Chapter 2

Extent of forest resources

OVERVIEW

The extent of forest resources is the first measure of sustainable forest management. It relates to the overall goal of maintaining adequate forest resources – of various forest types and characteristics, including other wooded land and trees outside forests – to support the social, economic and environmental objectives related to forests and forestry within a country or region. The aim of monitoring the extent and characteristics of forest resources is to understand and reduce unplanned deforestation, restore and rehabilitate degraded forest landscapes, evaluate the important function of carbon sequestration by forests, other wooded lands and trees outside forests, and designate forests for different purposes.

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 2010. 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. The proportion of land area under forests is used as one of the indicators for the Millennium Development Goals (United Nations, 2008), and information on trends in the area of forest is used to assess progress towards the 2010 Biodiversity Target of the CBD, as well as the Global Objectives on Forests contained in the Non-legally Binding Agreement on all Types of Forests. It is also a common indicator in all the ecoregional processes on criteria and indicators of sustainable forest management.

The most commonly quoted statistics from the global forest resources assessments continue to be the global rate of deforestation and the net loss of forest area. However, as was observed in earlier assessments (FAO, 2001 and FAO, 2006b), the significance of forest area as a single indicator of forest development has often been overemphasized, particularly in the public debate, and other aspects of forest resources have featured less prominently. Many other variables 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 the loss of forests due to deforestation and natural disasters, and gains in forest area from planting or natural expansion. On its own, the area of forest does not tell us what kinds of forests we have, how healthy they are, what benefits they might provide or how well they are managed. Hence, the global forest resources assessments have evolved over time and now contain information on a wide variety of aspects related to forests and forestry.

For FRA 2010, information was sought on the current status and changes over time (1990, 2000, 2005 and 2010) of the following six variables related to the extent of forest resources:

- Area of 'forest' and 'other wooded land'. Countries were also encouraged to provide information on 'other land with tree cover'.[3]
- Characteristics of forests according to three classes: primary forests, other naturally regenerated forests and planted forests. For the latter two, countries were also asked to provide data on the area of forest composed of introduced species.

[3] See Annex 2 for definitions.

- Area of selected forest types: mangroves, bamboo and rubber plantations.
- Standing volume of wood, i.e. the total growing stock in forests and other wooded land, and its composition.
- Forest biomass.
- Carbon stock contained in woody biomass, dead wood, litter and forest soils.

In regional and ecoregional criteria and indicator processes, as well as in national reports, more detailed classifications of the forest area are often used, for example, 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 except for the three selected forest types listed above. However, country reports for FRA 2010 contain considerably more detail than is shown in the global tables.

In FRA 2000, an independent remote sensing survey was carried out to supplement country reporting for the pantropical 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 processes of land-use change, including the documentation of different patterns of change in tropical regions. The results have been widely acknowledged and used (e.g. Mayaux *et al.*, 2005). A more ambitious global remote sensing survey is currently being carried out as part of FRA 2010 (see Box 2.3), which will complement the information in this report in terms of forest area changes over time in large biomes, as well as providing more detailed information on land-use change dynamics at regional and global levels.

KEY FINDINGS

Forests cover 31 percent of total land area

The world's total forest area in 2010 is estimated to be just over 4 billion hectares, corresponding to an average of 0.6 ha of forest per capita. However, the area of forest is unevenly distributed. The five most forest-rich countries (the Russian Federation, Brazil, Canada, the United States of America and China) account for more than half of the total forest area (53 percent), while 64 countries with a combined population of 2 billion people have forest on no more than 10 percent of their land area. These include a number of fairly large countries in arid zones, as well as many small island developing states (SIDS) and dependent territories. Ten of these have no forests at all.

The total area of other wooded land is estimated to be at least 1.1 billion hectares, equivalent to 9 percent of the total land area. The total area of other land with tree cover was reported to be 79 million hectares, but is undoubtedly much higher as information availability was limited.

The rate of deforestation shows signs of decreasing, but is still alarmingly high

Around 13 million hectares of forest were converted to other uses – largely agriculture – or lost through natural causes each year in the last decade. This compares with a revised figure of 16 million hectares per year in the 1990s. Both Brazil and Indonesia, which had the highest net loss of forest in the 1990s, have significantly reduced their rate of loss, while in Australia, severe drought and forest fires have exacerbated the loss of forest since 2000.

Afforestation and natural expansion of forests in some countries have significantly reduced the net loss of forest area at the global level

The net change in forest area in the period 2000–2010 is estimated at -5.2 million hectares per year at the global level (an area about the size of Costa Rica). This is down from -8.3 million hectares per year in the period 1990–2000. This substantial reduction is due to both a decrease in the deforestation rate and an increase in the area of new forest established through planting or seeding and the natural expansion of existing forests.

More than 90 percent of the total forest area consists of naturally regenerated forests

Primary forests – forests of native species in which there are no clearly visible signs of past or present human activity – are estimated to occupy 36 percent of the total forest area. Other naturally regenerated forests make up some 57 percent, while planted forests account for an estimated 7 percent, of the total forest area.

The area of mangroves continues to decline, while the area of bamboo and rubber plantations is increasing

The total area of mangroves is estimated at 15.6 million hectares as of 2010, down from 16.1 million hectares in 1990. Nearly half the total mangrove area (47 percent) is found in five countries: Indonesia, Brazil, Nigeria, Australia 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 information from 33 of the main bamboo-rich countries indicate that the total area is about 31.5 million hectares.

Rubber plantations are found in relatively few countries – primarily in Southeast Asia and Africa – and cover an estimated 10 million hectares. While the area of rubber increased rapidly in the 1990s, the rate of increase is now beginning to slow down and is currently decreasing in several countries.

In 2010, the estimated total growing stock in the world's forest amounted to about 527 billion m^3

This corresponds to an average of 131 m^3 per hectare. The highest levels of growing stock per hectare were found in central Europe and some tropical areas. There was a small decline in total growing stock over the period 1990–2010, but it is unlikely that this change is significant in statistical terms.

Forests contain more carbon than the entire atmosphere

The world's forests store more than 650 billion tonnes of carbon, 44 percent in the biomass, 11 percent in dead wood and litter, and 45 percent in the soil. While sustainable management, planting and rehabilitation of forests can conserve or increase forest carbon stocks, deforestation, degradation and poor forest management reduce them. For the world as a whole, carbon stocks in forest biomass decreased by an estimated 0.5 Gt annually during the period 2005–2010. This was mainly because of a reduction in the global forest area and occurred despite an increase in growing stock per hectare in some regions.

KEY CONCLUSIONS

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

FOREST AREA AND FOREST AREA CHANGE

Introduction

Forest area provides the first indication of the relative importance of forests in a country or region. Estimates of the change in forest area over time provide an indication of the demand for land for forestry and other uses. Forest area is relatively easy to measure and has been selected as one of 60 indicators for monitoring progress towards the Millennium Development Goals (Goal 7 – Ensuring environmental sustainability), the 2010 Biodiversity Target and the Global Objectives on Forests.

Data on the status of and trends in forest area are crucial to decisions about forest and land-use policies and resource allocations, but they need to be combined with information on other aspects such as forest health and vitality, and socio-economic and environmental functions and values of forests. These aspects are dealt with in other chapters of this report.

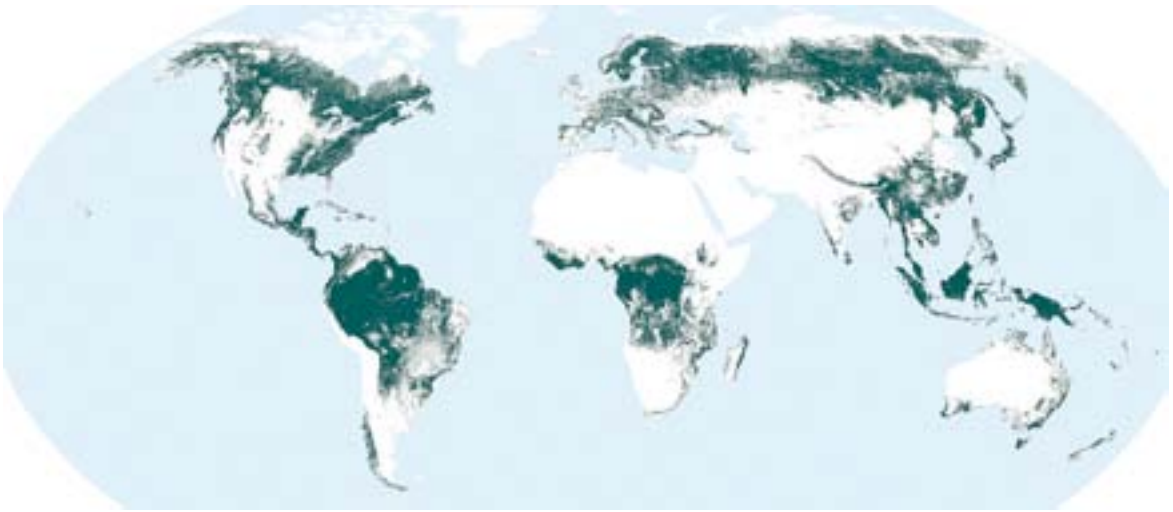
Status

All 233 countries and areas reporting for FRA 2010 provided information on the extent of forests. The total forest area in 2010 was estimated to be 4 billion hectares, or 31 percent of total land area. This corresponds to an average of 0.6 ha per capita. As can be seen from Figure 2.1, the area of forest is unevenly distributed. The five most forest-rich countries (the Russian Federation, Brazil, Canada, the United States of America and China) account for more than half of the total forest area (53 percent), while 64 countries, with a combined population of 2 billion people, have forest on no more than 10 percent of their land area.

The distribution of forests at the subregional level is shown in Table 2.1. Europe (including the Russian Federation) accounts for 25 percent of the world's total forest area, followed by South America (21 percent), and North and Central America (17 percent). Information on the area of forest and other wooded land by country can be found in Table 2 in Annex 3.

At the country level, the Russian Federation alone accounts for 20 percent of the total forest area in the world. Seven countries have more than 100 million hectares of forest each, and the ten most forest-rich countries (the Russian Federation, Brazil, Canada, United States of America, China, Democratic Republic of the Congo, Australia, Indonesia, Sudan and India) account for 67 percent of total forest area (Figure 2.2). The remaining 33 percent is spread among 213 countries and areas, while ten countries

FIGURE 2.1
The world's forests



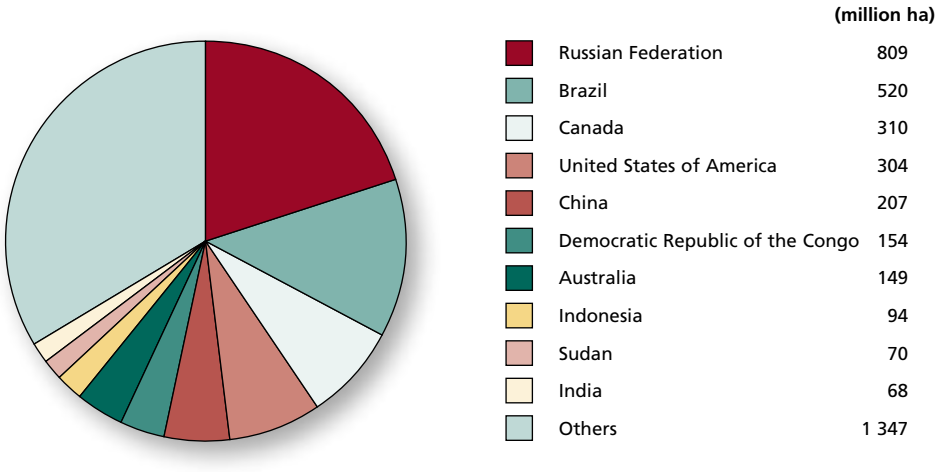
Note: Tree cover derived from MODIS VCF* 250 meter pixels for year 2005.

* Moderate-resolution Imaging Spectroradiometer Vegetation Continous Fields (Hansen *et al*. 2010).

TABLE 2.1
Distribution of forests by region and subregion, 2010

Region/subregion	Forest area	
	1 000 ha	% of total forest area
Eastern and Southern Africa	267 517	7
Northern Africa	78 814	2
Western and Central Africa	328 088	8
Total Africa	**674 419**	**17**
East Asia	254 626	6
South and Southeast Asia	294 373	7
Western and Central Asia	43 513	1
Total Asia	**592 512**	**15**
Russian Federation	809 090	20
Europe excl. Russian Federation	195 911	5
Total Europe	**1 005 001**	**25**
Caribbean	6 933	0
Central America	19 499	0
North America	678 961	17
Total North and Central America	**705 393**	**17**
Total Oceania	**191 384**	**5**
Total South America	**864 351**	**21**
World	**4 033 060**	**100**

FIGURE 2.2
Ten countries with the largest forest area, 2010



and areas (the Falkland Islands (Malvinas*), Gibraltar, the Holy See, Monaco, Nauru, Qatar, Saint Barthélemy, San Marino, Svalbard and Jan Mayen Islands, and Tokelau) reported that they have no areas that qualify as forests using the FRA 2010 definition.

In 50 countries and areas forests cover more than half the total land area (Figure 2.3) and in 12 of these forests occupy more than 75 percent of the total land area. Most of these high forest cover countries 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 shows the top ten). At the regional level, South America has the highest percentage of forest cover, followed by Europe (including the Russian Federation), and North and Central America. Asia has the lowest percentage of forest cover (Table 2.3).

* A dispute exists between the governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Malvinas).

FIGURE 2.3
Forest area as a percentage of total land area by country, 2010

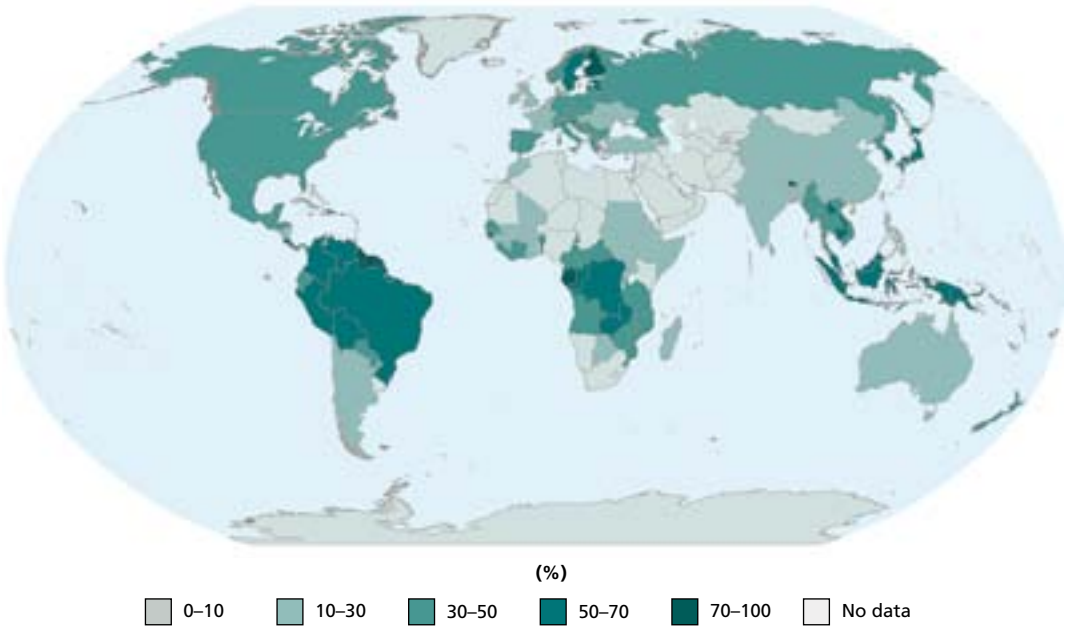


TABLE 2.2
High forest cover countries, 2010

Country/area	Forest area	
	1 000 ha	% of land area
French Guiana	8 082	98
Suriname	14 758	95
Micronesia (Federated States of)	64	92
American Samoa	18	89
Seychelles	41	88
Palau	40	88
Gabon	22 000	85
Pitcairn	4	83
Turks and Caicos Islands	34	80
Solomon Islands	2 213	79

In 64 countries and areas, forests cover no more than 10 percent of the total land area. Often referred to as low forest cover countries (LFCCs), these include many SIDS and dependent territories, as well as 16 larger countries with relatively substantial forest areas (more than 1 million hectares each). Three of these (Chad, the Islamic Republic of Iran and Mongolia) each have more than 10 million hectares of forest.

