Table 2 in Annex 3), while others had estimates that were incompatible, making trend analyses difficult.

Information on the extent of other wooded land as of 2005 was available from 180 countries and areas, which together account for 64.9 percent of total forest area.

Only 61 countries and areas reported on current extent of other land with tree cover, which is a new variable in global forest resources assessments. It aims to capture those areas in which forest cover criteria are met, but the predominant land use is agricultural (e.g. orchards and oil-palm plantations) or urban (e.g. urban parks).

Status

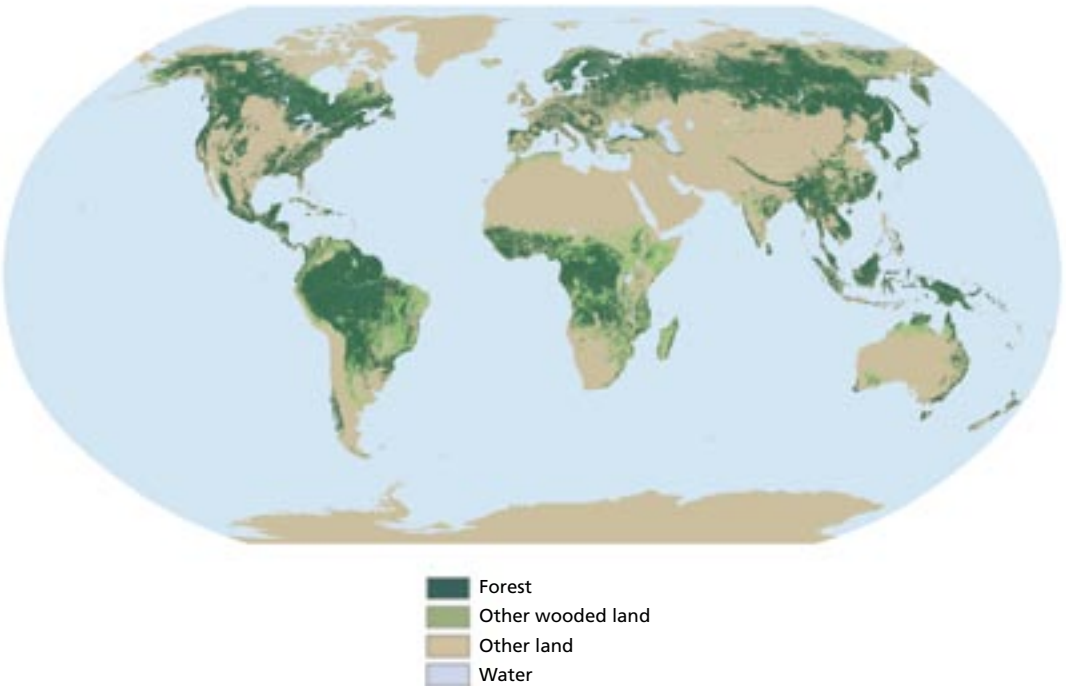
Total forest area as of 2005 is estimated at 3 952 million hectares or 30 percent of total land area. This corresponds to an average of 0.62 ha per capita. As can be seen from Figure 2.2, the area of forest is unevenly distributed. For example, 64 countries with a combined population of 2.0 billion have less than 0.1 ha of forest per capita.

Based on available information, total area of other wooded land is estimated to be at least 1 376 million hectares – about one-third of total forest area. This category suffered from reclassification problems, particularly in dry zones such as those in Australia, Kenya and the Sudan, in which the distinction between forest and other wooded land is not very clear. Total area of other land with tree cover is at least 76 million hectares. These two estimates, particularly the latter, were limited by lack of information, and the true extent of other land with tree cover is undoubtedly much higher.

Distribution of forests. A subregional summary of the distribution of forests is shown in Table 2.1. Europe accounts for one-quarter of total forest area, followed by South America and North and Central America with 21 and 18 percent respectively. Information on the area of forest and other wooded land by country can be found in Table 3 in Annex 3.

Forest-rich and forest-poor countries. The five most forest-rich countries (the Russian Federation, Brazil, Canada, the United States and China) account for more than half of total forest area (2 097 million hectares or 53 percent). The Russian Federation alone

FIGURE 2.2
The world's forests



accounts for 20 percent of the world total. Seven countries have more than 100 million hectares of forest each. The ten most forest-rich countries account for 66 percent of total forest area (Figure 2.3). The remaining 34 percent is spread among 212 countries and areas. Seven countries and areas (the Falkland Islands, Gibraltar, the Holy See, Monaco, Nauru, South Georgia and South Sandwich Islands and Tokelau) reported having no areas that qualify as forests using the FRA 2005 definition.

High and low forest cover countries. Forty-five countries and areas have more than half their total land area covered by forests (Figure 2.4), and 11 of these have more than 75 percent of their total land area covered. Most of these are small island states or territories, but the list also includes three low-lying coastal states in South America and one country in the Congo Basin (Table 2.2).

Sixty-four countries and areas have less than 10 percent of their total land area covered by forests. These include many SIDS and dependent territories, as well as 17 larger

TABLE 2.1
Distribution of forests by subregion 2005

Region/subregion	Forest area *(1 000 ha)*	% of global forest area
Eastern and Southern Africa	226 534	5.7
Northern Africa	131 048	3.3
Western and Central Africa	277 829	7.0
Total Africa	**635 412**	**16.1**
East Asia	244 862	6.2
South and Southeast Asia	283 127	7.2
Western and Central Asia	43 588	1.1
Total Asia	**571 577**	**14.5**
Total Europe	**1 001 394**	**25.3**
Caribbean	5 974	0.2
Central America	22 411	0.6
North America	677 464	17.1
Total North and Central America	**705 849**	**17.9**
Total Oceania	**206 254**	**5.2**
Total South America	**831 540**	**21.0**
World	**3 952 025**	**100.0**

FIGURE 2.3
Ten countries with largest forest area 2005
(million ha)

