Chapter 4

Forest health and vitality

OVERVIEW

Forests are subject to a variety of disturbances that are themselves strongly influenced by climate. Disturbances such as fire, drought, landslides, species invasions, insect and disease outbreaks, and climatic events such as hurricanes, windstorms and ice storms influence the composition, structure and functions of forests (Dale *et al.*, 2001). Climate change is expected to affect forests' susceptibility to disturbances, as well as the frequency, intensity, duration and timing of such disturbances. For example, increased fuel loads, longer fire seasons and the occurrence of more extreme weather conditions as a consequence of a changing climate are expected to result in increased forest fire activity (Mortsch, 2006).

A changing climate will also alter the disturbance dynamics of native forest insect pests and pathogens, as well as facilitating the establishment and spread of introduced pest species. Such changes in disturbance dynamics, in addition to the direct impacts of climate change on trees and forest ecosystems, can have devastating effects and can increase forests' susceptibility to other disturbances. For example, a major storm in January 2005 – and again in 2007 – caused severe windthrow in southern Sweden, especially in middle-aged and old spruce stands resulting in increased populations of insects, notably the European spruce bark beetle, *Ips typographus.* Severe storms were also experienced in several other countries in Europe including Slovakia, where the storm of 2004/2005 affected 12 000 hectares of forest in the Tatra National Park, resulting in a severe bark beetle outbreak. Such interactions make the prediction of future impacts of climate change on forest disturbances more difficult.

All of these impacts on trees and forests will inevitably have widespread effects on the forest sector. Changes in the structure and functioning of natural ecosystems and planted forests (due to changes in temperatures and rainfall regimes) and extreme events and disasters (such as the Indian Ocean Tsunami in 2004 and storms and blizzards in China in 2008) have had adverse impacts on the productive function of forest ecosystems, which in turn affect local economies.

Pests, both native and introduced, pose one of the greatest threats to forests. Risk analysis, forecasting of future pest outbreaks and the design and implementation of cost-effective protection strategies all depend on the availability of comprehensive data at various levels. The development of phytosanitary measures to minimize transboundary movement of pests must be based on knowledge of the geographical distribution and biology of each pest – hence the need for national, regional and global data.

Continuous monitoring of forest ecosystems is an expensive process, which makes it problematic for developing countries and those with economies in transition. Even some industrialized countries do not sufficiently consider risks of pest outbreaks in their management plans. National data collection on disturbances affecting forests should provide a basis for improved planning and decision-making and will increase awareness of the severe problems related to forest insect pests and diseases worldwide, which are often overshadowed in the media by the occurrence of fire.

While some forest ecosystems depend on fire for their regeneration, some sensitive forest ecosystems can be devastated by fire, which can also cause a loss of property and human life. However, many countries do not have a reliable reporting system for

wildfires. National and global monitoring must be improved if countries are to adopt integrated approaches to fire management in an ecologically and socially acceptable way.

Data collected for FRA 2010 on forest health and vitality focused on the following, largely quantifiable categories, for which many countries record incidence and extent:

- area of forest significantly affected by insects;
- area of forest significantly affected by diseases;
- area burned (separated into areas of forest, other wooded land and other land);
- number of wildfires (separated into those affecting forests, other wooded lands and other land);
- proportion of wildfires and planned fires;
- area of forest significantly affected by other biotic factors (such as wildlife browsing, grazing and physical damage by animals);
- area of forest significantly affected by abiotic factors (such as air pollution, wind, snow, ice, floods, landslides, tropical storms, drought and tsunami);
- area of forest significantly affected by invasive species (woody species only).

Countries were also requested to list and rank up to ten major outbreaks of insects and diseases that have occurred since 1990.

The categories listed above are not exclusive; hence an area of land with two or more types of disturbance that affect the health and vitality of the forest is included under each type of disturbance. The total area affected by disturbances is, therefore, not necessarily the sum of the individual disturbances as these may overlap.