A total of 161 countries and areas reported that they had some land classified as 'other wooded land' in 2010. However, it was evident from the comments provided in the country reports that the vast majority of the remaining 72 countries and areas also have vegetation that would be categorized as other wooded land using the definitions employed for FRA 2010, but currently have no reliable data on the actual extent.

The total area of other wooded land is estimated to be at least 1.1 billion hectares – equivalent to 9 percent of the total land area. This category suffered from reclassification problems, particularly in dry zones such as those in Australia, Kenya, Mozambique and Sudan, where the distinction between forest and other wooded land is not very clear.

TABLE 2.3
Forest cover by region and subregion, 2010

Region/subregion	Forest area	
	1 000 ha	% of land area
Eastern and Southern Africa	267 517	27
Northern Africa	78 814	8
Western and Central Africa	328 088	32
Total Africa	**674 419**	**23**
East Asia	254 626	22
South and Southeast Asia	294 373	35
Western and Central Asia	43 513	4
Total Asia	**592 512**	**19**
Russian Federation	809 090	49
Europe excl. Russian Federation	195 911	34
Total Europe	**1 005 001**	**45**
Caribbean	6 933	30
Central America	19 499	38
North America	678 961	33
Total North and Central America	**705 393**	**33**
Total Oceania	**191 384**	**23**
Total South America	**864 351**	**49**
World	**4 033 060**	**31**

The ten countries with the largest area of other wooded land (Australia, China, Canada, the Russian Federation, Argentina, Sudan, Ethiopia, Brazil, Botswana and Afghanistan) include six of the ten countries with the largest forest area.

Only 85 countries and areas, together accounting for 38 percent of the global forest area, reported on the current extent of other land with tree cover. This variable 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. parks). The total area of other land with tree cover is at least 79 million hectares. This estimate was limited by a lack of information, and the true extent is undoubtedly much higher.

The category 'other land with tree cover' includes part of the larger category 'trees outside forests'. These trees constitute an important resource in many countries, but one which is difficult to quantify (see Box 2.1).

Trends

All countries and areas provided estimates of forest area for all four reporting years (1990, 2000, 2005 and 2010) with the exception of two dependent territories, Saint Barthélemy and French Polynesia, which did not provide an estimate for 1990. For the purpose of analysis, the 1990 forest area for these two territories was estimated based on a linear extrapolation of the figures provided for 2000 and 2005. However, some countries possessed comprehensive information from only one point in time, while others had a number of estimates over time that were incompatible, making trend analyses difficult.

Deforestation, mainly due to conversion of forests to agricultural land, shows signs of decreasing in several countries but continues at an alarmingly high rate in others. Globally around 13 million hectares of forest were converted to other uses or lost through natural causes each year in the last decade. This compares with a revised figure of 16 million hectares per year in the 1990s. Both Brazil and Indonesia (which had the highest net loss of forest in the 1990s) have significantly reduced their rates of loss, while in Australia, severe drought and forest fires have exacerbated the loss of forest since 2000.

BOX 2.1

Special study on trees outside forests

The latest Expert Consultation on the Global Forest Resources Assessment (Kotka V, June 2006), recommended that a special study on trees outside forests should be carried out as part of FRA 2010. The inception workshop for the study was held in Rome on 9–10 June 2010. During the workshop, 42 experts from 31 institutions in 17 countries defined the objectives, scope and process for developing the study. The report is expected to be prepared by March 2011.

What are trees outside forests?

'Trees outside forests' refers to trees found on lands that are not categorized as 'forest' nor as 'other wooded land'. They include trees (isolated, linear and groups or stands of trees and tree systems) found in rural landscapes (e.g. on farms, in fields, pastures and various forms of horticulture and agroforestry systems, in hedges, along roads and streams) and in urban settings (e.g. on private or public lands and along streets).

Trees have been part of local land use systems for millennia. The products derived from them, such as food, medicine, cooking fuel, animal fodder and construction materials, are critical for the subsistence of hundreds of millions of people. Trees in rural landscapes also have protective functions at farm, landscape and global levels. They maintain soil fertility, allow more efficient water and nutrient resource use, control water erosion, and contribute to microclimate moderation. The ecosystem services they provide at a global level in carbon sequestration and biodiversity conservation are also significant. Trees in human settlements are no less important: in addition to their various products, they provide services, such as microclimate moderation and a 'green' environment conducive to good health.

The challenge: towards integration of trees outside forests in development policies

A recent study (Zomer *et al*., 2009) has shown the importance of trees outside forests at a global scale: almost half of the agricultural land in the world (more than 1 billion hectares) has tree cover of more than 10 percent. However, in most countries trees outside forests are still poorly reported in the official statistics used to support national decision-making and policy. The most basic information – such as location, number, species, spatial organization, biomass, growth and production – is often lacking. Trees outside forests are thus most often ignored in land-use planning and development policies. One major reason for this lack of information is the difficulty and cost of assessing trees outside forests at the national scale.

For this reason the experts gathered during the inception workshop for this study recommended that the report should encourage countries to carry out timely and high quality assessments of trees outside forests at a national level. The report will include:

- a review and comparative analysis of past and current large scale (national and regional) assessments of trees outside forests, including the methodology, results and precision, costs and uses of the assessment (including policy implications);
- a set of methodological and technical options for national-level assessments of trees outside forests, including an operational typology, enabling reporting to international processes such as FRA and IPCC;
- recommendations for improving integration of trees outside forests into the FRA reporting process.

The study is intended to support national agencies responsible for forestry, agriculture, environment, and rural and urban development, by providing adapted tools and methods to assess resources of trees outside forests, as well as their products, uses and economic and environmental functions, at a national level. Through such assessments, local and national decision-makers will be better able to take into account resources of trees outside forests and the services they provide. This support to decision-makers and land-use planners is especially important for developing countries as the contribution of trees outside forests to people's livelihoods and national economies is expected to dramatically increase in the current context of climate change, financial crisis and food insecurity.

At the same time, afforestation and natural expansion of forests in some countries and regions have significantly reduced the net loss of forest area at the global level (see Box 2.2). The total net change in forest area in the period 1990–2000 is estimated at -8.3 million hectares per year, which is equivalent to a loss of 0.20 percent of the remaining forest area each year during this period.

The total net change in forest area in the period 2000–2010 is estimated at -5.2 million hectares per year, an area slightly bigger than the size of Costa Rica, or equivalent to a loss of more than 140 km² of forest per day. The current annual net loss is 37 percent lower than that in the 1990s, and equals a loss of 0.13 percent of the remaining forest area each year during this period. This substantial reduction in the rate of forest loss is a result of both a decrease in the deforestation rate and an increase in the area of new forest established through planting or seeding and natural expansion of existing forests.

The changes in area of forest by region and subregion are shown in Table 2.4 and Figure 2.5. At a regional level, South America suffered the largest net loss of forests between 2000 and 2010 – about 4.0 million hectares per year – followed by Africa, which lost 3.4 million hectares annually.

In South America the net loss of forest decreased in recent years after a peak in the period 2000–2005. The average annual net loss of forest was 4.2 million hectares in the 1990s, 4.4 million hectares in the period 2000–2005, and has now dropped to an estimated 3.6 million hectares per year in the period 2005–2010. The regional figures primarily reflect the trends in Brazil, which accounts for 60 percent of the forest area in this region.

BOX 2.2

Deforestation and net change in forest area

Figure 2.4 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 and natural disasters. 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 too converts to other land.

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

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

For FRA 2010, countries were asked to provide information on their forest area for four points in time. This permits the 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.

FIGURE 2.4

Forest change dynamics

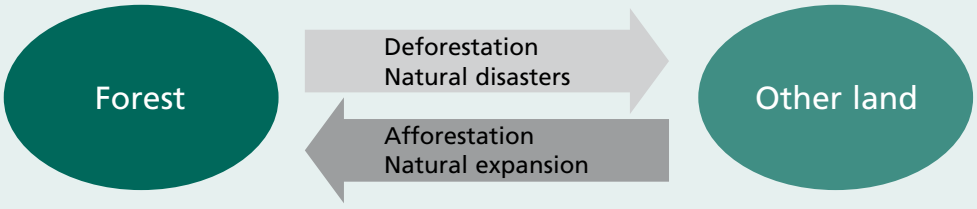
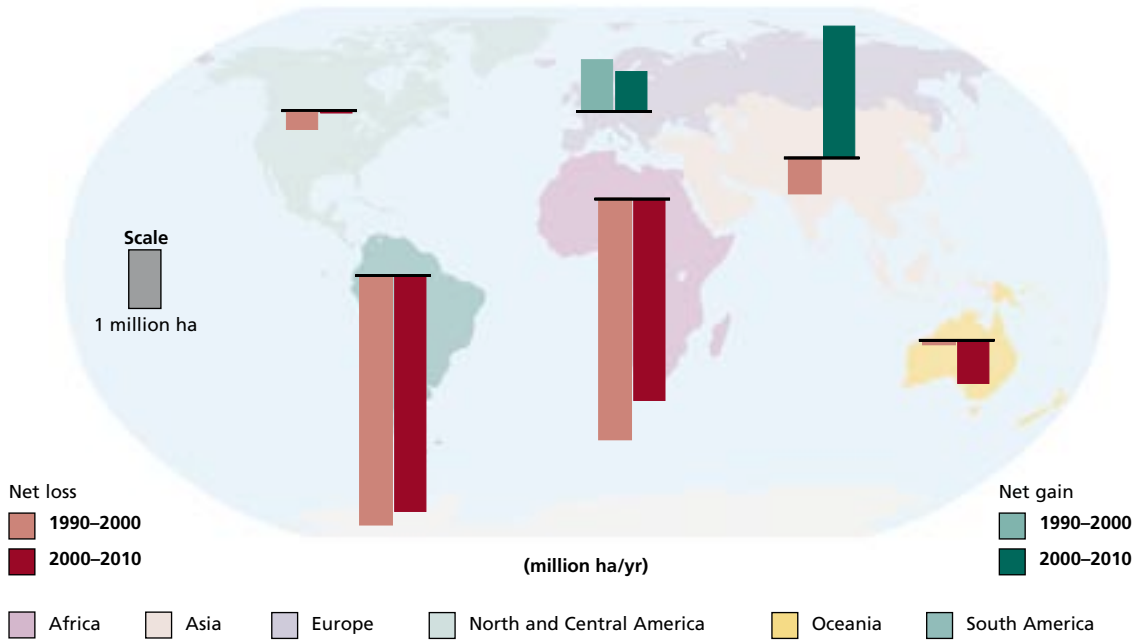


TABLE 2.4
Annual change in forest area by region and subregion, 1990–2010

Region/subregion	1990–2000		2000–2010	
	1 000 ha/yr	%	1 000 ha/yr	%
Eastern and Southern Africa	-1 841	-0.62	-1 839	-0.66
Northern Africa	-590	-0.72	-41	-0.05
Western and Central Africa	-1 637	-0.46	-1 535	-0.46
Total Africa	**-4 067**	**-0.56**	**-3 414**	**-0.49**
East Asia	1 762	0.81	2 781	1.16
South and Southeast Asia	-2 428	-0.77	-677	-0.23
Western and Central Asia	72	0.17	1 31	0.31
Total Asia	**-595**	**-0.10**	**2 235**	**0.39**
Russian Federation	32	n.s.	-18	n.s.
Europe excl. Russian Federation	845	0.46	694	0.36
Total Europe	**877**	**0.09**	**676**	**0.07**
Caribbean	53	0.87	50	0.75
Central America	-374	-1.56	-248	-1.19
North America	32	n.s.	188	0.03
North and Central America	**-289**	**-0.04**	**-10**	**-0.00**
Total Oceania	**-41**	**-0.02**	**-700**	**-0.36**
Total South America	**-4 213**	**-0.45**	**-3 997**	**-0.45**
World	**-8 327**	**-0.20**	**-5 211**	**-0.13**

FIGURE 2.5
Annual change in forest area by region, 1990–2010



While there are signs that the net loss of forests in Africa is decreasing (from 4.1 million hectares per year in the 1990s to 3.4 million hectares per year in the last decade), few countries have reliable data from comparable assessments over time, so the resulting trends should be treated with caution. One of the main reasons for the decreasing net loss overall is a sharp reduction in the net loss reported by Sudan, where

recent efforts to gather new data on actual changes taking place on an annual basis have resulted in much lower figures than those estimated for 1990–2000, which were based on fairly old data. As a result the forest area of Northern Africa is now estimated to be relatively stable, while it is still decreasing in the rest of the continent.

Asia, which saw a net loss of some 0.6 million hectares per year in the 1990s, reported an average net gain of more than 2.2 million hectares per year between 2000 and 2010. This was primarily a result of large-scale afforestation reported by China (where the forest area increased by 2 million hectares per year in the 1990s and by an average of 3 million hectares per year since 2000), but was also due to a reduction in the rate of deforestation in some countries, including Indonesia.

In South and Southeast Asia deforestation continues, but the net loss of 2.4 million hectares per year reported for the 1990s is now down to an estimated 0.7 million hectares annually. Indonesia reported a very significant drop in its rate of net loss in the 2000–2005 period compared with the 1990s and, although the rate increased again in the last five years, it is still less than half that seen during and shortly after the peak of the large-scale transmigration programme in the 1980s and early 1990s. This drop is consistent with other recent findings based on the use of remote sensing (Hansen *et al*., 2009). However, many other countries in South and Southeast Asia continue to report high rates of net loss of forest area. Forest area continues to grow rapidly in East Asia due to the afforestation efforts in China, while in Western and Central Asia the forest area is expanding slightly.

In Europe the forest area expanded over the period 2000 to 2010 by just under 0.7 million hectares per year, in comparison with slightly less than 0.9 million hectares per year in the 1990s. The slightly fluctuating trend seen in the Russian Federation is insignificant in statistical terms given the large forest area, while an apparent increase in forest area in Sweden between 2000 and 2005 is due to a change in assessment methodology.

In North and Central America as a whole, the forest area was estimated to be almost the same in 2010 as in 2000. While the forest area continues to decrease in all countries in Central America except Costa Rica, it is increasing in North America, where the net loss in Mexico is outweighed by a net gain in the United States of America. The Caribbean reports a gain in forest area due to afforestation in Cuba and because forests are expanding onto abandoned agricultural land in some islands.