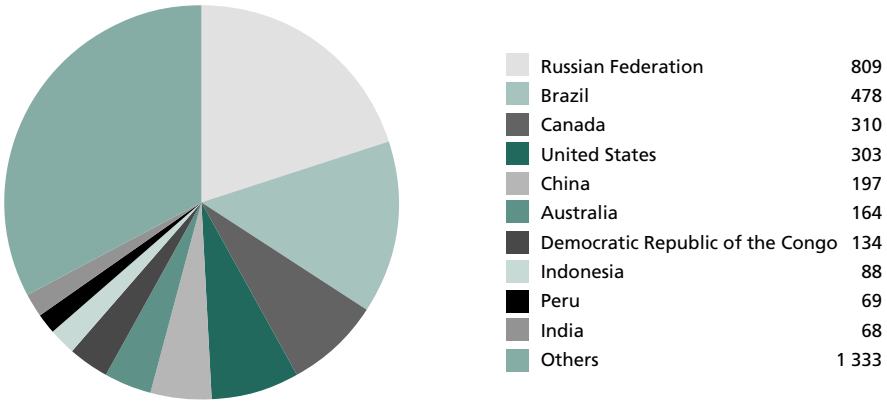


FIGURE 2.4
Forest area in percent of land area by country 2005

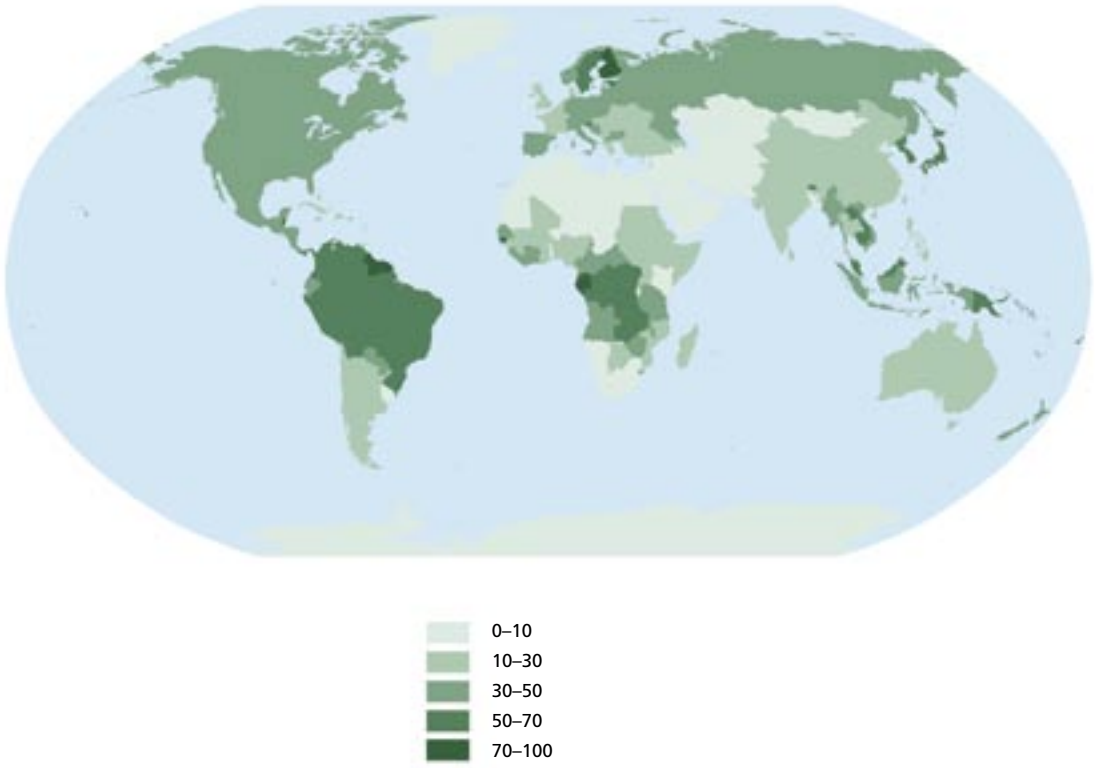


TABLE 2.2
High forest cover countries 2005

Country	Forest area *(1 000 ha)*	% of total forest area
Suriname	14 776	94.7
French Guiana	8 063	91.8
Micronesia (Federated States of)	63	90.6
American Samoa	18	89.4
Seychelles	40	88.9
Palau	40	87.6
Gabon	21 775	84.5
Pitcairn	4	83.3
Turks and Caicos Islands	34	80.0
Solomon Islands	2 172	77.6
Guyana	15 104	76.7

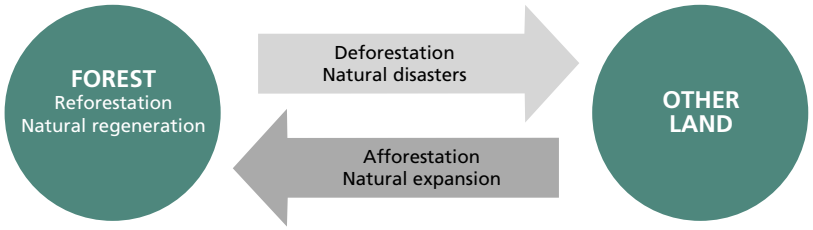
countries with relatively substantial forest areas (more than 1 million hectares each). Three of these (Chad, the Islamic Republic of Iran and Mongolia) have more than 10 million hectares of forest, but still qualify as LFCCs.

At the regional level, South America is the region with the highest percentage of forest cover, followed by Europe and North and Central America. Asia is the region with the lowest percentage of forest cover (Table 2.3).

TABLE 2.3
Forest cover by subregion 2005

Region/subregion	Forest area *(1 000 ha)*	% of land area
Eastern and Southern Africa	226 534	27.8
Northern Africa	131 048	8.6
Western and Central Africa	277 829	44.1
Total Africa	**635 412**	**21.4**
East Asia	244 862	21.3
South and Southeast Asia	283 127	33.4
Western and Central Asia	43 588	4.0
Total Asia	**571 577**	**18.5**
Total Europe	**1 001 394**	**44.3**
Caribbean	5 974	26.1
Central America	22 411	43.9
North America	677 464	32.7
Total North and Central America	**705 849**	**32.9**
Total Oceania	**206 254**	**24.3**
Total South America	**831 540**	**47.7**
World	**3 952 025**	**30.3**

FIGURE 2.5
Forest change dynamics



Trends

Figure 2.5 is a simplified model illustrating forest change dynamics. It has only two classes: forests and all other land. A *reduction* in forest area can happen through either of two processes. Deforestation, which is by far the most important, implies that forests are cleared by people and the land converted to another use, such as agriculture or infrastructure. Natural disasters may also destroy forests, and when the area is incapable of regenerating naturally and no efforts are made to replant it, it, too, reverts to other land.

An *increase* in forest area can also happen in two ways: Either through afforestation, i.e. planting of trees on land that was not previously forested, or through natural expansion of forests, e.g. on abandoned agricultural land – which is quite common in some European countries.

Where part of a forest is cut down but replanted (reforestation), or where the forest grows back on its own within a relatively short period (natural regeneration), there is no change in forest area.

For FRA 2005, countries were asked to provide information on their forest area for three points in time. This allows calculation of the net change in forest area over time. This net change is the sum of all negative changes due to deforestation and natural disasters and all positive changes due to afforestation and natural expansion of forests.

The total net change in forest area in the period 1990–2000 is estimated at -8.9 million hectares per year – equivalent to a loss of 0.22 percent of the remaining forest area each year during this period.

The total net change in forest area in the period 2000–2005 is estimated at -7.3 million hectares per year – an area the size of Panama or Sierra Leone – or equivalent to a loss of 200 km² of forest per day. Compared to the 1990s, the current annual net loss is 18 percent lower and equals a loss of 0.18 percent of the remaining forest area each year during this period.

Countries were not requested to provide information on each of the four components of net change, as most countries do not have such information. This, however, makes estimation of the deforestation rate difficult and no attempt has been made to do so at the country level. Rather, an estimate of the global deforestation rate has been made as follows:

The total net loss for countries with a negative change in forest area was 13.1 million hectares per year for 1990–2000 and 12.9 million hectares per year for 2000–2005. This would indicate that annual deforestation rates were at least at this level. Since the net change rate takes into account afforestation efforts and natural expansion of forests, the rate of deforestation might be higher still. On the other hand, Brazil, which accounts for 21 percent of the total net loss in the period 1990–2000 and 24 percent in 2000–2005, calculated its forest area in 2005 and 1990 based on information from 2000 and the sum of annual figures of the area of forests cleared. It did not take into account to what extent the land use of these areas had changed and to what extent cleared lands had been abandoned and had reverted to forest through natural regeneration. Such naturally regenerated secondary forests are thought to be quite extensive, but insufficient information is available to estimate the extent. Thus the area of deforestation and the net loss of forests in Brazil are likely overestimated.

Taking these considerations into account, the global deforestation rate was estimated at 13 million hectares per year during the period 1990–2005, with few signs of a significant decrease over time.

In summary, deforestation continues at an alarming rate – but the rate of net loss is decreasing due to afforestation and natural expansion of forests in some countries and regions.

Trends in area of other wooded land were analysed, based on the 171 countries and areas providing information for all three reporting years. The analysis indicates that other wooded land is more or less constant in North and Central America and Oceania. In Europe and South America, it decreased in the period 1990–2000, but remained almost constant in the period 2000–2005. It decreased in both periods in Africa and Asia. At the global level, area of other wooded land decreased by about 3.3 million hectares per year over the past 15 years. This finding should be treated with caution, however, since many countries do not have compatible information over time for other wooded land, and thus one estimate was frequently used as the best available figure for all three reporting years. Data for other land with tree cover were too limited to allow trend analysis.

Regional and subregional comparisons. Table 2.4 and Figure 2.6 show the changes in area of forest by region and subregion. South America suffered the largest net loss of forests from 2000 to 2005 – about 4.3 million hectares per year – followed by Africa, which lost 4.0 million hectares annually. While there are signs that the net loss in Africa is decreasing, it seems to be increasing in South America – primarily due to a reported increase in the net loss of forests in Brazil. However, as indicated above, the net loss reported by Brazil for both periods may be overestimated. Efforts are currently underway to design and implement a national forest assessment on a pilot basis in Brazil, which should yield better information for the next global forest resources assessment.

North and Central America and Oceania each had a net loss of about 350 000 ha, with a decreasing trend in Oceania, and a slightly increasing trend in North and Central America – the latter primarily owing to a decrease in the plantation establishment rate in the United States (down from an average of 596 900 ha per year in 1990–2000 to an average of 157 400 ha per year in the period 2000–2005) and the continued, albeit decreasing, net loss of forests in Mexico.