Countries were asked to provide data averaged over five years, so that large fluctuations in a single year did not significantly skew the figures. Data are thus presented for 1990 (an average of the period 1988–1992), 2000 (average of 1998–2002) and 2005 (average of 2003–2007).

To supplement the data obtained in the last assessment (FRA 2005), when only a small percentage of countries reported, a global review of forest pests and diseases was conducted (FAO, 2009a). Where appropriate, this study is referred to in this chapter in order to supplement the sometimes weak information obtained through the country reports. Similarly, a thematic study on forest fires was prepared as follow-up to FRA 2005 (FAO, 2007g).

KEY FINDINGS

Insect pests and diseases, natural disasters and invasive species are causing severe damage in some countries

Outbreaks of forest insect pests damage nearly 35 million hectares of forest annually, primarily in the temperate and boreal zones. The mountain pine beetle, *Dendroctonus ponderosae*, native to North America, has devastated more than 11 million hectares of forest in Canada and the western United States of America since the late 1990s and is spreading well beyond its normal range of occurrence in an unprecedented outbreak exacerbated by higher winter temperatures. Diseases, severe storms, blizzards and earthquakes have also damaged large areas of forest since 2000. Woody invasive species are of particular concern in SIDS, where they threaten the habitat of endemic species. Information availability and quality continue to be poor for most of these disturbances.

Forest fires are severely underreported at the global level

On average, 1 percent of all forests were reported to be significantly affected each year by forest fires. However, the area of forest affected by fires was severely underreported, with information missing from many countries, especially in Africa. Less than 10 percent of all forest fires are reported as prescribed burning; the rest are classified as wildfires.

KEY CONCLUSIONS

The overall conclusion drawn from the data supplied for FRA 2010 is that annually each type of disturbance (fire, insects, diseases, and other biotic and abiotic disturbances) usually affects less than one or two percent of the forest area, although in individual countries the affected area can be much higher. The assessment also clearly highlights the lack of timely and reliable data.

Intergovernmental efforts to gather, analyse and widely disseminate reliable country-based information on forest health factors must be further strengthened in order to provide a solid basis for decision-making and enhanced field level action. This information can provide the foundation for reliable risk analyses and the implementation of effective forest protection measures.

INSECTS AND DISEASES

Introduction

For the purposes of this report insects and diseases are discussed together as they are often co-dependent. While insects and diseases are integral components of forests and often fulfil important functions, sporadic outbreaks can have adverse effects on tree growth and survival, yield and quality of wood and non-wood forest products, wildlife habitat and the recreational, scenic and cultural value of forests.

In recent decades, two major factors have combined to increase the pest threat to forests:

- the volume, speed and variety of global trade have increased the opportunities for pests to move internationally;
- climate change appears to be increasing the likelihood of pest establishment and the severity of impacts of both native and introduced pests (see Box 4.1).

Threats to the world's forests require concerted international action. The development and implementation of phytosanitary measures is key to preventing the global movement of pests and their establishment in new areas. These measures have been developed through the International Plant Protection Convention (IPPC) and are delivered through International Standards for Phytosanitary Measures (ISPMs).

Despite the significant adverse impacts of forest pests, and indications that outbreaks are on the increase in some regions, they are still not sufficiently taken into consideration in the planning of forest management and conservation programmes. There has been no systematic attempt to gather and analyse comprehensive information on the type, scale and impact of such outbreaks at the global level.

Insect and disease problems are often either cyclical or chronic and they require long-term investment in data collection. A chronic disturbance by insects and diseases may be caused by a complex of species rather than a single entity. The complex can vary not only with the species involved, but also because of the impact of each individual species. Thus defining the beginning and end of a disturbance event can be a challenge.

Further complications arise when recording data on insect life cycles that overlap or are significantly longer than one year, or when cyclical disturbance events caused by pests last more than a year. For example, gypsy moth (*Lymantria dispar*) outbreaks of several generations can occur every seven to ten years. Capturing data on such long-term cyclical events is difficult, particularly when the length of the cycles is variable. The information supplied by countries for insect pests has been reported as annual averages over five years to help compensate for this. However, five-year reporting periods do not adequately reflect the status of long cyclical outbreaks.