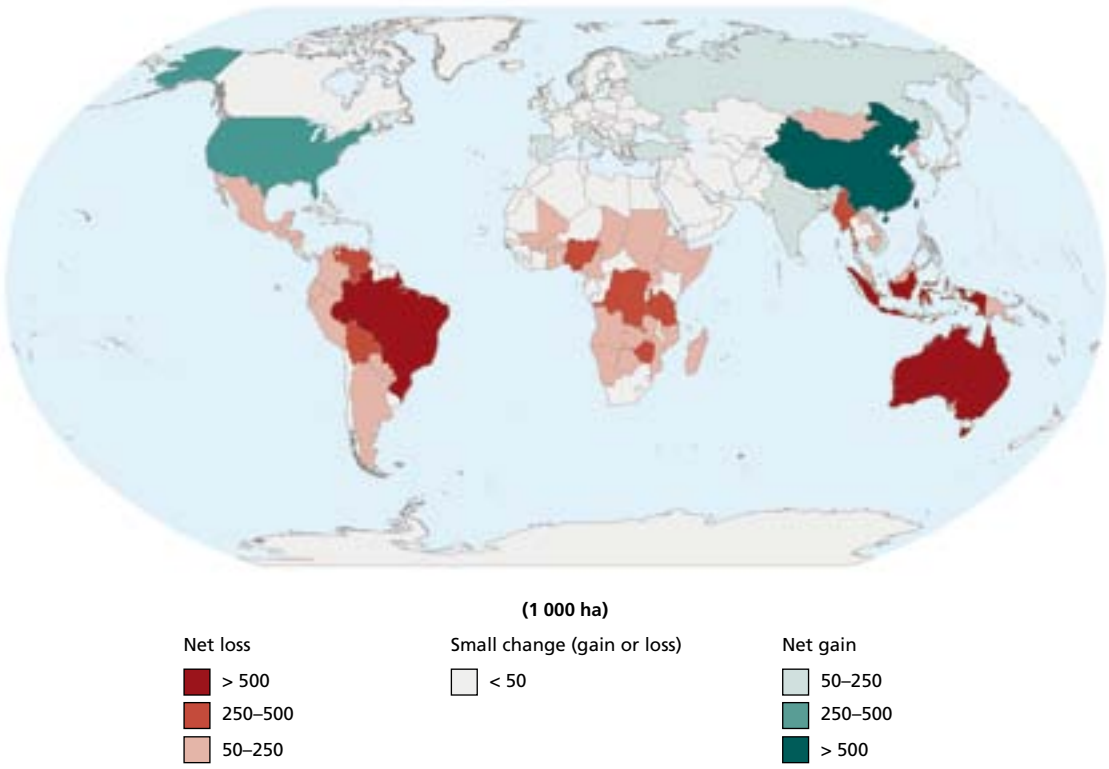
Oceania reported a net loss of about 0.7 million hectares per year over the period 2000–2010. The net loss seems to be increasing and is reported to be more than 1 million hectares per year in the last five years. This is due to large losses of forests in Australia, where severe drought and forest fires have exacerbated the loss of forest since 2000. However, as mentioned in the Country Report from Australia: "It is understood the most likely reason for the detected decline in forest extent is the extended drought across much of Australia since 2000 which has resulted in a double loss: a decline in forest regrowth along with a decline in tree foliage from water stress (the reduced foliage is detected by satellites as a loss of forest extent). It is unclear at this stage whether the climatic-induced reduction is a temporary or permanent loss of forest."[4]

For information on changes in forest area by country, see Table 3 in Annex 3 and Figure 2.6.

In the Caribbean, Europe, North America and Oceania the majority of countries show no significant changes in forest area over the last five years (using +/-0.5 percent annually as the threshold), while in Africa and Central America the majority of countries report a significant negative change rate. However, a large number of

[4] While a temporary loss of forest cover should not count as a loss of forest area using the definitions employed by the FRA process, the assessment method used in Australia did not allow for a differentiation between temporary and permanent loss of forest. As a result, the net loss of forest area reported to FRA 2010 may be overestimated.

FIGURE 2.6
Annual change in forest area by country, 2005–2010



countries in Oceania and the Caribbean reported no change in forest area simply because of a lack of data for more than one point in time.

The ten countries with the largest net loss per year in the period 1990–2000 had a combined net loss of forest area of 7.9 million hectares per year. In the period 2000–2010, this was reduced to 6.0 million hectares per year as a result of reductions in Indonesia, Sudan and Brazil and despite increased net losses in Australia (see Table 2.5).

The ten countries with the largest net gain per year in the period 1990–2000 had a combined net gain of forest area of 3.4 million hectares per year due to afforestation efforts and natural expansion of forests. In the period 2000–2010, this increased to 4.4 million hectares per year due to the implementation of ambitious afforestation programmes in China (Table 2.6).

Twenty-eight countries and areas have an estimated net loss of 1 percent or more of their forest area per year. The five countries with the largest annual net loss for 2000–2010 are: Comoros (-9.3 percent); Togo (-5.1 percent); Nigeria (-3.7 percent); Mauritania (-2.7 percent) and Uganda (-2.6 percent). Nineteen countries have an estimated annual net gain of 1 percent or more due to afforestation and natural expansion of forests. The five countries with the largest estimated annual positive change rates for 2000–2010 are: Iceland (5.0 percent); French Polynesia (4.0 percent); Kuwait (2.6 percent); Rwanda (2.4 percent) and Uruguay (2.1 percent). Most, but not all, of the countries with large change rates measured in percentages are low forest cover countries, in which a relatively small change in absolute values results in a large change in relative or percentage terms.

At the global level, the area of other wooded land decreased by about 3.1 million hectares per year during the decade 1990 to 2000 and by about 1.9 million hectares per

TABLE 2.5
Ten countries with largest annual net loss of forest area, 1990–2010

Country	Annual change 1990–2000		Country	Annual change 2000–2010	
	1 000 ha/yr	%		1 000 ha/yr	%
Brazil	-2 890	-0.51	Brazil	-2 642	-0.49
Indonesia	-1 914	-1.75	Australia	-562	-0.37
Sudan	-589	-0.80	Indonesia	-498	-0.51
Myanmar	-435	-1.17	Nigeria	-410	-3.67
Nigeria	-410	-2.68	United Republic of Tanzania	-403	-1.13
United Republic of Tanzania	-403	-1.02	Zimbabwe	-327	-1.88
Mexico	-354	-0.52	Democratic Republic of the Congo	-311	-0.20
Zimbabwe	-327	-1.58	Myanmar	-310	-0.93
Democratic Republic of the Congo	-311	-0.20	Bolivia (Plurinational State of)	-290	-0.49
Argentina	-293	-0.88	Venezuela (Bolivarian Republic of)	-288	-0.60
Total	**-7 926**	**-0.71**	**Total**	**-6 040**	**-0.53**

TABLE 2.6
Ten countries with largest annual net gain in forest area, 1990–2010

Country	Annual change 1990–2000		Country	Annual change 2000–2010	
	1 000 ha/yr	%		1 000 ha/yr	%
China	1 986	1.20	China	2 986	1.57
United States of America	386	0.13	United States of America	383	0.13
Spain	317	2.09	India	304	0.46
Viet Nam	236	2.28	Viet Nam	207	1.64
India	145	0.22	Turkey	119	1.11
France	82	0.55	Spain	119	0.68
Italy	78	0.98	Sweden	81	0.29
Chile	57	0.37	Italy	78	0.90
Finland	57	0.26	Norway	76	0.79
Philippines	55	0.80	France	60	0.38
Total	**3 399**	**0.55**	**Total**	**4 414**	**0.67**

year in the last decade (2000–2010). This finding should be treated with caution, however, because many countries still 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 four reporting years. The data reported for FRA 2010 indicate that the area of other wooded land is more or less constant in North and Central America, and Oceania. However, the latter is constrained by a lack of consistent trend data for Australia. In Europe it decreased in the period 1990–2000, but remained almost constant in the period 2000–2010. The area of other wooded land decreased in both periods in Africa, Asia and South America.

Data for other land with tree cover were very sparse. Based on the information provided by the 74 countries that provided data for all four reporting years, the area of other land with tree cover has been expanding by an average of slightly more than half a million hectares annually in the last 20 years.

Comparison with FRA 2005

The global forest area reported for FRA 2010 is larger than that reported for FRA 2005 for all reporting years (see Table 2.7). The difference is approximately 109 million hectares

(or 2.8 percent) for the estimates for 2005. This is mainly because Brazil reported an additional 53 million hectares of forest as a result of the use of higher resolution remote sensing imagery and both the Democratic Republic of the Congo and Mozambique reported more than 20 million hectares of additional forest – some of which was no doubt due to a reclassification of land earlier reported as other wooded land (see below). Indonesia reported an additional 9 million hectares for 2005 because the earlier estimate was forecasted based on data from 2000 and the annual deforestation rate for the 1990s, while the new estimate utilized updated figures from 2003 and 2006, which show that the deforestation rate had declined considerably, especially in the period 2000–2005. Australia, on the other hand, reported 9 million hectares less for 2005 than reported in the last global assessment. Again, this is due to new information on the actual forest area (from 2008) and revised annual change rates.

As in FRA 2005, data on deforestation rates were not directly compiled for FRA 2010 because few countries have this information. In FRA 2005 the global deforestation rate was estimated from net changes in forest area. Additional information on afforestation and natural expansion of forest for the past 20 years collected for FRA 2010 has now also made it possible to take into account deforestation and loss from natural causes within those countries that have had an overall net gain in forest area – including four of the five countries with the largest forest area in the world. As a result, the revised estimate of the global rate of deforestation and loss from natural causes for 1990–2000 (close to 16 million hectares per year) is higher, but more accurate, than was estimated in FRA 2005 (13 million hectares). While the deforestation rate for the tropical countries for the 1990s did not change significantly as a result of this additional information, the inclusion of countries in the temperate and boreal zone made a significant difference.

For FRA 2010, the global area of other wooded land in 2005 is 216 million hectares lower than that reported for the same year for FRA 2005, despite the fact that figures are now available for Afghanistan, Brazil, Indonesia and the United States of America, adding some 113 million hectares (for 2005). The reason is a substantial downward revision of the estimates of other wooded land in Australia (down 286 million hectares when comparing the new 2010 figure with the old 2005 figure), Democratic Republic of the Congo (down 72 million hectares), Saudi Arabia (down 33 million hectares), Mozambique (down 26 million hectares), Kenya and Mali (both down 6 million hectares). This is only partially outweighed by the area in the additional countries and upward revisions in China (up 17 million hectares), Myanmar and the United Republic of Tanzania (both up 9 million hectares), the Philippines and Colombia (both up 5 million hectares).

TABLE 2.7
Comparison of forest area estimates in FRA 2010 and FRA 2005

Region	Forest area (1 000 ha)								
	FRA 2010			FRA 2005			Differences FRA 2010–FRA 2005		
	1990	2000	2005	1990	2000	2005	1990	2000	2005
Africa	749 238	708 564	691 468	699 361	655 613	635 412	49 877	52 951	56 056
Asia	576 110	570 164	584 048	574 487	566 562	571 577	1 623	3 602	12 471
Europe	989 471	998 239	1 001 150	989 320	998 091	1 001 394	151	148	-244
North and Central America	708 383	705 497	705 296	710 790	707 514	705 849	-2 407	-2 017	-553
Oceania	198 743	198 381	196 745	212 514	208 034	206 254	-13 771	-9 653	-9 509
South America	946 454	904 322	882 258	890 818	852 796	831 540	55 636	51 526	50 718
World	**4 168 398**	**4 085 168**	**4 060 964**	**4 077 291**	**3 988 610**	**3 952 025**	**91 107**	**96 558**	**108 939**

Conclusions

Considerable progress has been made towards reversing the overall trend of forest area loss in recent years. However, most of the net loss of forest still happens in countries in the tropical region while most of the net gain takes place in the temperate and boreal zone and in some emerging economies such as India and Viet Nam.

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. However, the significance of forest area as a single indicator of forest development has often been overemphasized, particularly in the public debate. On its own, the area of forest does not tell us what kinds of forests we have, how healthy they are or what benefits they might provide. 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.

Information on the different components of net change in forest area is still weak in many countries. To obtain additional and more consistent information on deforestation, afforestation and natural expansion of forests, at regional and biome levels for the period 1990–2005, FAO is collaborating with countries and key partner organizations to undertake a global remote sensing survey based on a systematic sampling of some 13 500 sites around the globe. Results are expected at the end of 2011 (see Box 2.3).

FOREST CHARACTERISTICS

Introduction

For FRA 2010 countries were asked to provide information on forest characteristics, in order to determine the kinds of forest that exist in terms of their 'naturalness'. There is a continuum from primary forests with no – or no visible – indications of past or present human activity to intensively managed planted forests of introduced species, primarily managed for a single product, often on a relatively short rotation, and frequently consisting of only one species – in some cases a single clone. Between these two extremes lies a wide range of forests, and there are no clear cut-off points between classes along the continuum.

In an attempt to describe this range, countries were asked to characterize their forests according to three classes for FRA 2010: primary forests, other naturally regenerated forests and planted forests, and to include information on the proportion of the forest area composed primarily of introduced species.

This section provides an overview of the status and trends related to these forest characteristics. More detailed information on primary forests can be found in Chapter 3 (Biological Diversity), while further analysis of planted forests is provided in Chapter 5 (Productive Functions of Forests).

Status

Of the 233 countries and areas reporting for FRA 2010, 200 reported on the characteristics of their forests. Their combined forest area was estimated at 3.8 billion hectares – equivalent to 94 percent of the total forest area of the world. Although a large number of countries reported on the characteristics of their forests, many countries either did not collect information directly or used a different national classification system. Proxy values have often been used, which makes a detailed analysis of status and trends difficult. Several countries had, for example, no information on the area of primary forests, so they 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 2010. Thus it may not be possible to directly compare figures for different countries, because of differences in interpretation of the classification systems.

BOX 2.3

The global forest remote sensing survey – better global data on changes in forest extent

Why FAO is carrying out a remote sensing survey of the world's forests

FAO has led remote sensing studies focused on tropical forests for previous FRA reports for 1980, 1990 and 2000. This new study, carried out as part of FRA 2010, will be more comprehensive with satellite images collected globally and aims to substantially improve our knowledge of changes in tree cover and forest land use over time. The increasing importance of climate change is also driving the push for better information because forest and related land use changes are estimated to be responsible for approximately 17 percent of human induced carbon emissions (IPCC, 2007). Satellite data enable consistent information to be collected globally, which can be analysed in the same way for different points in time to derive better estimates of change. Remote sensing does not replace the need for good field data, but combining both provides better results than either method alone.

The key outcomes of the FRA 2010 Remote Sensing Survey will be:

- improved knowledge on land cover and land use changes related to forests, especially deforestation, afforestation and natural expansion of forests;
- information on the rate of change between 1990 and 2005 at global, biome and regional levels;
- a global framework and method for monitoring forest change;
- easy access to satellite imagery through an internet-based data portal;
- enhanced capacity in many countries for monitoring, assessing and reporting on forest area and forest area change.

A scientific sampling design

The survey uses a sampling grid design with imagery taken at each longitude and latitude intersection (approximately 100 kilometres apart), reduced to two degree spacing above 60 degrees North. See Figure 2.7. There are about 13 500 samples, of which about 9 000 are outside deserts and permanent ice (Antarctica is excluded). Each sample site is 10 km by 10 km, giving a total sampling area equivalent to about 1 percent of the Earth's land surface. This grid is compatible with that used for many national forest assessments including those supported by FAO.

FIGURE 2.7
The systematic sampling grid

Easy access to tools and satellite images

FAO and its partner organizations have made pre-processed imagery for the 13 689 sample areas easily available through the internet. (http://www.fao.org/forestry/fra/remotesensing/portal).

Access to free remote sensing data and specialized software will particularly benefit developing countries with limited forest monitoring data or capacity. Authorized national experts can log in and download draft labelled polygons for checking and then upload the validated data.

Improved globally consistent estimates of forest extent and change over time

For each sample, three Landsat images – from around 1990, 2000 and 2005 – have been extracted by the South Dakota State University and further processed by FAO or the European Commission Joint Research Centre (JRC) to a consistent standard using an automated image classification process. Draft land cover labels are then prepared and the changes in land cover over time are highlighted. National experts validate the preliminary results and then help undertake the transformation from land cover classes to land use classes (Figure 2.8).