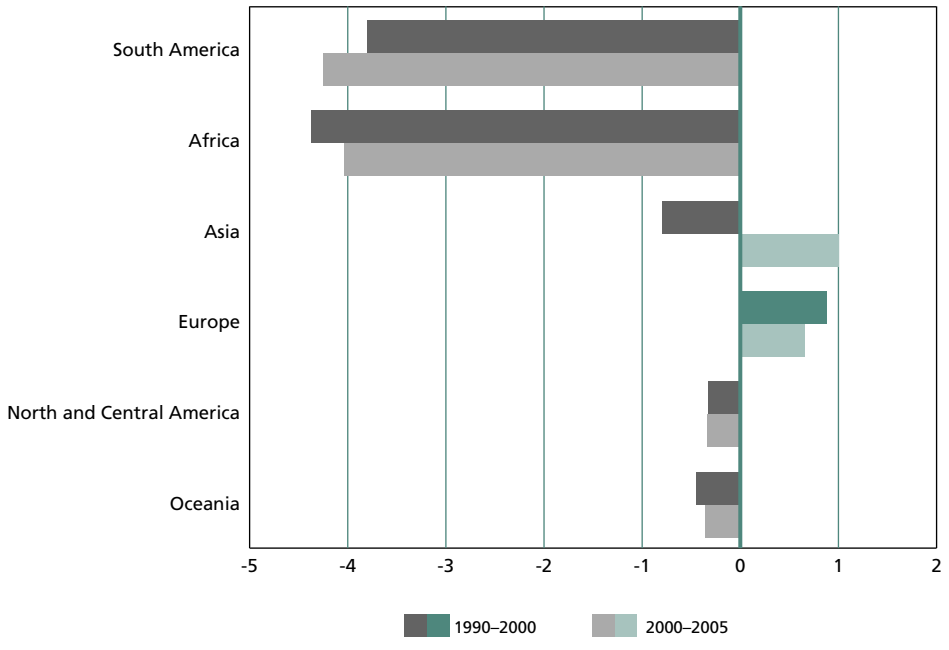
TABLE 2.4
Annual changes in forest area by subregion 1990–2005

Region/subregion	1990–2000		2000–2005	
	1 000 ha	%	1 000 ha	%
Eastern and Southern Africa	-1 731	-0.71	-1 702	-0.74
Northern Africa	-1 013	-0.72	-982	-0.73
Western and Central Africa	-1 631	-0.56	-1 356	-0.48
Total Africa	**-4 375**	**-0.64**	**-4 040**	**-0.62**
East Asia	1 751	0.81	3 840	1.65
South and Southeast Asia	-2 578	-0.83	-2 851	-0.98
Western and Central Asia	34	0.08	14	0.03
Total Asia	**-792**	**-0.14**	**1 003**	**0.18**
Total Europe	**877**	**0.09**	**661**	**0.07**
Caribbean	36	0.65	54	0.92
Central America	-380	-1.47	-285	-1.23
North America	17	n.s.	-101	-0.01
Total North and Central America	**-328**	**-0.05**	**-333**	**-0.05**
Total Oceania	**-448**	**-0.21**	**-356**	**-0.17**
Total South America	**-3 802**	**-0.44**	**-4 251**	**-0.50**
World	**-8 868**	**-0.22**	**-7 317**	**-0.18**

Note: percentages represent the proportion of remaining forest area lost or gained each year during the respective period.

n.s. = not significant

FIGURE 2.6
Annual net change in forest area by region 1990–2005
(million ha per year)



Asia, which had a net loss of some 800 000 ha per year in the 1990s, reported a net gain of 1 million hectares per year from 2000 to 2005, primarily as a result of the large-scale afforestation reported by China. Forest areas in Europe continued to expand, although at a slower rate than in the 1990s. For information on changes in forest area by country, see Table 4 in Annex 3.

Countries with large positive or negative changes. In the Caribbean, Europe, North America, Oceania and Western and Central Asia, a majority of countries have no major changes over the last five years, while in Africa a majority of countries have a negative change rate (Figure 2.7).

A large number of countries in Oceania and the Caribbean have reported no major change, primarily because of lack of data and particularly for more than one point in time.

The ten countries with the largest *net loss* per year in the period 2000–2005 had a combined net loss of forest area of 8.2 million hectares per year (Table 2.5).

The ten countries with the largest *net gain* per year in the period 2000–2005 had a combined net gain of forest area of 5.1 million hectares per year due to afforestation efforts and natural expansion of forests (Table 2.6). The large increase in forest area for China is due to recent, large-scale afforestation programmes.

FIGURE 2.7
Countries with large net changes in forest area 2000–2005

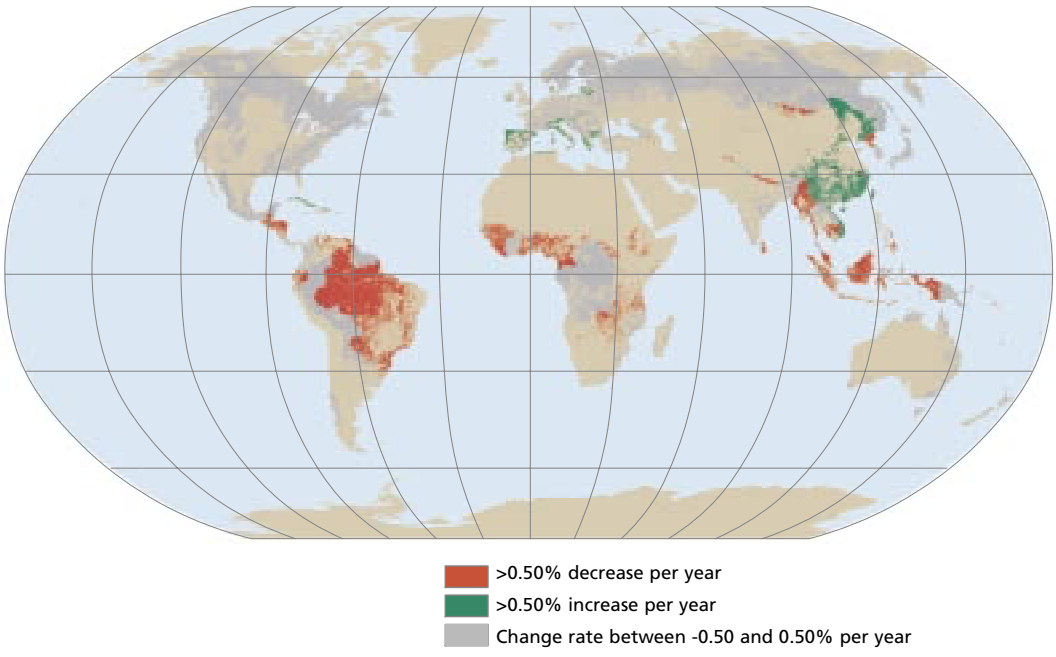


TABLE 2.5
Ten countries with largest annual net loss in forest area 2000–2005

Country	Annual change *(1 000 ha/yr)*
Brazil	-3 103
Indonesia	-1 871
Sudan	-589
Myanmar	-466
Zambia	-445
United Republic of Tanzania	-412
Nigeria	-410
Democratic Republic of the Congo	-319
Zimbabwe	-313
Venezuela (Bolivarian Republic of)	-288
Total	**-8 216**

TABLE 2.6
Ten countries with largest annual net gain in forest area 2000–2005

Country	Annual change *(1 000 ha/yr)*
China	4 058
Spain	296
Viet Nam	241
United States	159
Italy	106
Chile	57
Cuba	56
Bulgaria	50
France	41
Portugal	40
Total	**5 104**

Thirty-seven countries and areas have an estimated net negative change rate of 1 percent or more per year. The ten countries with the largest annual net negative change rates for 2000–2005 are: Comoros (-7.4 percent); Burundi (-5.2 percent); Togo (-4.5 percent); Mauritania (-3.4 percent); Nigeria (-3.3 percent); Afghanistan (-3.1 percent); Honduras (-3.1 percent); Benin (-2.5 percent); Uganda (-2.2 percent) and the Philippines (-2.1 percent).

Eighteen countries have an estimated annual positive change rate of 1 percent or more due to natural expansion of forests and afforestation. The ten countries with the largest estimated annual positive change rates for 2000–2005 are: Rwanda (6.9 percent); Iceland (3.9 percent); Bahrain (3.8 percent); Lesotho (2.7 percent); Kuwait (2.7 percent); Egypt (2.6 percent); China (2.2 percent); Cuba (2.2 percent); Viet Nam (2.0 percent) and Tunisia (1.9 percent).

Most but not all of the countries with large change rates measured in percentages are LFCCs or countries with a limited forest area, where a relatively small change in absolute values results in a large change in relative or percentage terms.

Comparison with previous estimates

Countries were asked to provide estimates for three points in time for FRA 2005: 1990, 2000 and 2005. The figures provided for 1990 and 2000 are likely to differ slightly from those reported for the previous assessment (FRA 2000) for the following reasons:

First, the estimates presented in both assessments are derived primarily through linear interpolation and extrapolation of the results from two or more recent assessments. National forest resources assessments are fairly expensive, thus they are often carried out at infrequent intervals and a new data set can significantly change previous forecasts based, for example, on estimates from the 1970s or 1980s.

Second, many more countries were actively involved in the FRA 2005 process than in previous assessments, and the national correspondents helped provide access to better and more recent information, while their detailed knowledge of forest types helped improve the reclassification of data into FRA 2005 categories.

Table 2.7 shows a comparison of the results provided in FRA 2000 and those reported in FRA 2005 for reporting years 1990 and 2000.

Globally, total forest area estimated in FRA 2005 for 1990 and 2000 was about 3 percent higher than that in FRA 2000. This was primarily owing to reclassification of unproductive forests in Canada and the United States (previously classified as other wooded land), but also to new and better information from other countries.