Moreover, due to the longer duration of some disturbance events, it is difficult to accurately assess the area affected annually. Some countries appear to have reported the cumulative area affected in a given year, rather than the additional area of forest affected within that year. Thus the figures for the different types of disturbances are not always directly comparable.

BOX 4.1

Climate change and forest pests

Climate change – in particular increased temperatures and levels of atmospheric carbon dioxide, as well as changes in precipitation and the frequency and severity of extreme climatic events – is having notable impacts on the world's forests and the forest sector. Climate change is predicted to increase the likelihood of pest establishment in new locations and also to increase the severity of impacts of both native and introduced pests. This is likely to arise from two interrelated effects on the interactions between pests and host trees:

- Pests are likely to encounter more suitable climatic conditions for their establishment and successful development, i.e. they will survive extremes of temperature, such as winter cold or high summer temperatures, and be able to complete a full life cycle. This applies particularly to pests at the edges of the areas of climate suitability where, in the past, aspects such as low winter temperatures or lack of synchrony between pest emergence and host tree development prevented successful breeding. There is evidence that the natural ranges of pests are changing, extending the areas of forest at risk of outbreaks. Pests also tend to establish in new areas without the natural enemies that normally keep them in check.
- Potential host tree species may become more susceptible to pest development because of climate induced 'stress' caused by increased drought, extended growing seasons and generally increased vulnerability caused by extreme climatic events (e.g. flooding, extreme temperatures and violent storms).

Combined with increased climate suitability, both the opportunity to encounter trees in new locations arising from increased trade, and the capacity to establish because of a wider availability of tree hosts have substantially increased the incidences of new pest incursions globally. In addition to these increased risk factors, the fact that introduced pests often establish without the normal range of natural enemies that tend to keep them at endemic levels may influence the severity of impacts from new pests.

The quality of the data on forests significantly affected by insect pests and diseases is poor, in part because of the lack of clarity in interpreting what constitutes a 'disturbance'. Insect and disease outbreaks in developing countries are primarily surveyed and reported for planted forests, and corresponding surveys of forest decline and dieback are rare in these countries. Serious outbreak situations may be recorded, but details of causative agents and the quantifiable impact on forest resources are rarely noted. In some instances, there may be a reluctance to record severe outbreaks because management jobs or even trade in forest products can be put at risk.

For some regions, more data exist but were not readily accessible through FRA 2010 because of a lack of information exchange among sectors, individuals and government agencies, or a lack of awareness of their existence. For example, data are missing from the Democratic People's Republic of Korea, which has had an ongoing outbreak of the pine moth (*Dendrolimus spectabilis*) since 1998, affecting more than 100 000 hectares of native *Pinus densiflora*. Countries in Eastern and Southern Africa have a complexity of insect and disease problems affecting their forests (FAO, 2009a and http://www.fao.org/forestry/fisna/en/) but this is not reflected in the FRA 2010 data. Similar situations exist in many countries, where other sources indicate disturbances that are not recorded in the country reports.

For FRA 2010 more detailed information was requested than in FRA 2005 and this resulted in considerable feedback from reporting countries about problems of

data collection. Most of these comments are applicable to all regions and should be considered for FRA 2015. A number of issues were highlighted.