Strong technical partnerships and engagement with countries

The project combines the technical forest and land cover experience in FAO in partnership with external agencies with funding support from the European Commission and technical expertise from their Joint Research Centre. The results from this work will be reviewed and validated by national experts in about 150 countries. This input makes the results some of the most detailed and widely checked global statistics on forest cover change from satellite data.

South Dakota State University has produced new global tree cover maps using medium resolution (250m) data which are major improvements on the previous 1 km map from FRA 2000. Scientists at Friedrich-Schiller University are testing radar data to 'see' through clouds and develop techniques to overcome some gaps in optical satellite data.

The results of the survey are planned for release in late 2011. Further information is available at: www.fao.org/forestry/fra/remotesensingsurvey/en.

FIGURE 2.8
Example of steps used in processing Landsat data to classified land cover map and resulting land cover change, 1990–2000

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

More than one-third (36 percent) of the total forest area was 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. More than half of all forests (57 percent) are naturally regenerated and show clearly visible indications of human activity. Seven percent were classified as forest established through planting or seeding (see Figure 2.9).

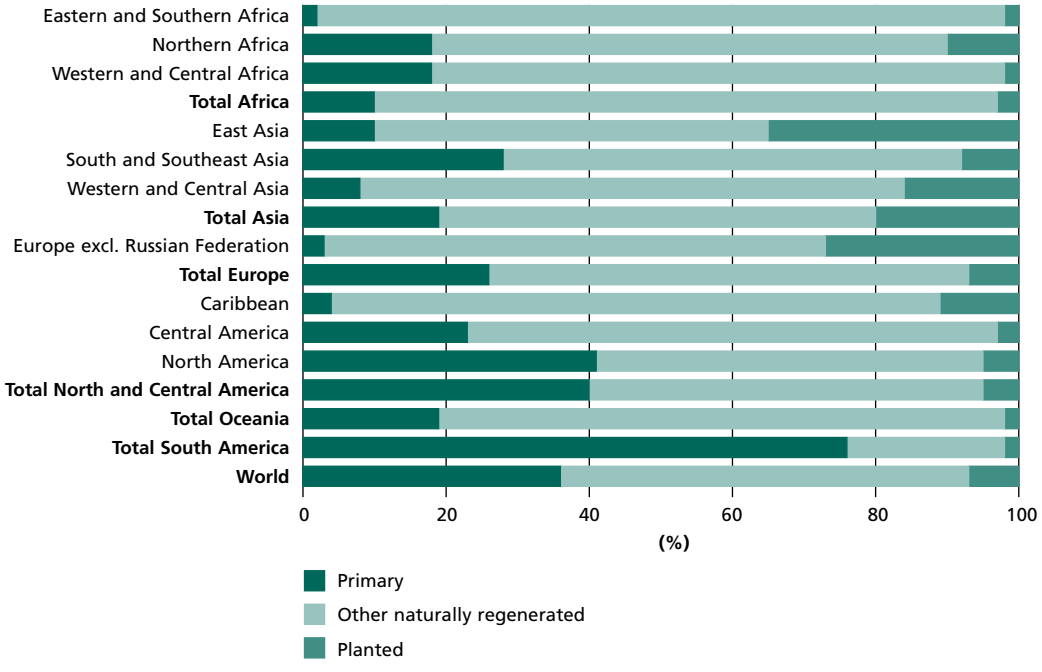
There is great variation in the distribution of primary forests, with limited areas reported from some of the countries of the Caribbean, Europe (excluding the Russian Federation) and the arid zones of Eastern and Southern Africa, Northern Africa, and Western and Central Asia. The largest expanse of primary forest is found in South America (the Amazon). Countries in Central Africa, North and Central America and the Russian Federation have also classified a relatively high proportion of their forests as primary (Table 7 in Annex 3).

East Asia, Europe and North America reported the greatest area of planted forests, together accounting for about 75 percent of the global planted forest area. In East Asia planted forests make up 35 percent of the total forest area, and most are found in China. Africa, the Caribbean, Central America and Oceania all reported relatively small areas of planted forests (Table 5.3).

A total of 83 countries (accounting for 45 percent of the total forest area) reported on the proportion of other naturally regenerated forests composed of introduced species, while 117 countries (67 percent of total forest area) reported on the proportion of introduced species in planted forests.

These countries reported a total area of close to 9 million hectares of naturally regenerated forests composed primarily of introduced species (i.e. naturalized tree

FIGURE 2.9
Forest characteristics by region and subregion, 2010



species) and 52 million hectares of planted forests consisting of introduced species. Together, these introduced species account for about 1.5 percent of the global forest area. Information was too limited to report on trends in introduced species in other naturally regenerated forests. A more detailed analysis of the use of introduced species in planted forests can be found in Chapter 5.

Trends

The trend analysis was based on data from the 183 countries[5] that provided estimates for all four reporting years. Together they account for only 67 percent of the global forest area, so the figures should be treated with caution.

As can be seen in Figure 2.10, the areas of primary forest and other naturally regenerated forests are decreasing, while the area of planted forests is increasing. The area of primary forest has decreased by more than 40 million hectares since 2000. This decrease, 0.4 percent per annum over a ten-year period is largely due to reclassification of primary forest to 'other naturally regenerated forest' because of selective logging and other human interventions during this period.

South America accounted for the largest proportion of the loss of primary forest, followed by Africa and Asia. Brazil alone accounted for an annual loss of primary forest of 2.5 million hectares. The data collected do not permit an analysis of exactly how much of this loss is due to deforestation and how much is a result of areas of forest being moved into the class of other naturally regenerated forests.

The rate of loss of primary forest is stable or decreasing in all regions except Oceania, where it is increasing (primarily as a result of a higher reported loss from Papua New Guinea for the period 2005–2010); and in Europe, and North and Central America which registered a net gain (Refer to Chapter 3 for details).

Between 2000 and 2010, the global area of planted forest increased by about 5 million hectares per year. Most of this was established through afforestation, i.e. planting of areas not forested in recent times, particularly in China.

Conclusions

People have modified the characteristics and species composition of forests for thousands of years to suit their needs. As a result, close to two-thirds of the world's forests show clear signs of past interventions of humans.

While 36 percent of forests are classified as primary, the area is decreasing by some 4 million hectares annually. However, some countries are setting aside parts of their natural forests in which no intervention should take place. With time, these areas evolve into forests that meet the definition of primary as used in the FRA process.

The area of planted forests is increasing and is likely to meet a larger proportion of the demand for wood in the future, thus alleviating the pressure on primary and other naturally regenerated forests.

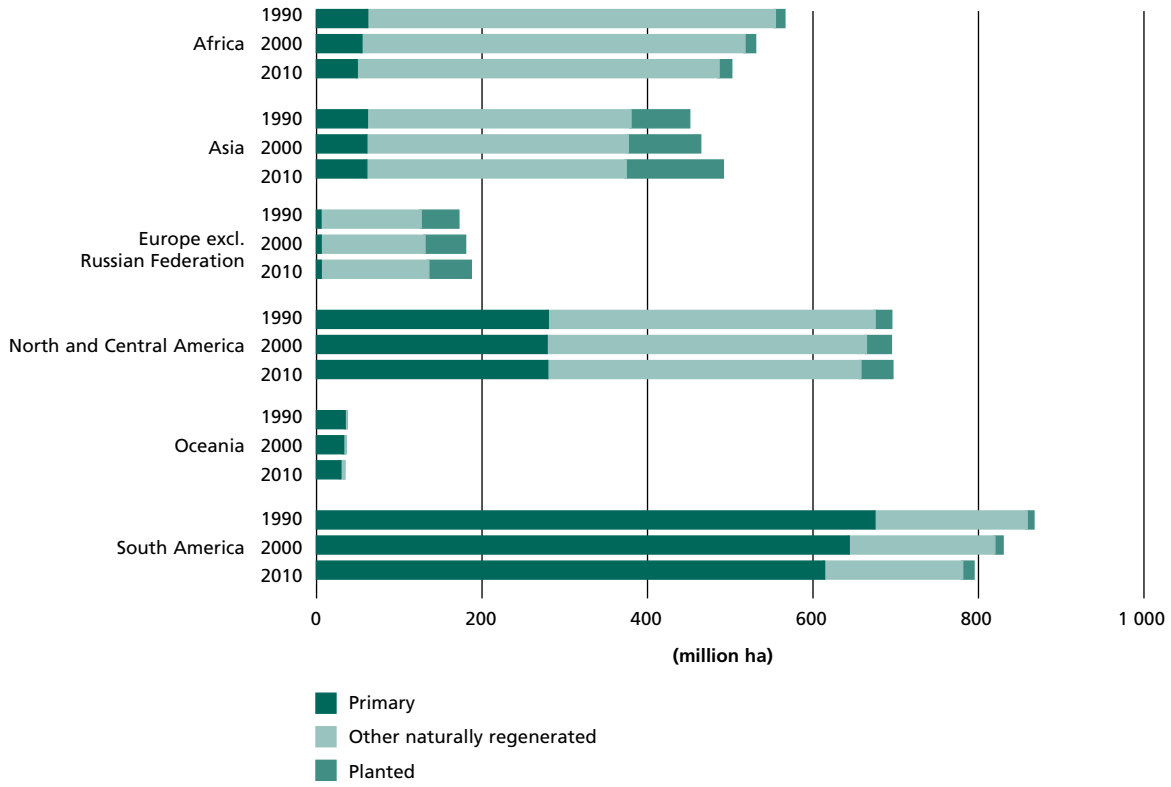
SELECTED FOREST TYPES AND SPECIES GROUPS

Introduction

Countries frequently classify their forest area 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, countries were asked to report separately on the areas of mangroves, bamboo and rubber plantations for FRA 2010 as these species groups are well defined and frequently used in countries where they exist. This allows for an analysis of trends in forest area excluding bamboo and rubber

[5] Excluding the Russian Federation where an irregular trend in primary forest is the result of a change in the classification system introduced in 1995.

FIGURE 2.10
Trends in forest characteristics by region and subregion, 1990–2010



plantations, which are not defined as forest in all countries, but are included as forests in the FRA process.

Mangroves

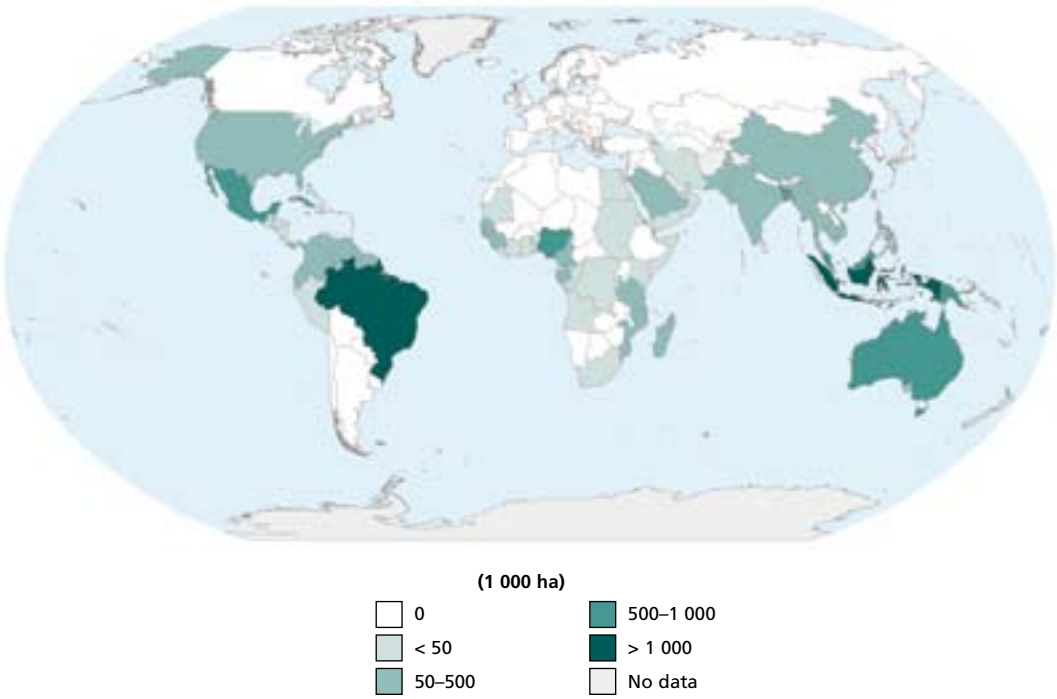
Mangroves are commonly found along sheltered coastlines in the tropics and subtropics where they fulfil important socio-economic and environmental functions. These include the provision of a large variety of wood and NWFPs; coastal protection against the effects of wind, waves and water currents; conservation of biological diversity; protection of coral reefs, seagrass beds and shipping lanes against siltation; and provision of spawning grounds and nutrients for a variety of fish and shellfish, including many commercial species. High population pressure in coastal areas has, however, led to the conversion of many mangrove areas to other uses including infrastructure, aquaculture, rice and salt production (FAO, 2007e).

Status

A total of 212 countries reported on this variable, of which 100 countries reported that they had no mangroves and 112 reported that they had some areas classified as mangroves[6] (see Figure 2.11). This is fewer than the 124 countries and areas with mangroves included in the FRA 2005 Thematic Study on Mangroves (FAO, 2007e), but apart from the Dominican Republic the missing countries and areas all have less than 1 000 ha of mangroves each.

[6] Brazil only reported an estimate for 2000 and Palau only for 1990. Due to a lack of other information, these figures have been used for all four reporting years in this analysis.

FIGURE 2.11
Area of mangroves by country, 2010



Together, the 112 countries and areas reported a total area of mangroves of 15.6 million hectares. The five countries with the largest areas of mangroves (Indonesia, Brazil, Nigeria, Australia and Mexico) together account for some 47 percent of the world total.

Together with the International Society for Mangrove Ecosystems, ITTO, UNEP-WCMC, UNESCO – Man and Biosphere, the United Nations University – Institute for Water Environment and Health and The Nature Conservancy, FAO has recently published a World Atlas of Mangroves containing detailed maps and descriptions of the mangroves in all countries and areas where they are known to exist, see www.fao.org/forestry/mangroves/atlas for details.

Trends

Information for 1990 was missing for eight countries (Australia, China, Cuba, Guadeloupe, the Philippines, Puerto Rico, Saint Kitts and Nevis, and Sudan), and two countries (Nicaragua and the Democratic Republic of the Congo) did not present information for 1990 and 2000. For these countries, the 2000 and 2005 figures respectively were used for this analysis. Given the overall negative trend in mangrove area, this is likely to overestimate the area of mangroves in 1990 and underestimate the loss over time.

The results indicate that the global area of mangroves has decreased from around 16.1 million hectares in 1990 to 15.6 million hectares in 2010[7] (Table 2.8). However, there are indications that there may have been a change in assessment methodologies over time in some countries, which means that the estimates from different years are not completely compatible. Indonesia, for instance, reported a significant increase in

[7] In comparison, FAO (2007e) contained information from 124 countries and areas and estimated the total mangrove area to be 16.9, 15.7 and 15.2 million hectares respectively in 1990, 2000 and 2005.