Most countries provided estimates of forest area that differed from those provided for FRA 2000. Many differences were minor and due to calibration of areas to match the official land areas as found in the FAO database FAOSTAT (FAO, 2005a). Others were due to reclassifications or to new and better information and, in some cases, resulted in significantly different figures.

A total of 79 countries provided estimates for 1990 for FRA 2005 that differed by more than 10 percent from those presented for FRA 2000. Similarly, a total of 85 countries provided new figures for 2000 that differed by more than 10 percent from those presented for FRA 2000. A separate working paper has been prepared explaining these differences (FAO, 2006a).

Annual net loss of forests in the 1990s appears to have been overestimated in previous studies. FRA 2000 estimated the annual net change in global forest area to be -9.4 million hectares per year for the period 1990–2000. FRA 2005 estimates the rate for the same period to be -8.9 million hectares per year, i.e. half a million hectares less per year.

The main differences are found in Africa, where the net loss is 1 million hectares lower than previously estimated, and in Asia, where FRA 2005 estimates a higher

TABLE 2.7
Comparison of forest area estimates in FRA 2005 and FRA 2000

Region	FRA 2005 estimates			FRA 2000 estimates		
	Forest area *(1 000 ha)*		Annual change *(1 000 ha/yr)*	Forest area *(1 000 ha)*		Annual change *(1 000 ha/yr)*
	1990	2000	1990–2000	1990	2000	1990–2000
Africa	699 361	655 613	-4 375	702 502	649 866	-5 262
Asia	574 487	566 562	-792	551 448	547 793	-364
Europe	989 320	998 091	877	1 030 475	1 039 251	881
North and Central America	710 790	707 514	-328	555 002	549 304	-570
Oceania	212 514	208 034	-448	201 271	197 623	-365
South America	890 818	852 796	-3 802	922 731	885 618	-3 711
World	**4 077 291**	**3 988 610**	**-8 868**	**3 963 429**	**3 869 455**	**-9 391**

loss for the 1990s than previously reported, primarily due to a revised change rate for Indonesia, based on more recent information.

For Africa, the results for FRA 2005 are closer to the results of the independent remote sensing analysis done for FRA 2000, which indicated that the net annual loss was -2.2 million hectares, while the reports indicated a net loss of -5.5 million hectares. However, the net loss of 4.3 million hectares reported for FRA 2005, which is based on national reports, may still be overestimated.

FOREST CHARACTERISTICS

The request for information on forest characteristics aimed to provide more detailed information on the kinds of forest that exist, in terms of their 'naturalness' or the intensity of silviculture and management practices. A continuum exists from primary forests with no – or no visible – indications of past or present human activity to intensively managed forest plantations of introduced species, primarily managed for a single product, often on a relatively short rotation. Between these two extremes lies a range of scenarios, and there are no clear cut-off points between possible classes along the continuum.

Countries were asked to characterize their forests and other wooded land according to five classes: primary, modified natural, semi-natural, protective forest plantation and productive forest plantation.

The first three classes comprise native forest tree species only, with the possible exception of small areas of natural regeneration of introduced or naturalized species in the semi-natural class. While the origin of primary and modified natural forests is natural regeneration, semi-natural forests are established through assisted natural regeneration, planting or seeding, while all forest plantations are established through planting or seeding.

Planted forests thus comprise all forest plantations and parts of semi-natural forests. All planted forests of introduced species were classified as forest plantations in FRA 2005. Planted forests of native species were classified as forest plantations if characterized by few species, straight, regularly spaced rows and/or even-aged stands. If they resembled natural forests of the same species mix, such as many planted forests in Europe, they were classified as semi-natural forests.

A thematic study on planted forests, including the planted-forest component of both semi-natural forests and forest plantations, is being completed for release during 2006 to complement the data available in FRA 2005 (Box 2.1).

The use of the five different classes helps clarify the extent to which forests are human-made or -modified, while at the same time providing an indication of the

BOX 2.1

FRA 2005 thematic study on planted forests

This study complements FRA 2005 with more detailed data, information and analysis on planted forests around the globe. Its aims are to: provide inputs into a global outlook on the future supply of forest products and services from planted forests; better understand the role of planted forests in the mosaic of land uses in the broader landscape; and offer factual inputs into the ongoing process of deriving a planted forest code.

A survey is being undertaken of countries reporting high proportions of semi-natural forests and large areas of forest plantations. As a first step, the survey requested countries to differentiate the planted forest component of semi-natural forests and forest plantations, collectively known as the planted forest subset.

Management and ownership of planted forests have changed over the period 1990–2005. Consequently, countries were asked to report their management designation for primarily productive or primarily protective purposes, as well as ownership, for the reporting periods 1990, 2000 and 2005. Planted forests managed primarily for productive purposes supply wood, fibre, fuelwood and NWFPs for industrial purposes, but can also provide social, cultural and environmental services. Planted forests managed primarily for protective purposes protect soil and water, rehabilitate degraded lands and conserve biological diversity and carbon sinks, but can also include minor harvesting of forest products. Management parameters reported include the top ten species, growth rates, rotation lengths and age and class distributions for both productive and protective designations, as well as harvest yields for planted forests managed for productive purposes. Ownership is reported as state, private-sector corporate, smallholder or 'other'.

Countries were also asked to report on the main forest products, including sawlogs, pulpwood and fibre, industrial bioenergy, NWFPs and 'unspecified'. In addition, data were solicited on the services offered by planted forests, including the environment, recreation, non-industrial fuelwood and 'unspecified'.

Data collection was carried out by FRA 2005 national correspondents, with the participation of in-country specialists in planted forests. At the time of writing, analysis was being completed for release of the study during 2006. A Web-based knowledge reference centre will be established, offering data, information and reference materials on planted forests and related topics (reproductive materials, forest health, invasive species, etc.) for wide access by stakeholders. The materials will also be provided in hard copy and compact disc for those without access to the Internet.

When available, the information will be posted on the FAO planted forest Web portal: www.fao.org/forestry/site/planted-forest/.

intensity of management and the potential for wood production, e.g. for use in global fibre supply models.

The typical modified forest is a tropical forest in which selective logging has taken place, but no silvicultural measures have influenced the natural regeneration of species. The typical semi-natural forest might be a temperate forest in Europe or a teak forest in Asia, in which the harvesting is much more intense, removing a larger volume and number of trees per hectare, and with specific interventions aimed at securing a desirable future species mix through assisted natural regeneration, seeding or planting of native species.

Forest plantations may be established for different purposes and have been divided into two classes, with protective forest plantations typically being unavailable for wood

supply (or at least having wood production as a secondary objective only) and often consisting of a mix of species managed on long rotations or under continuous cover.

This section provides an overview of status and trends as related to forest characteristics. More detailed information on primary forests can be found in the chapter on biological diversity, while analyses of productive and protective forest plantations can be found in the respective chapters on these themes.

Information availability

Although a large number of countries reported on the characteristics of their forests, information on all five classes was not always readily available, because countries either did not collect information or used a different national classification system. Proxy values have often been used, which makes a detailed analysis of status and trends difficult.

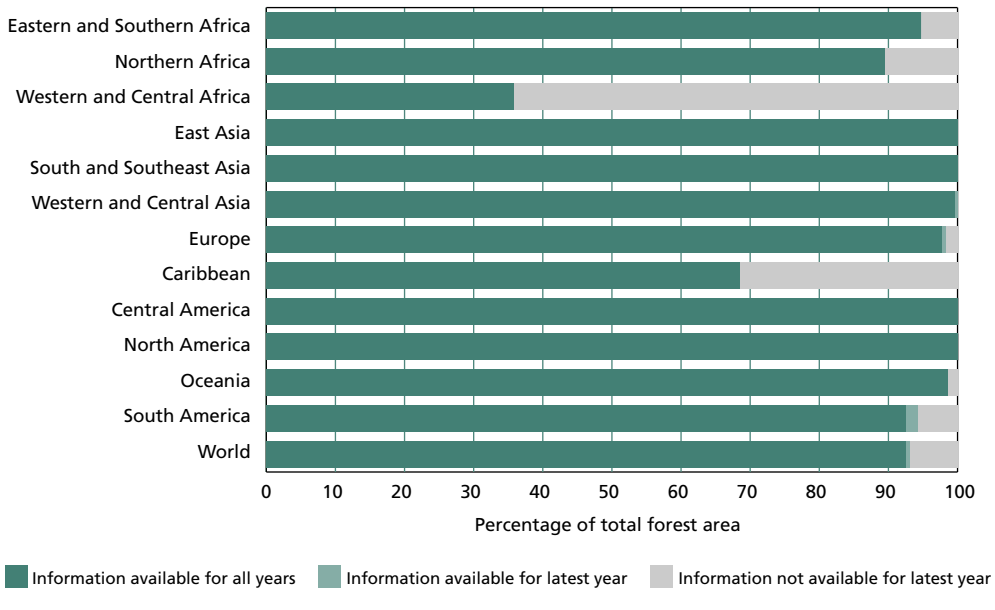
Information was unavailable for many of the countries in the Congo Basin, the second largest expanse of tropical forest, and this should be kept in mind when analysing the findings.