- Disturbances caused by insect pests, especially bark beetles and wood borers, may only be reported according to the amount of affected wood removed, rather than by the area infested: for example, in 2005, Poland reported the removal of more than 3.2 million cubic metres of infested wood. Reports may only include the actual area reforested after salvage. In addition, a forested area may be defoliated by more than one insect and this often results in an overlap of reported figures. Areas reported as defoliated may include patches that differ in the degree of defoliation severity. Areas of tree mortality caused by an insect attacking one or more species may include other tree species, which subsequently die from exposure because the stand is opened. Some areas of defoliation may be missed in the surveys.
- For diseases, it can be difficult to convert figures from the total area showing damage to an area newly affected in a year. The area damaged may be underestimated as it can be difficult to assess disease in standing trees. Diseases are very difficult to report especially in mixed planted forests; there may be spatial distribution of the disease and, especially for dispersed agents, it may be more appropriate to report the percentage of the population of the species that is infested instead of the area affected.
- For both insects and diseases, new reporting methods may have been adopted by countries between the reporting periods, making trend analysis difficult. Small areas which do not meet the definition of forest in the FRA process may be infected (by disease) or infested (by insect) and would therefore not be reported as significant. Data may be aggregated and difficult to separate or may only be available for state owned, not private, forests.
- Further complexities may be caused by diebacks and declines, as a multiplicity of biotic (insects, diseases, mammals) and abiotic factors contribute to the disturbance.

Status

Globally, information on forest insect pests and diseases is relatively sparse and the data collection methods are highly variable. Several countries could not disaggregate figures for insects and diseases. Many of the small island countries and dependent territories have not provided information for these two variables, as was the situation for FRA 2005. Reporting from Africa was also scant.

However, more countries reported for FRA 2010 than for FRA 2005. For insect damage this increased from 66 to 94 countries, which represent 53 percent of the world's forest area. East Asia, Europe and North and Central America provided reports that represented more than 90 percent of the total forest areas for these regions.

The reports indicate that close to 40 million hectares of forest per year were adversely affected by insects and diseases in 2005. The annual area of forest affected by insects alone was more than 34 million hectares, representing 1.6 percent of the forest area of the 94 reporting countries.

Tables 4.1 and 4.2 present a summary of results for the 2005 reporting period, while Figures 4.1 and 4.2 present the results by country. Table 4.1 shows that Northern Africa, North America, East Asia and Europe excluding the Russian Federation reported the highest percentage of forest area significantly affected by insect pests, while countries with tropical moist forests generally reported a very low proportion of their forests affected. This is most likely due to the high diversity of tree species in tropical moist forests.

Canada reported the highest area of insect disturbance for a single country of 17.3 million hectares. This included major outbreaks of two indigenous species in

TABLE 4.1
Average area of forest annually affected by insects by region and subregion, 2005

Region/subregion	Information availability		Area of forest affected by insects	
	Number of countries	% of total forest area	1 000 ha	% of forest area
Eastern and Southern Africa	4	4.7	n.s.	n.s.
Northern Africa	4	9.6	261	3.4
Western and Central Africa	3	4.9	2	n.s.
Total Africa	**11**	**5.3**	**263**	**0.7**
East Asia	4	97.4	4 078	1.7
South and Southeast Asia	5	26.6	985	1.2
Western and Central Asia	13	43.7	308	1.6
Total Asia	**22**	**57.2**	**5 372**	**1.6**
Europe excl. Russian Federation	36	79.4	3 458	2.3
Total Europe	**37**	**96.0**	**5 126**	**0.5**
Caribbean	7	50.0	2	0.1
Central America	3	48.0	7	0.1
North America	4	100.0	22 951	3.4
Total North and Central America	**14**	**98.0**	**22 961**	**3.3**
Total Oceania	**4**	**5.0**	**40**	**0.4**
Total South America	**6**	**15.0**	**726**	**0.5**
World	**94**	**53.0**	**34 487**	**1.6**

TABLE 4.2
Average area of forest annually affected by diseases by region and subregion, 2005