TABLE 2.8
Trends in area of mangroves by region and subregion, 1990–2010

Region/subregion	Area of mangroves (1 000 ha)			
	1990	2000	2005	2010
Eastern and Southern Africa	991	923	892	861
Northern Africa	4	4	3	3
Western and Central Africa	2 419	2 252	2 207	2 163
Total Africa	**3 414**	**3 178**	**3 102**	**3 027**
East Asia	83	83	83	83
South and Southeast Asia	5 926	6 361	6 200	6 022
Western and Central Asia	187	183	183	183
Total Asia	**6 196**	**6 627**	**6 466**	**6 288**
Total Europe	**0**	**0**	**0**	**0**
Caribbean	763	762	808	857
Central America	481	454	448	443
North America	1 172	1 094	1 086	1 086
Total North and Central America	**2 416**	**2 310**	**2 342**	**2 387**
Total Oceania	**1 860**	**1 841**	**1 537**	**1 759**
Total South America	**2 225**	**2 187**	**2 175**	**2 161**
World	**16 110**	**16 143**	**15 621**	**15 622**

the area of mangroves between 1990 and 2000. Australia reported a similar increase during the period 2005 to 2010 after an even bigger decrease from 2000 to 2005. The reported figures therefore warrant further analysis and the results above should be treated with caution.

The five countries with the largest net loss of mangrove area during the period 2000–2010 were Indonesia, Australia, Myanmar, Madagascar and Mozambique.

Bamboo

Bamboo is a major NWFP and wood substitute. It is found in all regions of the world, both as a component of natural forests and, increasingly, in plantations. Used for housing, crafts, pulp, paper, panels, boards, veneer, flooring, roofing, fabrics, oil, gas and charcoal, it also provides a healthy vegetable (the bamboo shoot). Bamboo industries are now thriving in Asia and are quickly spreading across the continents to Africa and America (FAO, 2007f).

Status

While 131 countries and areas, representing 60 percent of the world's forests, responded to this question, 110 of them reported that they had no bamboo. Only 21 countries reported that they had bamboo resources[8]. This list includes eight countries and areas (Cuba, El Salvador, Jamaica, Martinique, Mauritius, Senegal, Sudan, and Trinidad and Tobago) that were not included in the FRA 2005 Thematic Study on Bamboo (FAO, 2007f). Conversely, 11 countries that were included in the FRA 2005 Study did not report on bamboo for FRA 2010 (Brazil, Ecuador, Lao People's Democratic Republic, Malaysia, Nigeria, Pakistan, Papua New Guinea, Peru, Thailand, Uganda and United Republic of Tanzania). One country (Chile) reported zero for FRA 2010 but some 900 ha for the FRA 2005 Study.

Together, the 21 countries that did report accounted for a total area of 16.7 million hectares. To this should be added an estimated 14.8 million hectares from the 12 missing

[8] Indonesia only reported an estimate for 2000. Due to a lack of other information, this figure was used for 2010 for this analysis.

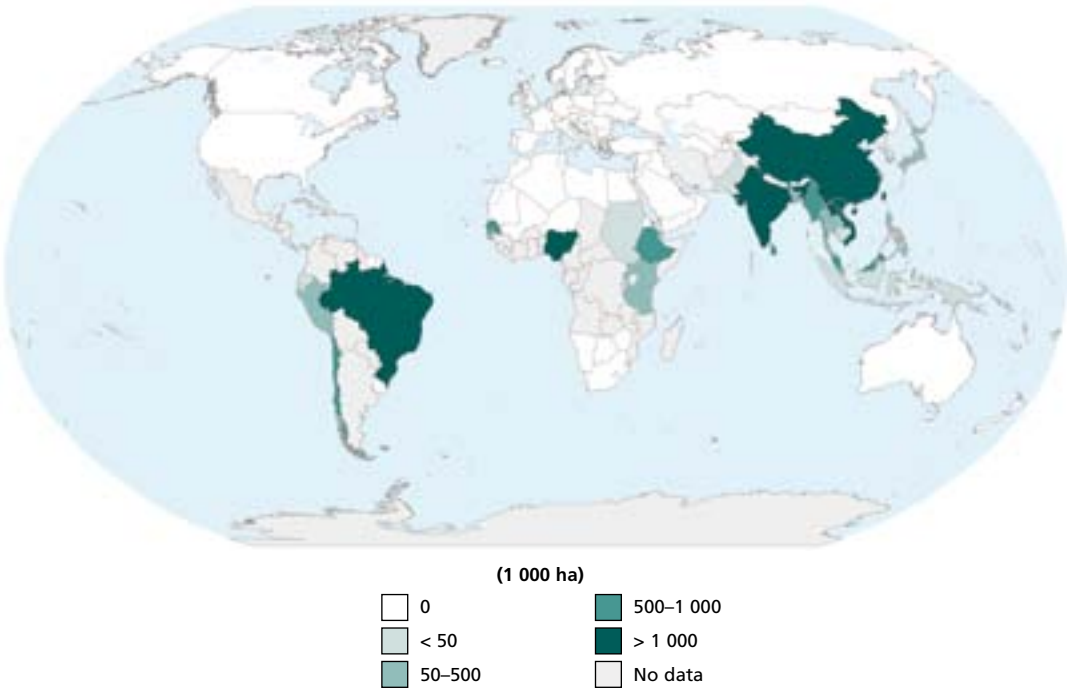
countries (based on information in FAO, 2007f), taking the total to some 31.5 million hectares globally (see Table 2.9 and Figure 2.12). This is lower than the global figure reported in FAO (2007f) (36.8 million hectares) despite the addition of the eight new countries, and the fact that Sir Lanka has revised its previous estimate upwards by more

TABLE 2.9
Trends in area of bamboo by country and region, 1990–2010

Country/region	Area of bamboo (1 000 ha)			
	1990	2000	2005	2010
Ethiopia**	1 000	1 000	1 000	1 000
Kenya	150	150	150	150
Mauritius	n.s.	n.s.	n.s.	n.s.
Nigeria*	1 590	1 590	1 590	1 590
Senegal	723	691	675	661
Sudan**	30	30	30	31
Uganda*	67	67	67	67
United Republic of Tanzania*	128	128	128	128
Total Africa	**3 688**	**3 656**	**3 640**	**3 627**
Bangladesh	90	86	83	186
Cambodia	31	31	36	37
China	3 856	4 869	5 426	5 712
India	5 116	5 232	5 418	5 476
Indonesia**	1	1	1	1
Japan	149	153	155	156
Lao People's Democratic Republic*	1 612	1 612	1 612	1 612
Malaysia*	422	592	677	677
Myanmar	963	895	859	859
Pakistan*	9	14	20	20
Philippines	127	156	172	188
Republic of Korea	8	6	7	8
Sri Lanka	1 221	989	742	742
Thailand*	261	261	261	261
Viet Nam	1 547	1 415	1 475	1 425
Total Asia	**15 412**	**16 311**	**16 943**	**17 360**
Total Europe	**0**	**0**	**0**	**0**
Cuba**	n.s.	n.s.	n.s.	2
El Salvador	n.s.	n.s.	n.s.	n.s.
Jamaica	34	34	34	34
Martinique	2	2	2	2
Trinidad and Tobago	1	1	1	1
Total North and Central America	**37**	**37**	**37**	**39**
Papua New Guinea*	23	38	45	45
Total Oceania	**23**	**38**	**45**	**45**
Brazil*	9 300	9 300	9 300	9 300
Chile*	900	900	900	900
Ecuador*	9	9	9	9
Peru*	190	190	190	190
Total South America	**10 399**	**10 399**	**10 399**	**10 399**
World	**29 560**	**30 442**	**31 065**	**31 470**

Notes:
* Data for 1990, 2000 and 2005 from FAO (2007f). Data for 2005 also used for 2010. For countries in South America, the figures for 2000 were also used for 1990.
** Gaps in data series filled by FAO estimates.
n.s. = not significant

FIGURE 2.12
Area of bamboo by country, 2010



Note: Information for Brazil, Chile, Ecuador, Lao People's Democratic Republic, Malaysia, Nigeria, Pakistan, Papua New Guinea, Peru, Thailand, Uganda and United Republic of Tanzania is based on FAO, 2007f.

than 700 thousand hectares. This is because India revised its estimate downwards by more than 5 million hectares and Indonesia by 2 million hectares.

Trends

Information was missing for 1990 and 2000 for Cuba, Ethiopia and Sudan. For these three countries, the figure for 2005 was used for 1990 and 2000 as well. Indonesia only reported an estimate for 2000 and, due to a lack of other information, this figure was used for all four reporting years.

Based only on the 21 countries that reported some bamboo resources for FRA 2010, the total area of bamboo has increased by some 1.6 million hectares (or close to 11 percent) since 1990. By also taking into account data from the FRA 2005 study, the increase was 2 million hectares. However, there is clearly a need for better internal communication and more accurate assessments of the area of bamboo in many countries.

Rubber plantations

Rubber trees (primarily *Hevea brasiliensis* originating from Brazil) have been planted in many countries over the past 100 years. Most rubber tree plantations are located in South and Southeast Asia and some also exist in tropical West Africa. Many of the early plantations are not very productive and the senescent trees are increasingly entering the wood production chain. Thailand in particular has carved out a niche market in toys and handicrafts made from rubber wood.

Status

A total of 169 countries, accounting for 84 percent of the total forest area reported on the area of rubber plantation. Of these, only 19 reported the existence of rubber plantations.

Annual statistics on the area harvested to produce natural rubber are collected by FAO as part of its agricultural statistics. In the FAOSTAT database, information is available for 28 countries. Combining the two sources of information yields a list of 32 countries, because four countries reported to FRA 2010 but are not included in FAOSTAT. Table 2.10 and Figure 2.13 show the combined list of countries and the estimated areas.[9] The FAOSTAT figures refer to 'area harvested' and are therefore likely

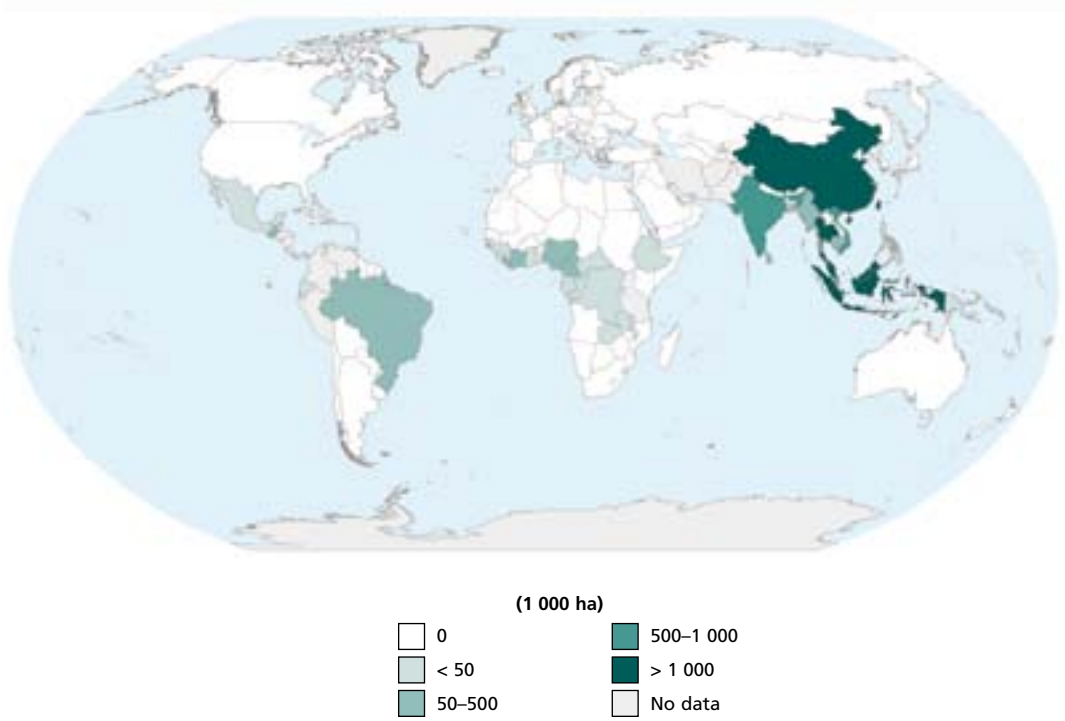
TABLE 2.10
Trends in area of rubber plantations by country and region, 1990–2010

Country/region	Area of rubber plantations (1 000 ha)			
	1990	2000	2005	2010
Cameroon*	39	43	49	52
Central African Republic*	1	1	1	1
Congo*	2	2	2	2
Côte d'Ivoire	60	84	120	120
Democratic Republic of the Congo*	41	19	15	15
Ethiopia**	1	1	1	1
Gabon	13	13	13	13
Ghana*	11	17	17	17
Guinea	1	4	6	6
Liberia	109	109	109	109
Malawi**	2	2	2	2
Nigeria*	223	319	339	340
Sierra Leone	2	2	2	2
Zambia	0	n.s.	n.s.	1
Total Africa	**506**	**615**	**676**	**680**
Bangladesh	20	35	35	8
Brunei Darussalam*	3	3	4	4
Cambodia	67	79	74	69
China	781	1 058	1 039	1 001
India	502	563	597	631
Indonesia*	1 860	2 441	2 826	2 898
Malaysia	1 836	1 431	1 229	1 132
Myanmar*	40	54	72	73
Philippines**	8	8	8	8
Sri Lanka	183	157	129	117
Thailand	1 908	1 993	2 202	2 591
Viet Nam	222	412	460	630
Total Asia	**7 431**	**8 234**	**8 674**	**9 161**
Total Europe	**0**	**0**	**0**	**0**
Dominican Republic*	n.s.	n.s.	n.s.	n.s.
Guatemala*	16	39	50	62
Mexico*	10	12	13	14
Total North and Central America	**10**	**12**	**13**	**14**
Papua New Guinea	16	20	22	24
Total Oceania	**16**	**20**	**22**	**24**
Brazil	64	97	116	174
Ecuador*	2	4	8	9
Total South America	**65**	**100**	**124**	**183**
World	**8 027**	**8 981**	**9 509**	**10 062**

Notes:
* Figures obtained from FAOSTAT.
** Missing data for two reporting years estimated by FAO.
n.s. = not significant

[9] To overcome the problem of erratic harvesting, five year averages were used from the FAOSTAT database for 1990, 2000 and 2005, with 2008 used as the best available estimate for 2010.

FIGURE 2.13
Area of rubber plantations by country, 2010



to result in an underestimate of the total area, as was also evident when comparing the two sources for countries that had reported to both processes. Nevertheless, the difference, in most cases, was relatively small.

At the global level, it is estimated that at least 10 million hectares of rubber plantations exist. The vast majority of these are located in Southeast Asia (Indonesia, Thailand and Malaysia) and in China.

Trends

Based on the information available, the area of rubber plantations has steadily increased by some 2 million hectares (or 25 percent) since 1990 (see Table 2.10). However, the area is decreasing in Malaysia and is expected to decrease even further in the future as older rubber plantations are being converted to other uses.

Conclusions

As a follow-up to the thematic studies on mangroves and bamboo undertaken for FRA 2005 and in order to obtain data on rubber plantations, which in some countries are not classified as forests, countries were asked to report separately on these three distinct forest types as part of FRA 2010. The results show that the area of mangroves is decreasing, while the area of bamboo and of rubber plantations is increasing. Although the response rate overall was fairly good, data were missing from some countries despite the fact that they had been reported in the FRA 2005 study or supplied to FAO's statistical database on agriculture (FAOSTAT). Furthermore, analysis of the existing data on trends suggests that these should be treated with caution, so there is clearly room for improvement in future assessments of the status and trends of these selected forest types.

GROWING STOCK

Introduction

Growing stock has formed part of the global forest resources assessments since the first report. In addition to providing information on existing wood resources, growing stock estimates form the basis for the 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. For FRA 2010 information was also collected on the proportion of broadleaved and coniferous tree species, and on the growing stock of commercial species.

Status

In total, 180 countries and areas, representing 94 percent of the world's forests, reported the total growing stock in forests for 2010. For the remaining countries and areas, FAO estimated total growing stock by taking subregional averages of growing stock per hectare and multiplying these by the forest area for the respective years.