Few countries had information on the area of primary forests. Some used the current area of forests in national parks and other protected areas as a proxy value or provided an expert estimate of the percentage of natural forests that could be considered primary according to the definition used for FRA 2005. There were also some inconsistencies in reporting planted forests of native species: some countries reported these as semi-natural forests, while others preferred to include them as forest plantations. Thus it may not be possible to directly compare figures for different countries, owing to differences in interpretation of the classification systems.

Of 229 countries and areas reporting, 174 reported on the characteristics of their forests. Their combined forest area was estimated at 3 678 million hectares – equivalent to 93 percent of the total forest area of the world (Figure 2.8).

Of the 180 countries providing information on the area of other wooded land, 114 provided information on characteristics.

FIGURE 2.8
Information availability – forest characteristics



Status

More than one-third (36 percent) of total forest area is classified as primary forest, i.e. forest of native species, in which there are no clearly visible indications of human activity and ecological processes are not significantly disturbed (Figure 2.9).

Great variation exists in terms of the distribution of primary forests, with limited areas reported from the Caribbean, Europe (excluding the Russian Federation) and the arid zones of Eastern and Southern Africa, Northern Africa and Western and Central Asia. The largest expanse of primary forest is found in South America (the Amazon). Countries in North and Central America and the Russian Federation have also classified a relatively high proportion of their forests as primary.

Slightly more than half of all forests (53 percent) are considered modified natural forests (forests of naturally regenerated native species in which there are clearly visible indications of human activity) and 7 percent are classified as semi-natural forests (forests comprising native species, established through planting, seeding or assisted natural regeneration).

Forest plantations constitute an estimated 4 percent of forest area (forests of introduced species, and in some cases native species, established through planting or seeding), classified either as productive (3 percent of total forest area) or protective (0.8 percent of total forest area).

The vast majority of other wooded land (69 percent) was classified as modified natural, 28 percent as primary and the remaining 3 percent as semi-natural.

Trends

A trend analysis was generated based on the 167 countries providing estimates for all three reporting years,[2] including those reporting no primary forest.

As can be seen in Figure 2.10, the areas of primary forest and modified natural forest are decreasing, while the areas of semi-natural forest and forest plantation are increasing.

About 6 million hectares of primary forest have been lost or modified each year since 1990,[3] and there is no indication that the rate of change is slowing down. This rapid decrease stems not only from deforestation, but also from modification of forests due to selective logging and other human interventions – whereby primary forests move into the class of modified natural forests. The rate of loss of primary forests is stable or slightly decreasing in most subregions, but is increasing in South America and, to a lesser extent, in North America.

Brazil and Indonesia alone account for an annual loss of primary forest of 4.9 million hectares. The data collected do not permit an analysis of how much of this net loss is due to deforestation and how much is owing to areas of forest moving into the modified natural forest class.

A number of countries registered positive change rates in the area of primary forests, including several European countries and Japan (see Table 9 in Annex 3). In most of these cases, countries have been setting aside natural forest areas in which no intervention is to take place. With time, these areas evolve into forests in which there are no clearly visible indications of human activity and ecological processes are not significantly disturbed, which is the definition of primary forests used in FRA 2005. Japan and some of the

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[2] This list of countries excludes the Russian Federation (see comment related to primary forests in footnote 3). Australia did not provide information for all categories for 1990; its primary forest has been assumed to be constant and the remaining forest area not classified as forest plantation has been assumed to be modified natural forest based on information from 2000 and 2005.

[3] This estimated net loss excluded the Russian Federation, in which a large difference in the change rate (from -1.6 million hectares per year in the 1990s to +0.5 million hectares per year in the last five years) is likely due to a change in the methodology used, rather than being a reflection of actual change.

FIGURE 2.9
Forest characteristics 2005
(%)

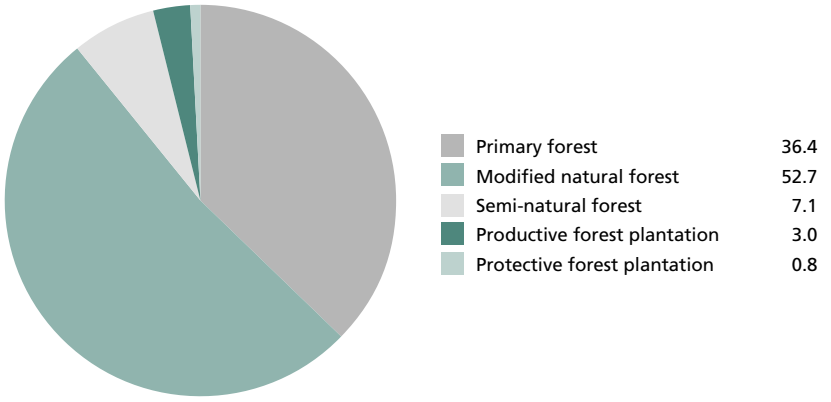
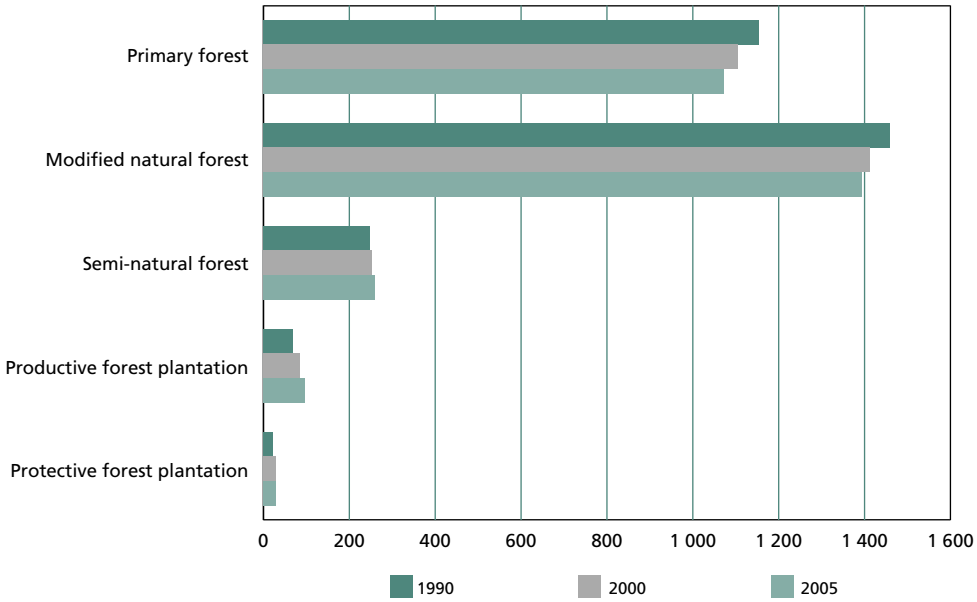


FIGURE 2.10
Global trends in forest characteristics 1990–2005
(million ha)



European countries, for example, classified all natural forests over a certain age or size as primary forests if no interventions had been conducted in the last 25 years.

There has been an increase in the area of forest plantations of about 14 million hectares in the last five years, or about 2.8 million hectares per year, 87 percent of which are in the productive class.

Information availability on the characteristics of other wooded land was insufficient for analysing trends over time.

Forest types and species groups. In addition to the thematic study on planted forests mentioned above, two studies on specific forest types and species groups were undertaken to complement the FRA 2005 main report – one on mangroves (Box 2.2) and another on bamboo (Box 2.3).

The total area of mangroves was estimated at 15.2 million hectares, down from 18.8 million hectares in 1980. An estimated 47 percent of this area was found in five countries: Indonesia, Australia, Brazil, Nigeria and Mexico.

As mentioned earlier, the area of bamboo is difficult to assess, as these species often occur as patches within or outside forests. Nevertheless, preliminary findings based on reports from 30 of the main bamboo-rich countries indicate that total area of bamboo amounts to some 40 million hectares – or 1 percent of the global forest area – and it is increasing.

BOX 2.2

FRA 2005 thematic study on mangroves

Mangroves are salt-tolerant forest ecosystems commonly found along sheltered coastlines, in deltas and along river banks in the tropics and subtropics. These trees and shrubs have developed morphological adaptations to tidal environments, such as aerial roots, salt excretion glands and, in some species, vivipary of seeds.