Region/subregion	Information availability		Area of forest affected by diseases	
	Number of countries	% of total forest area	1 000 ha	% of forest area
Eastern and Southern Africa	4	4.7	n.s.	n.s.
Northern Africa	2	1.3	n.s.	n.s.
Western and Central Africa	4	5.3	4	n.s.
Total Africa	**10**	**4.6**	**4**	**n.s.**
East Asia	3	92.7	349	0.2
South and Southeast Asia	4	26.2	n.s.	n.s.
Western and Central Asia	12	42.6	41	0.2
Total Asia	**19**	**54.9**	**390**	**0.1**
Europe excl. Russian Federation	33	71.8	1 786	1.3
Total Europe	**34**	**94.6**	**2 918**	**0.3**
Caribbean	6	48.9	n.s.	n.s.
Central America	1	18.9	n.s.	n.s.
North America	2	9.7	19	n.s.
Total North and Central America	**9**	**10.3**	**19**	**n.s.**
Total Oceania	**4**	**4.7**	**320**	**3.5**
Total South America	**4**	**10.5**	**113**	**0.1**
World	**80**	**36.3**	**3 764**	**0.3**

2006: the mountain pine beetle (*Dendroctonus ponderosae*), which damaged 9.2 million hectares of forest, and the forest tent caterpillar (*Malacosoma disstria*), which affected 5 million hectares.

Information on diseases is still sporadic and countries reporting on this variable represent only 36 percent of the total forest area. However, more countries reported on diseases for FRA 2010 than for FRA 2005, increasing from 57 countries to 80.

FIGURE 4.1
Average area of forest annually affected by insects by country, 2005

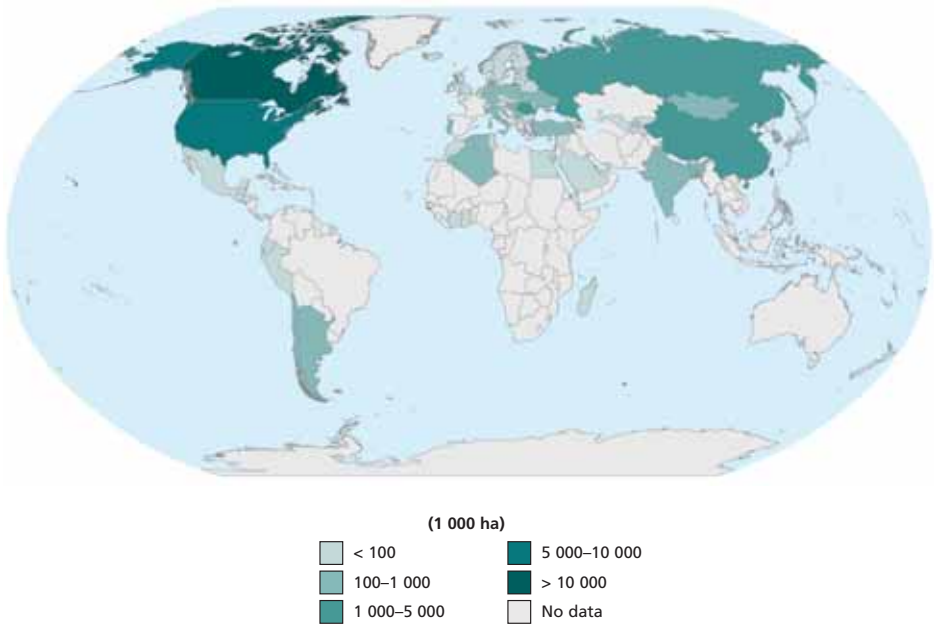
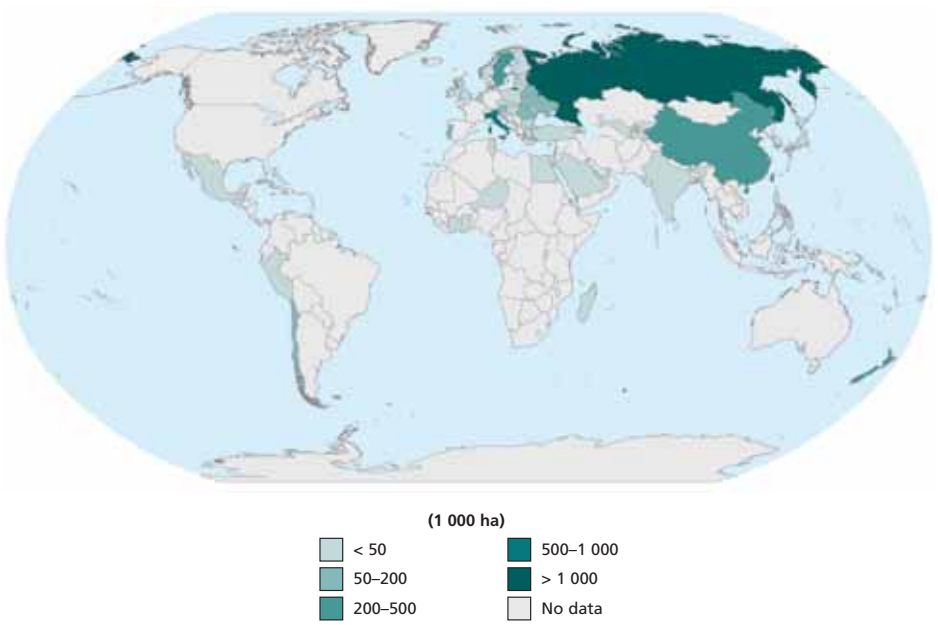