In 2010, the estimated total growing stock in the world's forest amounted to 527 billion m^3. Table 2.11 and Figure 2.14 show that the growing stock per hectare is highest in the tropical moist forests of South America and Western and Central Africa, but is also high in temperate and boreal forests.

The composition of the growing stock, divided into broadleaved and coniferous species, was reported by 117 countries, representing 71 percent of the total forest area and 74 percent of the world's total growing stock. In 2010, about 39 percent of the total growing stock was coniferous and 61 percent broadleaved species. However, it is likely that in reality the share of broadleaved species is higher, as most of the countries that have not reported on growing stock distribution are developing countries with weak information, and in most of these countries coniferous species represent a very small part of the total growing stock. Coniferous species clearly dominate the growing stock in Europe, and North and Central America, while

TABLE 2.11
Growing stock by region and subregion, 2010

Region/subregion	Total growing stock (million m^3)	Growing stock (m^3/ha)
Eastern and Southern Africa	13 697	51
Northern Africa	1 346	17
Western and Central Africa	61 908	189
Total Africa	**76 951**	**114**
East Asia	21 337	84
South and Southeast Asia	29 031	99
Western and Central Asia	3 316	76
Total Asia	**53 685**	**91**
Europe excl. Russian Federation	30 529	156
Total Europe	**112 052**	**111**
Caribbean	584	84
Central America	2 891	148
North America	82 941	122
Total North and Central America	**86 416**	**123**
Total Oceania	**20 885**	**109**
Total South America	**177 215**	**205**
World	**527 203**	**131**

broadleaved species are predominant in Africa, Oceania and South America (see Figure 2.15).

A total of 112 countries, representing 64 percent of the total forest area and 67 percent of the world's total growing stock, reported on the growing stock of commercial species for 2010. The proportion of the total growing stock made up of commercial species is presented in Table 2.12.

FIGURE 2.14
Growing stock per hectare by country, 2010

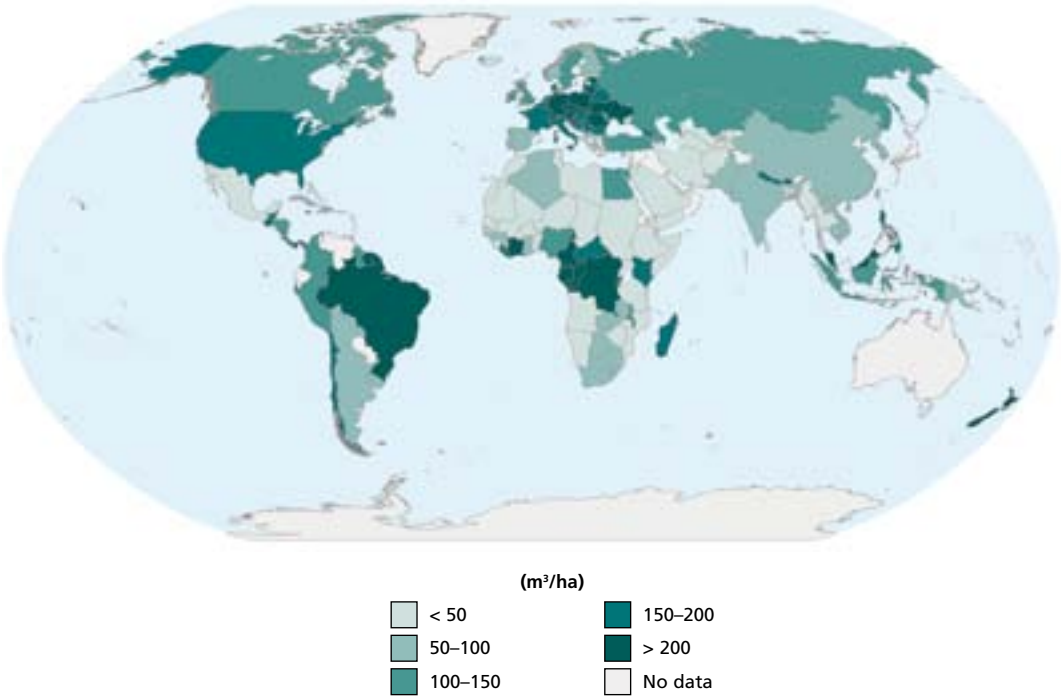
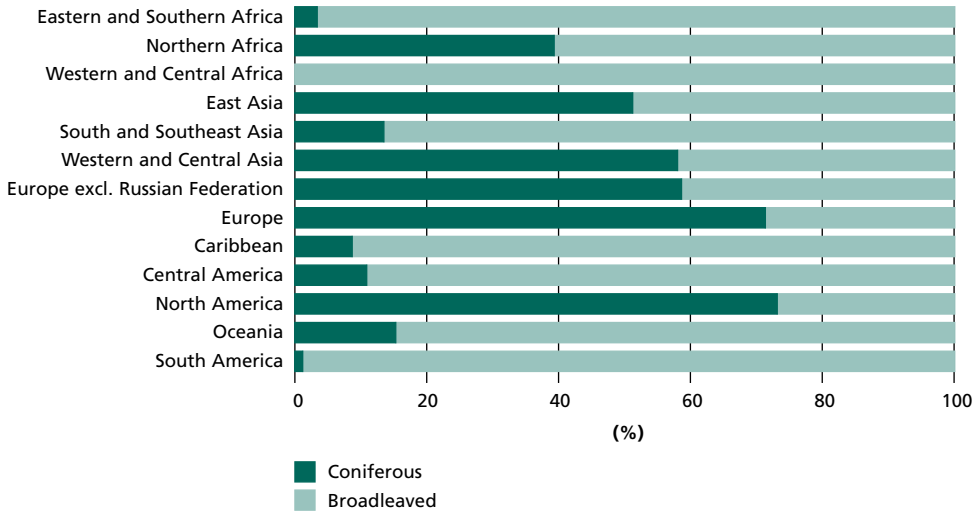


FIGURE 2.15
Growing stock composition by subregion, 2010



About 61 percent of the world's total growing stock is made up of commercial species. This includes all trees of commercial species, not only those that have reached commercial size or those growing on land available for wood supply. While countries in North America and Europe consider most of the growing stock to be commercial, less than half of the growing stock is considered to comprise commercial species in Africa, Asia and South America.

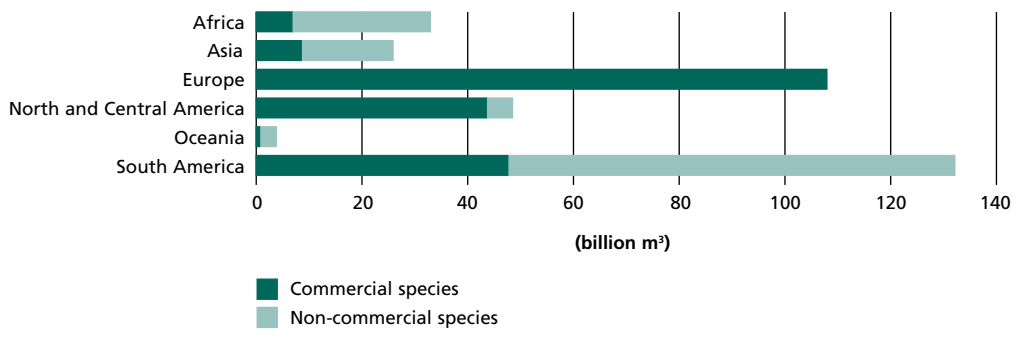
In absolute terms – and bearing in mind that the figures are based on countries representing only 67 percent of the world's total growing stock – the largest stocks of commercial species are found in Europe, South America, and North and Central America (see Figure 2.16). However, some large forest countries in Africa, Asia and Oceania did not provide data on growing stock of commercial species, so the totals shown are likely to be underestimates.

The global total growing stock on other wooded land in 2010 is estimated at about 15 billion m^3 or an average of about 13.1 m^3 per hectare. It should be noted however

TABLE 2.12:
Growing stock of commercial species by region and subregion, 2010

Region/subregion	Growing stock of commercial species (% of total)
Eastern and Southern Africa	16.5
Northern Africa	71.8
Western and Central Africa	21.6
Total Africa	**20.5**
East Asia	32.4
South and Southeast Asia	28.8
Western and Central Asia	53.9
Total Asia	**32.9**
Europe excl. Russian Federation	99.3
Total Europe	**99.8**
Caribbean	75.0
Central America	17.1
North America	91.5
Total North and Central America	**89.8**
Total Oceania	**16.5**
Total South America	**36.0**
World	**61.2**

FIGURE 2.16
Growing stock of commercial species by region, 2010



that country data on growing stock on other wooded land are generally weak and in most cases rough estimates were made based on limited inventory data.

Trends

In total, 175 countries and areas, representing 93 percent of the world's forests, reported a complete time series (1990, 2000, 2005 and 2010) for total growing stock in forests. For the remaining countries and areas FAO estimated total growing stock by taking subregional averages of growing stock per hectare and multiplying these by the forest area for the respective years. In a few cases, where only one or two data points were missing for a complete time series, the FAO estimates for the missing data points were based on the growing stock per hectare for the closest data point. By this procedure a complete dataset with no gaps was obtained, which has been used in further analysis.

A summary of growing stock by region and subregion is shown in Table 2.13, which indicates that there has been a small decline in total growing stock over the period 1990–2010. However, it is unlikely that this change (0.5 percent over 20 years) is significant in statistical terms.

Growing stock is strongly correlated to forest area, which means that if the forest area declines, so usually does the growing stock. Growing stock per hectare provides a better indication of whether forests are becoming more or less well stocked. Growing stock per hectare is increasing globally, particularly in North America and in Europe excluding the Russian Federation. The uneven trend for South and Southeast Asia is primarily a result of the data reported by Indonesia (which showed an increase in growing stock per hectare from 1992 to 1998 followed by a decrease between 1998 and 2003). This may be because the methods used in Indonesia were not fully compatible over time.

It is interesting to note that the growing stock figures presented in FRA 2010, including growing stock per hectare, are in general higher than those contained in

TABLE 2.13
Trends in growing stock in forest by region and subregion, 1990–2010

Region/subregion	Growing stock (million m³)				Growing stock (m³/ha)			
	1990	2000	2005	2010	1990	2000	2005	2010
Eastern and Southern Africa	15 300	14 486	14 091	13 697	50.3	50.7	50.9	51.2
Northern Africa	1 415	1 351	1 355	1 346	16.6	17.1	17.2	17.1
Western and Central Africa	66 319	64 067	63 009	61 908	184.3	186.5	187.7	188.7
Total Africa	**83 035**	**79 904**	**78 455**	**76 951**	**110.8**	**112.8**	**113.5**	**114.1**
East Asia	15 987	18 577	20 226	21 337	76.4	81.9	83.6	83.8
South and Southeast Asia	32 400	30 865	30 132	29 031	99.6	102.5	100.7	98.6
Western and Central Asia	2 949	3 101	3 204	3 316	71.1	73.5	74.7	76.2
Total Asia	**51 336**	**52 543**	**53 563**	**53 685**	**89.1**	**92.2**	**91.7**	**90.6**
Europe excl. Russian Federation	23 810	27 487	29 176	30 529	131.9	145.5	151.7	155.8
Total Europe	**103 849**	**107 757**	**109 655**	**112 052**	**105.0**	**107.9**	**109.5**	**111.5**
Caribbean	445	529	567	584	75.5	82.3	84.3	84.2
Central America	3 782	3 253	3 073	2 891	147.1	148.0	148.1	148.2
North America	74 913	76 925	79 924	82 941	110.7	113.6	117.9	122.2
Total North and Central America	**79 141**	**80 708**	**83 564**	**86 416**	**111.7**	**114.4**	**118.5**	**122.5**
Total Oceania	**21 293**	**21 415**	**21 266**	**20 885**	**107.1**	**108.0**	**108.1**	**109.1**
Total South America	**191 451**	**184 141**	**181 668**	**177 215**	**202.3**	**203.6**	**205.9**	**205.0**
World	**530 105**	**526 469**	**528 170**	**527 203**	**127.2**	**128.9**	**130.1**	**130.7**

the FRA 2005 report. This is because many countries have collected new and better data for FRA 2010, more countries have reported, and more effort has been made to help countries provide the best possible estimates with the weak data they often have available.

Table 2.14 shows trends in the relative share of coniferous and broadleaved species by region and subregion between 1990 and 2010. It is based on data from 110 countries and areas (representing 71 percent of the total forest area) which reported a complete time series of growing stock distributed by coniferous and broadleaved species. For most regions, the changes over time are minimal; however East Asia shows a clear trend towards a higher proportion of broadleaved species, primarily due to planting of broadleaved species in China. Europe shows a similar, but less pronounced, trend. The figures for Oceania exclude both Australia and New Zealand as neither provided a full time series.

A complete time series of the growing stock of commercial species was reported by 105 countries and areas, representing 64 percent of total forest area. Table 2.15 shows the proportion of the total growing stock made up of commercial species and how it changes over time. The slightly increasing global trend is unlikely to be significant in statistical terms. Most regions show no, or a very small, change. Only Asia demonstrates a clear declining trend in the proportion of commercial species in the total growing stock, despite the fact that the total growing stock is increasing over time in the region. This is primarily due to a decrease in the growing stock of commercial species reported by China.

A complete time series for growing stock on other wooded land was reported by 111 countries (including those that reported zero). For the remaining countries and areas, FAO estimated growing stock on other wooded land by taking the subregional averages of growing stock per hectare and multiplying these by the area of other wooded land for the respective years.

TABLE 2.14
Trends in growing stock composition by region and subregion, 1990–2010

Region/subregion	Coniferous species (% of total growing stock)				Broadleaved species (% of total growing stock)			
	1990	2000	2005	2010	1990	2000	2005	2010
Eastern and Southern Africa	3.9	3.6	3.4	3.4	96.1	96.4	96.6	96.6
Northern Africa	38.5	39.0	39.0	39.3	61.5	61.0	61.0	60.7
Western and Central Africa	0	0	0	0	100.0	100.0	100.0	100.0
Total Africa	**1.0**	**1.1**	**1.1**	**1.1**	**99.0**	**98.9**	**98.9**	**98.9**
East Asia	59.3	55.7	51.6	51.2	40.7	44.3	48.4	48.8
South and Southeast Asia	12.8	13.2	13.3	13.5	87.2	86.8	86.7	86.5
Western and Central Asia	57.9	58.2	58.0	58.0	42.1	41.8	42.0	42.0
Total Asia	**43.7**	**42.4**	**40.2**	**40.1**	**56.3**	**57.6**	**59.8**	**59.9**
Europe excl. Russian Federation	61.0	60.2	59.1	58.9	39.0	39.8	40.9	41.1
Total Europe	**75.2**	**69.3**	**69.4**	**71.4**	**24.8**	**30.7**	**30.6**	**28.6**
Caribbean	8.5	9.4	9.0	9.0	91.5	90.6	91.0	91.0
Central America	12.1	11.5	11.3	10.9	87.9	88.5	88.7	89.1
North America	72.9	69.4	70.1	73.1	27.1	30.6	29.9	26.9
Total North and Central America	**70.8**	**67.7**	**68.5**	**71.5**	**29.2**	**32.3**	**31.5**	**28.5**
Total Oceania	**0**	**0**	**0**	**0**	**100.0**	**100.0**	**100.0**	**100.0**
Total South America	**0.9**	**1.0**	**1.1**	**1.2**	**99.1**	**99.0**	**98.9**	**98.8**
World	**37.1**	**36.0**	**36.7**	**38.8**	**62.9**	**64.0**	**63.3**	**61.2**

Table 2.16 shows the growing stock on other wooded land. There are some variations in the time series, but most are unlikely to be statiscally significant. The decrease seen between 1990 and 2000 for the Russian Federation is likely to be a result of data reported on the extent of other wooded land for 1990 and 2000, for which the methods used may not be fully compatible.