A large proportion of coastal populations in tropical regions depend on mangroves for their subsistence, either directly through the extraction of wood and non-wood forest products, such as fuelwood, charcoal, timber, food and medicines, or indirectly through the many aquatic and terrestrial species for which these ecosystems provide nutrients and a habitat. Mangroves serve as spawning grounds and nurseries for a variety of fish and shellfish, playing a significant role in the marine food system. When mangrove forests are destroyed, declines in local fish catches often result. These ecosystems also play an important role in preventing and reducing coastal erosion, providing nearby communities with protection against the effects of wind, waves and water current. This was demonstrated during the 2004 tsunami in Asia – in locations in which extensive areas of mangroves existed, coastal villages suffered less damage. Moreover, these unique coastal forests provide other important services: conservation of biological diversity and – by trapping sediment from upland erosion – protection of coral reefs, sea-grass beds and shipping lanes against siltation.

Despite their many important uses and benefits, high population pressure in coastal areas has frequently led to the conversion of mangrove areas to other uses, including fish and shrimp farming, agriculture, salt or rice production and urban development. Mangroves have also been fragmented and degraded due to overexploitation and pollution. Numerous case studies describe mangrove losses over time, but comprehensive information at the global level is scarce. Despite past attempts to estimate total mangrove area, recent reliable information on status and trends at the global level is limited. The past attempts include: FAO and UNEP, 1981a, b and c; Saenger, Hegerl and Davie, 1983; Groombridge, 1992; Clough, 1993; Diop, 1993; Fisher and Spalding, 1993; Lacerda, 1993; Spalding, Blasco and Field, 1997; and Aizpuru, Achard and Blasco, 2000.

The FRA 2005 thematic study on mangroves was coordinated by FAO and cofunded by ITTO. It provides an overview of the current extent of mangroves, their species composition, uses and threats, and changes in the extent of mangroves over time for the 124 countries or areas in which they exist. The study aims to facilitate access to comprehensive, comparable information that may serve as a tool for policy- and decision-makers and mangrove managers worldwide. The initiative builds on FRA 1980 and on information provided for FRA 2000 and 2005, for which countries were asked to provide information on current forest area according to forest types, using their own classification systems. Since mangroves form a distinct and relatively easily defined forest type, most countries with mangroves provided specific information on their extent. An extensive literature search and inputs from national mangrove experts yielded additional information. Where recent national information was lacking, it was updated through interpretation of remote sensing data (an

in-kind contribution from the UNEP World Conservation Monitoring Centre – WCMC). Local authorities and national experts played a key role in the process of gathering and reviewing the extensive country-level information collected. Regression analyses yielded estimates for 1980, 1990, 2000 and 2005 for each country.

About 15.2 million hectares of mangroves currently exist worldwide, down from 18.8 million hectares in 1980, with the largest extent found in Asia, followed by Africa and South America. The area of mangroves present in each country varies from a few hectares to more than 3 million, with close to half the global area found in just five countries: Indonesia, Australia, Brazil, Nigeria and Mexico. Over the last 25 years, 3.6 million hectares of mangroves (or about 20 percent of the total extent found in 1980) have disappeared worldwide. Although alarming, the rate of net loss of mangroves is showing signs of slowing down. From about 185 000 ha lost annually in the 1980s (-1.03 percent per annum), it dropped to some 105 000 ha/year (-0.67 percent) during the 2000–2005 period. This reflects an increased awareness of the value of mangrove ecosystems, which has led, in turn, to the preparation of new legislation, better protection and management and, in some countries, to an expansion of mangrove areas through active planting or natural regeneration.

The detailed findings of the thematic study will consitute an important contribution to the revised *World atlas of mangroves* (www.fao.org/forestry/site/mangrove-atlas). The study report was being completed for release during 2006. Further information on the study and the profiles for the 124 countries or areas in which mangroves occur can be found at www.fao.org/forestry/site/mangrove. The country profiles will also be compiled into five regional reports.

BOX 2.3

FRA 2005 thematic study on bamboo

Bamboo is an integral part of tropical and subtropical forests, and bamboo resources have increasing importance in poverty alleviation and sustainable development of the rural poor. These species continue to play a crucial role in Asia, while their use is rapidly growing in Africa and Latin America. Bamboo is moving out of the craft-industry phase and now provides raw material for preindustrial processing and for industry products (bamboo shoots, construction poles, panelling and flooring products, pulp, etc.), thus gaining significance as both an internationally traded commodity and a tool for livelihood and industrial development.

A first attempt at assessing the extent of bamboo resources at the global level was made by FAO and UNEP as part of FRA 1980, for which 13 countries provided estimates. The FRA 2005 thematic study on bamboo is a joint effort of FAO and the International Network for Bamboo and Rattan (INBAR). The inclusion of bamboo among the seven thematic studies under FRA 2005 seeks to raise awareness of the value, dynamics and importance of the bamboo sector – attracting investment and formulating and redesigning forest policies.

Following the general methodology of the FRA 2005 country reports, the specifically designed bamboo reports included information on the extent and characteristics of bamboo resources, ownership, growing stock, and amount and value of removals. The information provided by 22 country reports was analysed, reviewed and, where needed, complemented by additional information from a literature search and expert consultations. Two workshops were organized to discuss the design of the study and then the preliminary results. Additional information was obtained from the *Production to consumption studies* already carried out by INBAR in various countries. With the integration of existing information

through a systematic data-collection procedure, the thematic study constitutes a focused investigation into the extent of bamboo resources on a global scale.

The quality and quantity of the information varied significantly among regions, with a richer contribution from Asian countries as compared with Africa and Latin America. This was hardly a surprise: it is in the Asian region that bamboo has had the longest tradition of use and where it has a fundamental role today for a significant portion of the population. However, Africa and Latin America are quickly developing greater interest in bamboo resources and their potential, and several country representatives of these regions highlighted the need for more systematic investigation and assessment.

Due to the scattered nature of the data provided and the ongoing analysis, only preliminary results can be offered here. Sixteen countries in Asia reported a total of roughly 25 million hectares of bamboo forest. Major contributors were India (9 million hectares) and China (5 million hectares), followed by Indonesia, Myanmar and Thailand. In this region, bamboo forests constitute approximately 4 percent of the total forest cover, with peaks of over 10 percent for India, Laos and Sri Lanka. Although the information gathered from Africa is still partial, six countries reported a total of approximately 3 million hectares of bamboo forest, with Ethiopia, Kenya and Nigeria showing the largest areas. In Latin America, at least ten countries have significant bamboo resources, although precise assessments have not yet been done. A total of 11 million hectares is considered a realistic estimate for the region, with Brazil, Chile, Colombia, Ecuador and Mexico among the richest in these resources. Information on other characteristics of bamboo forests and the amount and value of removals will be presented in the thematic study, to be released during 2006.

Bamboo is often intermixed with other species or is cultivated outside forests, along village and farm boundaries, which presents a challenge to the study. For this reason, the 'bamboo forest' can have different definitions. In addition, most harvesting and trade occur locally among villages, with no official records. These combined factors explain why current bamboo resource statistics are inconsistent, fragmented and in need of upgrading. Nevertheless, steps to improve the availability of quantitative data have been made by several countries, in recognition of the importance of bamboo to poverty alleviation, forest conservation and economic and environmental development. The main value of this study is thus the development of a systematic methodology for the recording of bamboo forest characteristics and sector data.

GROWING STOCK

Growing stock has formed part of global forest resources assessments since the first report. In addition to providing information on existing wood resources, growing stock estimates constitute the basis for estimation of biomass and carbon stocks for most countries.

Country information on total growing stock and forest area was used to estimate growing stock per hectare as an indicator of how well or poorly stocked the forests are. FRA 2005 has also collected country information on commercial growing stock. Chapter 5 (Productive functions of forest resources) presents results for this indicator, as well as a more detailed discussion of total growing stock.

Information availability

Of the 229 countries and territories covered by FRA 2005, 150 countries, representing 88 percent of the world's forest area, reported on growing stock for 2005. Oceania was the only region for which information was available for only a small portion of forest area (15 percent), given that Australia did not provide information on this variable. With a few exceptions, reporting countries gave information for all three reporting years (see Figure 5.6 in Chapter 5).

Although many countries provided information on growing stock, the quality of the information is variable. A few countries with repeated national forest assessments have very reliable information, but many countries do not have good inventory data to support growing stock estimates and changes in growing stock over time.

Status

In order to obtain consistent global, regional and subregional estimates of total growing stock, growing stock per hectare was estimated for each region/subregion for those countries providing information. These estimates were then multiplied by the total forest area of each region and subregion. Table 5.7 in Chapter 5 shows the status of growing stock in 2005 and its distribution by region and subregion.

Total growing stock is estimated at 434 billion m^3, of which some 30 percent is found in South America.

The five countries with the greatest total growing stock account for almost 261 billion m^3, which corresponds to 60 percent of the global total. Of these, Brazil has the largest growing stock, with 81 billion m^3 or 19 percent of the total.

The global average for growing stock per hectare is 110 m^3/ha. The countries with the highest growing stock per hectare are found in central Europe and in some tropical countries.