FIGURE 4.2
Average area of forest annually affected by diseases by country, 2005



Disease affected 3.8 million hectares (5-year average) representing 0.3 percent of the total forest area of the 80 reporting countries. For the 2005 reporting period, East Asia and Europe provided data for over 90 percent of the forest areas within the region. However, for many countries information on diseases was missing, not available or was recorded as zero, particularly by countries in Africa, Central and North America and the Caribbean.

No data were reported on diseases for the United States of America in this reporting period, compared with 17.4 million hectares reported for FRA 2005. This was due to substantial changes in the forest disturbances indicator design that included altering the presentation to specify the proportion of forest damage caused by non-native insects and pathogens (Heinz Center, 2008). Consequently disease data was not recorded for this reporting period.

Europe (excluding the Russian Federation) reported a high incidence of disease affecting 1.3 percent of the forest area. The Russian Federation reported disease affecting 1.1 million hectares of forest, equivalent to less than 0.2 percent of its forest area, but the causative agents were not specified.

In Oceania, New Zealand only reported diseases in planted forests; no diseases were reported in indigenous forests. In Asia the highest incidence of disease was reported for China and this represented 0.2 percent of China's total forest area; no details on causative agents were provided.

Trends

For insect infestations, of the 233 countries and areas included in FRA 2010, 69 countries, representing 49 percent of the total forest area, provided data for all periods i.e. 1990, 2000 and 2005. A further 25 countries provided data for the 2005 reporting period only.

For diseases, 58 countries provided data for all three reporting periods. A further 22 countries provided data for the 2005 reporting period only. Relatively few countries reported quantitative data, and it is therefore not possible to undertake a detailed trend analysis for the three reporting periods. As a result only regional results are presented here.

Generally speaking, no significant trends were noted and any changes within these reporting periods may be attributable to altered methods of assessment for the three periods rather than actual trends. However, there appears to be a decreasing trend in the area affected by forest insect pests for the period 1990 to 2005 in North and South America. An increase was noted in the area of forest affected by disease since 1990 in Asia (particularly East Asia) and in Europe (including the Russian Federation) (see Tables 4.3 and 4.4). It should be noted, however, that this information is indicative only. Although there are three data points in time, disease data are missing for a number of the larger forest countries such as Australia, Canada and the United States of America.

Countries were also invited to list and rank up to ten major outbreaks of insects and diseases that have occurred since 1990, recording the name of the causative agent, the tree species affected, year of outbreak, area affected (if recorded) and the outbreak cycle (see Tables 4.5 and 4.6).

Similarities were noted in insect and disease distributions among some of the regions. However, the distribution is indicative only, as many countries did not provide this information. Table 4.5 therefore includes mainly European countries. More details about many of these pest species and their distributions are available in FAO (2009a).

Conclusions

Two main conclusions can be drawn.