TABLE 2.15
Trends in growing stock of commercial species by region and subregion, 1990–2010

Region/subregion	Commercial species (% of total growing stock)			
	1990	2000	2005	2010
Eastern and Southern Africa	16.2	16.4	16.4	16.5
Northern Africa	75.6	73.3	72.6	71.8
Western and Central Africa	20.7	21.0	21.3	21.6
Total Africa	**19.7**	**20.0**	**20.2**	**20.5**
East Asia	67.0	45.7	32.3	32.4
South and Southeast Asia	29.2	29.1	28.8	28.8
Western and Central Asia	66.6	64.9	58.9	53.8
Total Asia	**52.8**	**41.5**	**33.2**	**32.9**
Europe excl. Russian Federation	99.4	99.4	99.5	99.5
Total Europe	**99.9**	**99.9**	**99.9**	**99.9**
Caribbean	65.3	73.9	77.0	78.0
Central America	17.1	17.1	17.1	17.1
North America	89.8	91.6	91.6	91.5
Total North and Central America	**87.1**	**89.3**	**89.6**	**89.8**
Total Oceania	**51.2**	**51.2**	**51.2**	**51.2**
Total South America	**35.8**	**35.8**	**35.8**	**36.0**
World	**60.0**	**60.7**	**60.7**	**61.6**

TABLE 2.16
Trends in growing stock in other wooded land by region and subregion, 1990–2010

Region/subregion	Growing stock (million m^3)				Growing stock (m^3/ha)			
	1990	2000	2005	2010	1990	2000	2005	2010
Eastern and Southern Africa	3 266	3 086	2 995	2 907	15.4	15.0	14.7	14.5
Northern Africa	510	479	465	449	7.9	7.9	7.9	7.8
Western and Central Africa	1 794	1 722	1 690	1 662	16.0	16.8	17.3	17.8
Total Africa	**5 570**	**5 288**	**5 150**	**5 018**	**14.3**	**14.3**	**14.3**	**14.3**
East Asia	1 064	1 046	1 070	1 113	10.0	10.3	10.0	10.7
South and Southeast Asia	963	1 161	1 248	1 247	16.0	18.1	19.2	19.2
Western and Central Asia	195	190	185	184	3.0	2.8	2.8	2.7
Total Asia	**2 223**	**2 397**	**2 503**	**2 544**	**9.6**	**10.3**	**10.5**	**10.8**
Europe excl. Russian Federation	356	310	279	273	12.1	11.3	10.2	10.4
Total Europe	**1 961**	**1 903**	**1 931**	**2 048**	**25.5**	**19.2**	**19.2**	**20.6**
Caribbean	40	40	42	41	38.5	38.1	35.7	37.2
Central America	155	165	167	173	26.1	25.4	25.7	26.5
North America	229	228	228	227	1.8	1.8	1.8	1.8
Total North and Central America	**424**	**434**	**438**	**441**	**3.1**	**3.2**	**3.2**	**3.3**
Total Oceania	**2 367**	**2 399**	**2 431**	**2 463**	**16.5**	**16.7**	**16.9**	**17.2**
Total South America	**2 654**	**2 582**	**2 543**	**2 508**	**14.0**	**14.0**	**14.0**	**14.0**
World	**15 199**	**15 003**	**14 995**	**15 022**	**13.0**	**12.9**	**12.9**	**13.1**

Conclusions

The world's total growing stock in forests is 527 billion m^3 or 131 m^3/ha. The total growing stock shows a slightly decreasing trend caused by a global decrease in forest area. However, the growing stock per hectare is increasing globally – this is particularly the case in North America and in Europe excluding the Russian Federation. The growing stock per hectare is highest in the tropical forests of South America, and Western and Central Africa, but is also high in temperate and boreal forests. Total growing stock on other wooded land amounts to about 15 billion m^3 or 13 m^3/ha.

While the quality of the data has improved since FRA 2005 as more countries have conducted national forest inventories, the absence of reliable trend information is still an issue of concern. The vast majority of countries have only one estimate of growing stock per hectare and for these countries any changes in growing stock reflect only the changes in forest area.

For many countries, there is still no clear explanation of how the original country data on growing stock were obtained, and how related key parameters such as threshold values were used, volume equations applied and species included. More work is needed to further improve the quality and the comparability of the growing stock estimates.

BIOMASS

Introduction

Forest biomass, expressed in terms of dry weight of living organisms, is an important measure for analysing ecosystem productivity and also for assessing energy potential and the role of forests in the carbon cycle. Although closely correlated to – and often estimated directly from – growing stock it constitutes an important characteristic of the forest ecosystem and has formed part of the global forest resources assessments since FRA 1990.

Status

In total, 180 countries and areas, representing 94 percent of the world's forests, reported on biomass in forest for 2010. Dead wood was reported by 73 countries and areas representing 60 percent of the world's forests. For the remaining countries and areas, FAO estimated the biomass and dead wood by taking subregional averages per hectare and multiplying these by the forest area for the respective years.

Table 2.17 shows that in 2010 the total biomass (above-ground and below-ground) contained in the world's forests amounted to 600 Gt. This corresponds to about 149 tonnes per hectare. The highest biomass stock per hectare was found in regions with tropical forests, such as South America, and Western and Central Africa, where biomass stocks are over 200 tonnes per hectare. Dead wood in the world's forests was estimated to be about 67 Gt of dry matter or 16.6 tonnes per hectare.

The global estimates of biomass for FRA 2010 are higher than those for FRA 2005. This is mainly because the estimates of forest area are higher in FRA 2010 than in FRA 2005, but also because the biomass stock per hectare is slightly higher in FRA 2010.

The vast majority of countries have used the conversion factors provided by the IPCC to estimate biomass from growing stock. The relationships between growing stock, above-ground and below-ground biomass are therefore fairly constant over time. Table 2.18 shows the biomass conversion and expansion factor[10], the root–shoot ratio[11] and the dead–live ratio[12] by subregion based on the estimates of growing stock

[10] The biomass conversion and expansion factor is calculated as the above-ground biomass in tonnes divided by growing stock in m^3.

[11] The root–shoot ratio is calculated as below-ground biomass divided by above-ground biomass.

[12] The dead–live ratio is calculated as the dry weight of dead wood divided by the total living biomass (above-ground and below-ground).

TABLE 2.17
Biomass and dead wood stock by region and subregion, 2010

Region/subregion	Biomass		Dead wood	
	million tonnes	t/ha	million tonnes	t/ha
Eastern and Southern Africa	33 385	124.8	6 888	25.7
Northern Africa	3 711	47.1	1 069	13.6
Western and Central Africa	81 603	248.7	7 747	23.6
Total Africa	**118 700**	**176.0**	**15 704**	**23.3**
East Asia	18 429	72.4	2 514	9.9
South and Southeast Asia	51 933	176.4	5 964	20.3
Western and Central Asia	3 502	80.5	70	1.6
Total Asia	**73 864**	**124.7**	**8 548**	**14.4**
Europe excl. Russian Federation	25 602	130.7	1 434	7.3
Total Europe	**90 602**	**90.2**	**15 790**	**15.7**
Caribbean	1 092	157.5	120	17.2
Central America	3 715	190.5	419	21.5
North America	76 929	113.3	8 633	12.7
Total North and Central America	**81 736**	**115.9**	**9 172**	**13.0**
Total Oceania	**21 302**	**111.3**	**3 932**	**20.5**
Total South America	**213 863**	**247.4**	**13 834**	**16.0**
World	**600 066**	**148.8**	**66 980**	**16.6**

TABLE 2.18
Biomass conversion and expansion factor, root–shoot ratio and dead–live ratio by region and subregion, 2010

Region/subregion	Biomass conversion and expansion factor	Root–shoot ratio	Dead–live ratio
Eastern and Southern Africa	1.94	0.26	0.21
Northern Africa	2.15	0.28	0.29
Western and Central Africa	1.07	0.23	0.09
Total Africa	**1.24**	**0.24**	**0.13**
East Asia	0.66	0.31	0.14
South and Southeast Asia	1.43	0.30	0.11
Western and Central Asia	0.82	0.28	0.02
Total Asia	**1.08**	**0.30**	**0.12**
Europe excl. Russian Federation	0.67	0.26	0.06
Total Europe	**0.65**	**0.25**	**0.17**
Caribbean	1.51	0.24	0.11
Central America	1.04	0.24	0.11
North America	0.76	0.22	0.11
Total North and Central America	**0.78**	**0.22**	**0.11**
Total Oceania	**0.77**	**0.33**	**0.18**
Total South America	**0.99**	**0.20**	**0.06**
World	**0.92**	**0.24**	**0.11**

and biomass for 2010. As expected, the calculated factors are well within the range of default values presented in the latest IPCC Guidelines (IPCC, 2006).

Trends

In total, 174 countries and areas reported a complete time series for above-ground and below-ground biomass in forests. These countries represent more than 93 percent of

the global forest area. This is a considerable increase in reporting in comparison with FRA 2005 when 146 countries and areas provided information. For the remaining countries and areas, FAO estimated biomass by taking the subregional averages of biomass per hectare and multiplying them by forest area for the respective years.

Table 2.19 shows that, between 1990 and 2010, the global biomass stock decreased by about 23 Gt, or 3.6 percent globally. Africa and South America show the largest decrease in total stocks, mainly because of a decrease in forest area. In contrast, Europe and North America show an increase in total biomass stock.

Globally, biomass stock per hectare does not show any major changes for the period 1990–2010. South and Southeast Asia show a decrease in biomass stock per hectare, while Africa, Europe, North and Central America, and South America show a slight increase. With the exception of South and Southeast Asia, the trends in biomass stock per hectare follow the trends in growing stock per hectare.

Countries were asked to provide data on dead wood only if they had national data available, because the latest IPCC guidelines (IPCC, 2006) do not provide any default factors for estimating it. Consequently, the response rate for dead wood is low with complete time series data available for only 65 countries and areas, representing 59 percent of the world's forest area.[13] The estimates of dead wood are therefore much weaker than the biomass estimates. For the remaining countries and areas, FAO made estimates by taking the subregional averages of dead wood stock per hectare and multiplying them by the forest area for the respective years. Table 2.20 shows the estimated amount of dead wood in forests expressed in million tonnes dry matter. Dead wood stocks have decreased by about 3 Gt over the period 1990–2010, mainly due to the decrease in forest area.

TABLE 2.19
Trends in total biomass in forests by region and subregion, 1990–2010

Region/subregion	Total biomass in forest (million tonnes)				Biomass in forest (t/ha)			
	1990	2000	2005	2010	1990	2000	2005	2010
Eastern and Southern Africa	37 118	35 232	34 304	33 385	122.0	123.2	124.0	124.8
Northern Africa	3 931	3 721	3 731	3 711	46.2	47.0	47.2	47.1
Western and Central Africa	88 340	84 886	83 275	81 603	245.5	247.2	248.0	248.7
Total Africa	**129 390**	**123 839**	**121 309**	**118 700**	**172.7**	**174.8**	**175.4**	**176.0**
East Asia	13 877	16 185	17 563	18 429	66.3	71.4	72.6	72.4
South and Southeast Asia	60 649	57 111	54 904	51 933	186.4	189.6	183.4	176.4
Western and Central Asia	3 063	3 236	3 355	3 502	73.8	76.7	78.2	80.5
Total Asia	**77 589**	**76 532**	**75 822**	**73 864**	**134.7**	**134.2**	**129.8**	**124.7**
Europe excl. Russian Federation	19 866	22 630	24 097	25 602	110.0	119.8	125.3	130.7
Total Europe	**84 874**	**86 943**	**88 516**	**90 602**	**85.8**	**87.1**	**88.4**	**90.2**
Caribbean	822	987	1 060	1 092	139.3	153.4	157.5	157.5
Central America	4 803	4 145	3 931	3 715	186.7	188.6	189.5	190.5
North America	72 518	74 453	75 646	76 929	107.2	110.0	111.6	113.3
Total North and Central America	**78 143**	**79 585**	**80 637**	**81 736**	**110.3**	**112.8**	**114.3**	**115.9**
Total Oceania	**22 095**	**21 989**	**21 764**	**21 302**	**111.2**	**110.8**	**110.6**	**111.3**
Total South America	**230 703**	**222 251**	**217 504**	**213 863**	**243.8**	**245.8**	**246.5**	**247.4**
World	**622 794**	**611 140**	**605 553**	**600 066**	**149.4**	**149.6**	**149.1**	**148.8**

[13] This does not imply that 65 countries have national data on dead wood – some countries decided to report the same stock as they reported to FRA 2005 based on the default factors in the IPCC 2003 Good Practice Guidance (IPCC, 2003).

TABLE 2.20
Trends in dead wood stocks by region and subregion, 1990–2010

Region/subregion	Dead wood stock (million tonnes)				Dead wood (t/ha)			
	1990	2000	2005	2010	1990	2000	2005	2010
Eastern and Southern Africa	7 836	7 362	7 126	6 888	25.8	25.8	25.8	25.7
Northern Africa	1 019	1 024	1 059	1 069	12.0	12.9	13.4	13.6
Western and Central Africa	8 740	8 271	8 019	7 747	24.3	24.1	23.9	23.6
Total Africa	**17 595**	**16 658**	**16 205**	**15 704**	**23.5**	**23.5**	**23.4**	**23.3**
East Asia	1 920	2 193	2 362	2 514	9.2	9.7	9.8	9.9
South and Southeast Asia	7 435	6 491	6 257	5 964	22.8	21.6	20.9	20.3
Western and Central Asia	65	69	69	70	1.6	1.6	1.6	1.6
Total Asia	**9 420**	**8 753**	**8 689**	**8 548**	**16.4**	**15.4**	**14.9**	**14.4**
Europe excl. Russian Federation	1 261	1 348	1 391	1 434	7.0	7.1	7.2	7.3
Total Europe	**15 456**	**15 371**	**15 355**	**15 790**	**15.6**	**15.4**	**15.3**	**15.7**
Caribbean	89	105	113	120	15.0	16.4	16.8	17.2
Central America	552	472	441	419	21.5	21.5	21.3	21.5
North America	8 072	8 334	8 474	8 633	11.9	12.3	12.5	12.7
Total North and Central America	**8 713**	**8 911**	**9 029**	**9 172**	**12.3**	**12.6**	**12.8**	**13.0**
Total Oceania	**4 050**	**4 045**	**4 032**	**3 932**	**20.4**	**20.4**	**20.5**	**20.5**
Total South America	**14 838**	**14 353**	**14 233**	**13 834**	**15.7**	**15.9**	**16.1**	**16.0**
World	**70 072**	**68 089**	**67 542**	**66 980**	**16.8**	**16.7**	**16.6**	**16.6**

Conclusions

The world's forests contain 600 Gt of biomass (above-ground and below-ground) and about 67 Gt of dead wood. The decrease in total biomass stock is mainly a result of the loss of forest area.

While data availability and quality have improved since FRA 2005, trend data are still weak. Biomass is usually estimated by applying conversion factors to growing stock. However, the majority of countries do not have time series data on growing stock so the weaknesses in growing stock trend estimates are also directly translated into biomass. Data on dead wood dry matter are very weak and are unlikely to improve until the IPCC provides new and better default values and conversion factors.

CARBON STOCK

Introduction

Forests, like other ecosystems, are affected by climate change. In some places, impacts may be negative, while in others they may be positive. 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 when forest land is cleared.