Trends

Based on data from the 147 countries that reported growing stock figures for all three reporting years, total growing stock shows a slight decreasing tendency at the global level (see Table 5.9 in Chapter 5). There are some regional tendencies: Africa, Asia and South America show a slight decrease, while Europe and North and Central America show a slight increase.

As regards growing stock per hectare, changes at the global level are not significant. At regional and subregional levels, however, there are more significant changes. For example, Europe, excluding the Russian Federation, shows a net increase of 0.3 percent (or 1.2 m^3 per hectare) annually for the last 15-year period, while South and Southeast Asia show a net decrease of 1.0 percent (or 1.0 m^3 per hectare) annually, mainly due to a decrease in growing stock per hectare in Indonesia.

Changes in total growing stock reflect the combined effects of changes in forest area and in growing stock per hectare. However, for many countries, changes in growing stock reflect only the changes in forest area, because their estimates of growing stock are based on a single figure per hectare determined at one point in time (see Chapter 5). Thus the actual trends may be more pronounced than those in this analysis.

BIOMASS AND CARBON

At a casual glance, the amounts of biomass and carbon seem simply to reflect the extent of forests and their growing stock. A more meaningful understanding emerges in the context of the global carbon cycle, climate change and related international agreements such as the United Nations Framework Convention on Climate Change (UNFCCC). Since half the dry weight of biomass is carbon (IPCC, 2003), the following analysis addresses biomass implicitly. For data related to biomass stock in forest and other wooded land, refer to Table 13 in Annex 3.

Forests, like other ecosystems, are affected by climate change, be it a sea-level rise that threatens coastal forests or changes in temperature and rainfall patterns. In some places, impacts may be negative, while in others they may be positive. However, forests also influence climate and the climate change process. They absorb carbon in wood, leaves and soil and release it into the atmosphere when burned, for example during forest fires or the clearing of forest land.

The Kyoto Protocol entered into force in the same year that this assessment was carried out. The protocol and the UNFCCC oblige all member countries to regularly

assess and report national greenhouse gas emissions, including emissions and removals of carbon reflected as stock changes in forests. To that end, IPCC has created guidelines, methods and default values for all parameters needed to assess carbon stocks and their changes in forests (IPCC, 2003). It has thus furnished all countries with the means of estimating and reporting carbon stocks, greenhouse gas emissions and removals, irrespective of the availability of country-specific data. Striving for synergies and for streamlined country reporting to international organizations, FAO incorporated the IPCC guidelines on assessment of carbon stocks in forests into its guidelines for country reporting for FRA 2005.

Reporting on carbon stocks in forests under the UNFCCC, the Kyoto Protocol and to FAO may overlap, but are not necessarily identical. For FRA 2005, countries reported *carbon stocks* for the years 1990, 2000 and 2005. The UNFCCC mandates reporting *carbon stock changes*. However, in one of its methods, IPCC estimates net emissions of carbon as the difference between periodic carbon stocks.

In a further difference, UNFCCC members report on 'managed forests' only. The convention does not define 'forest' or managed forest. However, IPCC considers managed forests as "all forests under direct human influence" or "forests subject to the process of planning and implementing practices for stewardship and use aimed at fulfilling relevant ecological, economic and social functions" (IPCC, 2003). Given this broad definition, many countries may classify all their forests as managed forests. However, only by assuming both a steady state of biomass in 'unmanaged forests' and identical definitions of 'forest' will *carbon stock changes* be the same under the two reporting systems. Even in this case, estimates of the total *carbon stock* may still differ, depending on whether all forests are included or not in reporting under the UNFCCC.

Quantifying the substantial roles of forests as carbon stores, as sources of carbon emissions and as carbon sinks has become one of the keys to understanding and modifying the global carbon cycle. Global forest resources assessments have the potential to contribute to or substantiate estimates of the magnitude of stocks and flows by scientific bodies such as IPCC. Simultaneously, they complement and facilitate international reporting by countries on greenhouse gas emissions and removals under the UNFCCC.

Information availability

By integrating IPCC guidance into the guidelines for country reporting for FRA 2005, FAO sought to facilitate complete reporting on biomass and carbon pools by all countries. Yet many of the 229 countries and territories had difficulty in providing complete information for all pools of carbon, i.e. above- and below-ground biomass, dead wood, litter and soil carbon to a depth of 30 cm.

With few exceptions, countries that reported growing stock also successfully transformed this data into above- and below-ground biomass and then to carbon stock in forest biomass (Figure 2.11). Many countries based the conversion from growing stock to biomass on the IPCC good practice guidance factors (IPCC, 2003), reflecting a lack of country-specific biomass expansion factors.

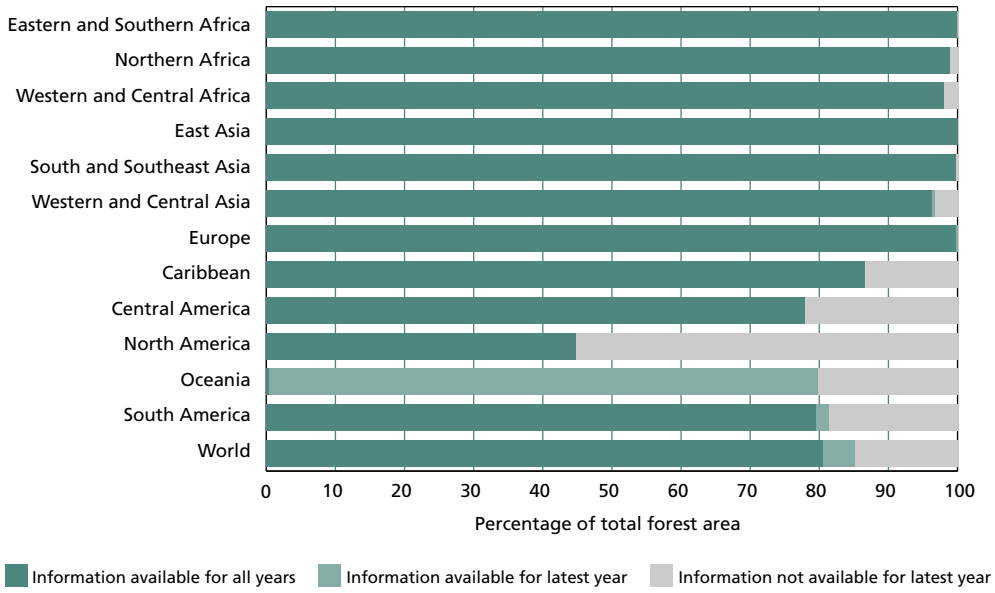
Of the 151 countries that reported on forest biomass:

- 87 have used the IPCC good practice guidance biomass expansion factors exclusively;
- 41 have used the IPCC factors in combination with factors from other sources;
- 13 have used national data – either direct estimates or national expansion factors;
- 5 have used factors/models from FAO and FAO/UNECE publications;
- 5 are based on expert estimates.

Response rates for carbon pools other than forest biomass decreased steeply, to merely 20 percent of the countries, representing 51 percent of the total forest area for soil carbon.

It is clear that many countries do not possess country-specific information on the parameters necessary for calculating all carbon pools. However, perhaps blanks in

FIGURE 2.11
Information availability – carbon stock in forest biomass



the reporting tables also reflect political concerns, institutional and human capacity for reporting, or difficulties with the IPCC guidelines. Response rates for carbon in biomass were high from developing countries in all subregions except the Caribbean, while some large industrialized countries in North America and Oceania did not report biomass and carbon data at all or only incompletely, because they are currently in the process of finalizing their overall carbon inventories.

Overall, this report assesses carbon in all pools based on a fairly representative fraction of over half the global forest area for all components and more than 80 percent of total forest area for carbon in forest biomass.

Although countries were asked to provide information on carbon in forest soils in the top 30 cm, some countries used other threshold values. In these cases, the figures were adjusted to the common threshold of 30 cm.

Status

Carbon stock per hectare. Table 2.8 provides forest-area-weighted average carbon stocks per hectare for biomass, dead wood, litter and soils by region for the year 2005. Biomass and dead wood account for 44 and 6 percent of total forest ecosystem carbon respectively, while soils to a depth of 30 cm and litter contribute approximately 46 and 4 percent respectively.

Carbon stocks in forest biomass reach the highest values per hectare in Central and South America and Western and Central Africa, while East Asia, Northern Africa and Western and Central Asia report the lowest values.

IPCC (2000) estimated an average carbon stock of 86 tonnes per hectare in the vegetation of the world's forests for the mid-1990s. The corresponding carbon in biomass and dead wood in forests reported here amounts to 82 tonnes per hectare for the year 1990 and to 81 tonnes per hectare for the year 2005.

Each cubic metre of growing stock equals different amounts of biomass and carbon in biomass in the regions. Table 2.9 provides average conversion factors compiled from country submissions. Globally, each cubic metre of growing stock equals, on average, 1 tonne of above-ground biomass, 1.3 tonnes of total biomass and 0.7 tonnes of carbon in biomass.