The Kyoto protocol and the UNFCCC request all member countries to assess and report national greenhouse gas emissions regularly, including emissions and removals of carbon reflected as stock changes in forests. To this end, the IPCC has developed guidelines, methods and default values for the parameters needed to assess carbon stocks and their changes in forests (IPCC, 2006). It has thus provided all countries with the means of estimating and reporting carbon stocks, greenhouse gas emissions and removals, irrespective of the availability of country-specific data. In order to maximize synergies and streamline country reporting to international organizations, FAO incorporated the IPCC 2006 guidelines on assessment of carbon stocks in forests into its guidelines for country reporting for FRA 2010.

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 influencing the global carbon cycle. Global forest resources assessments have the potential to contribute to, or substantiate, the estimates of the magnitude of carbon stocks and flows made by scientific bodies such as IPCC. At the same time, they complement and facilitate international reporting by countries on greenhouse gas emissions and removals under the UNFCCC.

Figures on carbon stocks in forests reported under the UNFCCC, the Kyoto Protocol and to FAO are not necessarily identical. Forest definitions may vary and furthermore UNFCCC members are requested to report on 'managed forests' which may comprise all or only part of the forest area of a given country. FRA specific methods such as calibration, reclassification, estimating and forecasting are also not always implemented in exactly the same way in the reporting under the UNFCCC and the Kyoto Protocol.

Status

In total, 180 countries and areas, representing 94 percent of the world's forests, reported on carbon in biomass for 2010. For carbon in dead wood the corresponding figures are 72 countries (61 percent), for carbon in litter 124 countries (78 percent) and for soil carbon 121 countries (78 percent). For the remaining countries and areas, FAO estimated the carbon stocks by taking subregional averages per hectare and multiplying these by the forest area for the respective years.

Table 2.21 shows the estimated carbon stock in forests by region, subregion and at a global level. In 2010, the total carbon stock in the biomass of the world's forests is estimated at 289 Gt. For most countries, carbon in biomass merely reflects the biomass stock as the default carbon fraction from the IPCC guidelines has been used. In FRA 2010, most countries used a carbon fraction of 0.47 (as in the 2006 IPCC Guidelines), while some countries used the carbon fraction of 0.5 suggested in the

TABLE 2.21
Carbon stock in forest by region and subregion, 2010

Region/subregion	Carbon in biomass		Carbon in dead wood and litter		Carbon in soil		Total carbon stock	
	million tonnes	t/ha	million tonnes	t/ha	million tonnes	t/ha	million tonnes	t/ha
Eastern and Southern Africa	15 762	58.9	3 894	14.6	12 298	46.0	31 955	119.4
Northern Africa	1 747	22.2	694	8.8	2 757	35.0	5 198	66.0
Western and Central Africa	38 349	116.9	3 334	10.2	19 406	59.1	61 089	186.2
Total Africa	**55 859**	**82.8**	**7 922**	**11.7**	**34 461**	**51.1**	**98 242**	**145.7**
East Asia	8 754	34.4	1 836	7.2	17 270	67.8	27 860	109.4
South and Southeast Asia	25 204	85.6	1 051	3.6	16 466	55.9	42 722	145.1
Western and Central Asia	1 731	39.8	546	12.6	1 594	36.6	3 871	89.0
Total Asia	**35 689**	**60.2**	**3 434**	**5.8**	**35 330**	**59.6**	**74 453**	**125.7**
Europe excl. Russian Federation	12 510	63.9	3 648	18.6	18 924	96.6	35 083	179.1
Total Europe	**45 010**	**44.8**	**20 648**	**20.5**	**96 924**	**96.4**	**162 583**	**161.8**
Caribbean	516	74.4	103	14.8	416	60.0	1 035	149.2
Central America	1 763	90.4	714	36.6	1 139	58.4	3 616	185.4
North America	37 315	55.0	26 139	38.5	39 643	58.4	103 097	151.8
Total North and Central America	**39 594**	**56.1**	**26 956**	**38.2**	**41 198**	**58.4**	**107 747**	**152.7**
Total Oceania	**10 480**	**54.8**	**2 937**	**15.3**	**8 275**	**43.2**	**21 692**	**113.3**
Total South America	**102 190**	**118.2**	**9 990**	**11.6**	**75 473**	**87.3**	**187 654**	**217.1**
World	**288 821**	**71.6**	**71 888**	**17.8**	**291 662**	**72.3**	**652 371**	**161.8**

IPCC 2003 Good Practice Guidance. A few countries have used country-specific carbon fractions for their estimates. Globally, the average carbon fraction used is 0.48 with minor variations between subregions.

The total carbon stock in dead wood and litter in 2010 amounts to 72 billion tonnes or 17.8 tonnes per hectare. This is slightly more than reported in FRA 2005. However, data on carbon stock in dead wood and litter are still very weak. Most countries do not have national data on these carbon pools, so until the IPCC provides better default values, estimates of these carbon pools will continue to be weak.

The total stock of carbon in soil is estimated at 292 billion tonnes or 72.3 tonnes per hectare. This is slightly more than the total carbon stock in forest biomass.

Taking together all carbon in biomass, dead wood, litter and soils, the estimated total carbon stock in forests in 2010 is 652 billion tonnes, corresponding to 161.8 tonnes per hectare.

Trends

In total, 174 countries and areas (representing 93 percent of the total forest area) have reported a complete time series on carbon stock in forest biomass (above-ground and below-ground). For the remaining countries and areas, FAO estimated carbon stock in forest biomass by taking the subregional averages of carbon stock per hectare and multiplying them by the forest area for the respective years.

Table 2.22 shows the trends in estimated carbon stock in forest biomass by subregion, region and at the global level for the period 1990–2010. The total carbon stock in the biomass of the world's forests shows a decrease of about 10 Gt for the period 1990–2010 or -0.5 Gt per year on average, mainly due to a reduction in the world's forest area. As for biomass, the carbon stock per hectare does not show any significant change at the global level.

For dead wood carbon the response rate for FRA 2010 was lower than in FRA 2005, mainly because of the IPCC's decision to omit default conversion factors from the latest version of their guidelines. A complete time series on carbon in dead wood was reported by 66 countries and areas (representing 61 percent of the world's forest area).

TABLE 2.22
Trends in carbon stocks in forest biomass by region and subregion, 1990–2010

Region/subregion	Carbon in forest biomass (million tonnes)				Carbon in forest biomass (t/ha)			
	1990	2000	2005	2010	1990	2000	2005	2010
Eastern and Southern Africa	17 524	16 631	16 193	15 762	57.6	58.2	58.5	58.9
Northern Africa	1 849	1 751	1 756	1 747	21.7	22.1	22.2	22.2
Western and Central Africa	41 525	39 895	39 135	38 349	115.4	116.2	116.6	116.9
Total Africa	**60 898**	**58 277**	**57 083**	**55 859**	**81.3**	**82.2**	**82.6**	**82.8**
East Asia	6 592	7 690	8 347	8 754	31.5	33.9	34.5	34.4
South and Southeast Asia	29 110	27 525	26 547	25 204	89.5	91.4	88.7	85.6
Western and Central Asia	1 511	1 599	1 658	1 731	36.4	37.9	38.7	39.8
Total Asia	**37 213**	**36 814**	**36 553**	**35 689**	**64.6**	**64.6**	**62.6**	**60.2**
Europe excl. Russian Federation	9 699	11 046	11 763	12 510	53.7	58.5	61.2	63.9
Total Europe	**42 203**	**43 203**	**43 973**	**45 010**	**42.7**	**43.3**	**43.9**	**44.8**
Caribbean	387	466	500	516	65.5	72.4	74.4	74.4
Central America	2 279	1 969	1 865	1 763	88.6	89.6	89.9	90.4
North America	35 100	36 073	36 672	37 315	51.9	53.3	54.1	55.0
Total North and Central America	**37 766**	**38 508**	**39 038**	**39 594**	**53.3**	**54.6**	**55.3**	**56.1**
Total Oceania	**10 862**	**10 816**	**10 707**	**10 480**	**54.7**	**54.5**	**54.4**	**54.8**
Total South America	**110 281**	**106 226**	**103 944**	**102 190**	**116.5**	**117.5**	**117.8**	**118.2**
World	**299 224**	**293 843**	**291 299**	**288 821**	**71.8**	**71.9**	**71.7**	**71.6**

For carbon in litter the response rate was much higher than in FRA 2005 when only 54 countries reported. For FRA 2010, 119 countries (accounting for 77 percent of the world's forest area) reported on carbon in litter. For the remaining countries and areas, FAO estimated carbon stocks by taking the subregional average carbon stocks per hectare and multiplying them by the forest area for the respective years. Table 2.23 shows trends in carbon stocks of dead wood and litter combined for the period 1990–2010.

A complete time series on soil carbon was reported by 117 countries and areas (representing 78 percent of the world's forest area). This is a substantially larger response rate than in FRA 2005 when only 43 countries reported. For the remaining countries and areas, FAO made estimates by taking the subregional average soil carbon stocks per hectare and multiplying these by the forest area for the respective years. Most countries have used IPCC default values of stocks per hectare which relate to a soil depth of 30 cm. In this analysis, no adjustment has been made for countries reporting soil carbon to non-standard soil depths.

The declining trend in the total stock of carbon in the soil for the period 1990–2010 (see Table 2.24) is attributed to the loss of forest area during this period as the stocks per hectare show almost no change.

Table 2.25 summarizes the FRA 2010 global estimates of carbon stocks in forest.

The estimated total carbon stock in forests in 2010 is 652 billion tonnes, which equates to 161.8 tonnes per hectare. The total carbon stock has decreased during the period 1990–2010, mainly as a result of the loss of forest area during the period. Carbon stocks per hectare show a slight increase, but it is unlikely to be significant in statistical terms.

FRA 2010 shows slightly higher carbon stocks than those estimated for FRA 2005. This is mostly because forest area is estimated to be higher in FRA 2010 compared with FRA 2005. The stocks per hectare are almost the same, but while FRA 2005 presented a decreasing trend in stocks per hectare, FRA 2010 shows almost no change over time.

TABLE 2.23
Trends in carbon stocks in dead wood and litter combined, by region and subregion, 1990–2010

Region/subregion	Carbon in dead wood and litter (million tonnes)				Carbon in dead wood and litter (t/ha)			
	1990	2000	2005	2010	1990	2000	2005	2010
Eastern and Southern Africa	4 419	4 156	4 025	3 894	14.5	14.5	14.5	14.6
Northern Africa	674	668	688	694	7.9	8.4	8.7	8.8
Western and Central Africa	4 118	3 761	3 542	3 334	11.4	11	10.6	10.2
Total Africa	**9 211**	**8 586**	**8 255**	**7 922**	**12.3**	**12.1**	**11.9**	**11.7**
East Asia	1 428	1 608	1 729	1 836	6.8	7.1	7.1	7.2
South and Southeast Asia	1 134	1 069	1 067	1 051	3.5	3.6	3.6	3.6
Western and Central Asia	502	517	530	546	12.1	12.2	12.4	12.6
Total Asia	**3 064**	**3 194**	**3 325**	**3 434**	**5.3**	**5.6**	**5.7**	**5.8**
Europe excl. Russian Federation	3 337	3 495	3 561	3 648	18.5	18.5	18.5	18.6
Total Europe	**20 254**	**20 223**	**20 259**	**20 648**	**20.5**	**20.3**	**20.2**	**20.5**
Caribbean	72	89	97	103	12.2	13.8	14.3	14.8
Central America	929	799	756	714	36.1	36.4	36.4	36.6
North America	25 590	25 621	25 932	26 139	37.8	37.8	38.3	38.5
Total North and Central America	**26 591**	**26 510**	**26 784**	**26 956**	**37.5**	**37.6**	**38**	**38.2**
Total Oceania	**3 027**	**3 025**	**3 014**	**2 937**	**15.2**	**15.3**	**15.3**	**15.3**
Total South America	**10 776**	**10 382**	**10 154**	**9 990**	**11.4**	**11.5**	**11.5**	**11.6**
World	**72 923**	**71 919**	**71 792**	**71 888**	**17.5**	**17.6**	**17.7**	**17.8**

TABLE 2.24
Trends in carbon stocks in forest in soil by region and subregion, 1990–2010

Region/subregion	Carbon in soil (million tonnes)				Carbon in soil (t/ha)			
	1990	2000	2005	2010	1990	2000	2005	2010
Eastern and Southern Africa	13 871	13 084	12 690	12 298	45.6	45.8	45.9	46.0
Northern Africa	2 952	2 748	2 771	2 757	34.7	34.7	35.1	35.0
Western and Central Africa	21 083	20 223	19 814	19 406	58.6	58.9	59.0	59.1
Total Africa	**37 907**	**36 055**	**35 275**	**34 461**	**50.6**	**50.9**	**51.0**	**51.1**
East Asia	14 220	15 402	16 432	17 270	68.0	67.9	67.9	67.8
South and Southeast Asia	18 071	16 760	16 701	16 466	55.5	55.7	55.8	55.9
Western and Central Asia	1 534	1 550	1 564	1 594	37.0	36.7	36.5	36.6
Total Asia	**33 826**	**33 712**	**34 698**	**35 330**	**58.7**	**59.1**	**59.4**	**59.6**
Europe excl. Russian Federation	17 503	18 495	18 632	18 924	97.0	97.9	96.9	96.6
Total Europe	**95 503**	**96 495**	**96 632**	**96 924**	**96.5**	**96.7**	**96.5**	**96.4**
Caribbean	354	386	403	416	59.9	59.9	60.0	60.0
Central America	1 511	1 287	1 212	1 139	58.7	58.6	58.4	58.4
North America	39 752	39 645	39 613	39 643	58.7	58.6	58.4	58.4
Total North and Central America	**41 617**	**41 318**	**41 229**	**41 198**	**58.7**	**58.6**	**58.5**	**58.4**
Total Oceania	**8 584**	**8 533**	**8 490**	**8 275**	**43.2**	**43.0**	**43.2**	**43.2**
Total South America	**82 989**	**78 961**	**76 909**	**75 473**	**87.7**	**87.3**	**87.2**	**87.3**
World	**300 425**	**295 073**	**293 232**	**291 662**	**72.1**	**72.2**	**72.2**	**72.3**

TABLE 2.25
Trends in total carbon stocks in forests, 1990–2010

	Total carbon stock (million tonnes)				Carbon stock (t/ha)			
	1990	2000	2005	2010	1990	2000	2005	2010
Carbon in biomass	299 224	293 843	291 299	288 821	71.8	71.9	71.7	71.6
Carbon in dead wood	34 068	33 172	32 968	32 904	8.2	8.1	8.1	8.2
Carbon in litter	38 855	38 748	38 825	38 984	9.3	9.5	9.6	9.7
Carbon in soil	300 425	295 073	293 232	291 662	72.1	72.2	72.2	72.3
Total carbon stock	**672 571**	**660 836**	**656 323**	**652 371**	**161.4**	**161.8**	**161.6**	**161.8**

Conclusions

The world's forests store more than 650 billion tonnes of carbon, 44 percent in the biomass, 11 percent in dead wood and litter, and 45 percent in the soil. Globally carbon stocks are decreasing as a result of the loss of forest area; however the carbon stock per hectare has remained almost constant for the period 1990–2010. According to these estimates, the world's forest is therefore a net source of emissions due to the decrease in total forest area.

Data availability and quality have improved since FRA 2005, but there are still some issues of concern. As with growing stock and biomass, trend data are weak as most countries only have national data on growing stock for one point in time. This means that changes in stocks merely reflect changes in forest area. Default carbon values for dead wood were omitted from the 2006 IPCC Guidelines and the default values on carbon in litter are very rough. For soil carbon there are some issues related to the data from countries that estimate carbon to different soil depths. Finally, some countries with large areas of forested peat land have had difficulties assessing soil carbon using the IPCC guidelines.