TABLE 2.8
Carbon stock per hectare 2005 *(tonnes/ha)*

Region/subregion	Carbon in living biomass	Carbon in dead wood	Carbon in litter	Carbon in soil	Total carbon
Eastern and Southern Africa	63.5	7.5	2.1		73.0
Northern Africa	26.0	3.3	2.1	33.5	64.9
Western and Central Africa	155.0	9.8	2.1	56.0	222.9
Total Africa	**95.8**	**7.6**	**2.1**	**55.3**	**160.8**
East Asia	37.0	5.0			41.9
South and Southeast Asia	77.0	9.0	2.7	68.4	157.1
Western and Central Asia	39.7	3.6	11.4	41.0	95.8
Total Asia	**57.0**	**6.9**	**2.9**	**66.1**	**132.9**
Total Europe	**43.9**	**14.0**	**6.1**	**112.9**	**176.9**
Caribbean	99.7	8.8	2.2	70.5	181.2
Central America	119.4	14.4	2.1	43.3	179.2
North America	57.8	8.8	15.4	35.8	117.8
Total North and Central America	**60.1**	**9.0**	**14.8**	**36.6**	**120.6**
Total Oceania	**55.0**	**7.4**	**9.5**	**101.2**	**173.1**
Total South America	**110.0**	**9.2**	**4.2**	**71.1**	**194.6**
World	**71.5**	**9.7**	**6.3**	**73.5**	**161.1**

TABLE 2.9
Average factors for estimating biomass and carbon from growing stock

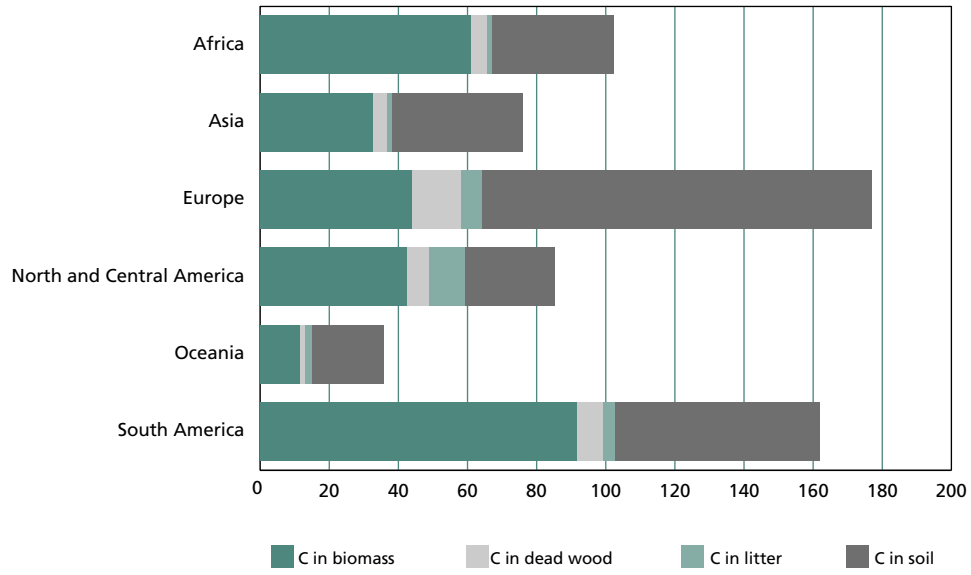
Region/subregion	1 m³ of growing stock represents:		
	Tonnes of above-ground biomass	Tonnes of total biomass	Tonnes of carbon in biomass
Eastern and Southern Africa	2.3	2.9	1.4
Northern Africa	2.1	2.7	1.4
Western and Central Africa	1.3	1.7	0.8
Total Africa	**1.5**	**1.9**	**0.9**
East Asia	0.7	0.9	0.5
South and Southeast Asia	1.4	1.8	0.9
Western and Central Asia	0.9	1.1	0.5
Total Asia	**1.1**	**1.4**	**0.7**
Total Europe	**0.7**	**0.8**	**0.4**
Caribbean	2.0	2.6	1.2
Central America	1.4	1.8	0.9
North America	1.0	1.1	0.5
Total North and Central America	**1.0**	**1.2**	**0.5**
Total Oceania	**1.4**	**2.0**	**1.0**
Total South America	**1.1**	**1.5**	**0.7**
World	**1.0**	**1.3**	**0.7**

Note: soil carbon to 30 cm depth.

Total carbon stock. As a consequence of missing data, it is not possible to sum country data to obtain complete regional or global totals for carbon in any pool. Yet, in the context of climate change, these totals and their changes over the years are beyond mere academic interest. Figure 2.12 shows estimated total carbon stock for all pools by region. The figures were obtained by expanding reported data through the use of subregional estimates of carbon per hectare of forest, multiplied by the total forest area for each subregion.

The country reports indicate that global forest vegetation stores 283 Gt of carbon in its biomass, and an additional 38 Gt in dead wood, for a total of 321 Gt. A prior estimate

FIGURE 2.12
Total carbon stock (C) in forests by region 2005
(Gt)



by IPCC (2000) assumed 359 Gt of carbon in these pools. An assumed amount in FRA 2005 of only 10 tonnes per hectare of carbon in dead wood, on average, probably represents an underestimate and might be one reason for the discrepancy between the IPCC and country reports. Another may be exclusion of the biomass of undergrowth by some countries.

Soils (down to 30 cm) and litter contain 317 Gt of carbon according to country estimates in this assessment. There are large data gaps for major boreal forests with typically large amounts of soil carbon; thus the figures are likely underestimates.

The total carbon content of forest ecosystems for the year 2005 is, therefore, 638 Gt of carbon, which is more than the amount of carbon in the entire atmosphere. Roughly half of total carbon is found in forest biomass and dead wood combined, and half in soils and litter combined.

Trends

From 1990 to 2005, carbon in biomass decreased in Africa, Asia and South America, remained approximately constant in Oceania and increased in Europe and in North and Central America. Not all subregions followed this trend. Thus total biomass carbon stocks increased in East Asia and in Western and Central Asia, and decreased in Central America (Table 2.10). The decrease in overall biomass carbon stocks since 1990 was driven by South and Southeast Asia (33 percent decrease), Western and Central Africa (7 percent) and South America (6 percent).

If an average change of total biomass carbon stocks of at least 0.5 percent per year is defined as significant, then of a total of 146 countries and territories, 42 reported decreases, 55 increases and 49 reported no significant change in total carbon stocks within forest biomass.

In interpreting the reliability and meaning of these results, it is helpful to examine carbon stocks per hectare concurrently. Based on the same significance level, 99 countries reported no substantial change of carbon stock per hectare for the 1990–2005 period, 11 countries reported a decrease and 36 countries an increase.

TABLE 2.10
Trends in carbon stocks in forest biomass 1990–2005

Region/subregion	Carbon in living biomass (Gt)		
	1990	2000	2005
Eastern and Southern Africa	15.9	14.8	14.4
Northern Africa	3.8	3.5	3.4
Western and Central Africa	46.0	43.9	43.1
Total Africa	**65.8**	**62.2**	**60.8**
East Asia	7.2	8.4	9.1
South and Southeast Asia	32.3	25.5	21.8
Western and Central Asia	1.6	1.7	1.7
Total Asia	**41.1**	**35.6**	**32.6**
Total Europe	**42.0**	**43.1**	**43.9**
Caribbean	0.4	0.5	0.6
Central America	3.4	2.9	2.7
North America	37.2	38.5	39.2
Total North and Central America	**41.0**	**41.9**	**42.4**
Total Oceania	**11.6**	**11.4**	**11.4**
Total South America	**97.7**	**94.2**	**91.5**
World	**299.2**	**288.6**	**282.7**

Of the 42 countries communicating significant declines in total carbon stocks in forest biomass, only 17 percent also described lower levels of carbon stocks per hectare. In contrast, 78 percent – overwhelmingly developing countries – presumed virtually identical carbon stocks per hectare at the beginning and end of the 15-year period. In these countries, therefore, a reduction in total carbon stock in forest biomass reflects a net loss of forest area. Of the 20 countries reporting the highest absolute reduction in carbon stock, 15 did not report decreases in carbon stock per hectare. Essentially all the carbon stock reduction, therefore, is due to a net loss of forest area. Of the two countries with the highest decrease in carbon stocks, Brazil and Indonesia, only Indonesia recorded a significantly lower level of carbon per hectare in 2005, indicating that not only the forest area but also the biomass and carbon stock per hectare had decreased.

In contrast, of all countries reporting significant total carbon stock increases (mainly Chile, China, many European countries, India, Japan and the United States), 67 percent also documented substantially higher levels of carbon stock per hectare, indicating a higher likelihood that stocks were actually assessed more than once. For 25 percent of these countries, carbon stocks per hectare remained essentially the same, pointing to an increase in forest area as the main reason for increased total stocks.