While usually affecting less than 2 percent of the global forest area, insect pests and diseases are causing severe damage in some countries, primarily in the temperate

TABLE 4.3
Trends in area of forest annually affected by insects by region and subregion, 1990–2005

Region/subregion	Information availability		Area of forest affected by insects					
	Number of countries	% of total forest area	1990		2000		2005	
			1 000 ha	% of forest area	1 000 ha	% of forest area	1 000 ha	% of forest area
Eastern and Southern Africa	4	4.7	0	0	n.s.	n.s.	n.s.	n.s.
Northern Africa	3	9.5	272	3.7	178	2.4	260	3.5
Western and Central Africa	2	3.2	0	0	0	0	0	0
Total Africa	**9**	**4.5**	**272**	**0.9**	**178**	**0.6**	**260**	**0.8**
East Asia	4	97.4	829	0.4	3 761	1.7	4 078	1.7
South and Southeast Asia	3	3.5	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Western and Central Asia	10	41.9	420	2.5	549	3.2	300	1.7
Total Asia	**17**	**45.2**	**1 250**	**0.6**	**4 309**	**1.7**	**4 378**	**1.7**
Europe excl. Russian Federation	26	61.3	2 673	2.4	2 292	2.0	2 747	2.3
Total Europe	**27**	**92.6**	**4 390**	**0.5**	**7 245**	**0.8**	**4 415**	**0.5**
Caribbean	5	8.8	1	0.1	0	0	0	0
Central America	1	1.5	1	0.2	1	0.2	1	0.4
North America	3	100.0	33 666	5.0	21 206	3.1	22 951	3.4
Total North and Central America	**9**	**96.2**	**33 667**	**5.0**	**21 206**	**3.1**	**22 953**	**3.4**
Total Oceania	**3**	**4.2**	**60**	**0.8**	**50**	**0.6**	**40**	**0.5**
Total South America	**4**	**10.5**	**868**	**0.9**	**533**	**0.6**	**318**	**0.3**
World	**69**	**49.3**	**40 507**	**2.1**	**33 521**	**1.7**	**32 363**	**1.6**

TABLE 4.4
Trends in area of forest annually affected by diseases by region, 1990–2005

Region	Information availability		Area of forest affected by diseases					
	Number of countries	% of total forest area	1990		2000		2005	
			1 000 ha	% of forest area	1 000 ha	% of forest area	1 000 ha	% of forest area
Africa	7	3.6	0	0	n.s.	n.s.	n.s.	n.s.
Asia	15	42.7	155	0.1	460	0.2	389	0.2
Europe	24	91.4	838	0.1	1 700	0.2	2 069	0.2
North and Central America	6	9.4	11	0	2	n.s.	19	n.s.
Oceania	3	4.2	265	3.4	240	2.9	320	3.9
South America	3	2.7	13	0.1	810	3.4	110	0.5
World	**58**	**31.7**	**1 282**	**0.1**	**3 212**	**0.3**	**2 907**	**0.2**

and boreal zones. As a recent example, the mountain pine beetle, *Dendroctonus ponderoseae*, native to North America has devastated more than 11 million hectares in Canada and the western United States of America since the late 1990s and is spreading well beyond its normal range of occurrence in an unprecedented outbreak exacerbated by milder winter temperatures.

Information availability on the area of forest significantly affected by insect pests and disease continues to be poor and data collection methods are highly variable. Methods need to be devised to obtain and analyse data on diseases in particular.

The problems with data reporting in the country reports should be taken into consideration and methods need to be devised to obtain and analyse data on diseases in particular.

TABLE 4.5
Ten most prevalent insect pests reported

Pest	Number of reports	Countries
Lymantria dispar, gypsy moth (European and Asian strains)	27	Algeria, Armenia, Belarus, Bulgaria, Croatia, Georgia, Germany, Hungary, Israel, Kyrgyzstan, Latvia, Lithuania, Lebanon, Maldives, Mongolia, Morocco, Republic of Moldova, Russian Federation, Serbia, Slovakia, Switzerland, The Former Yugoslav Republic of Macedonia, Tunisia, Turkey, Ukraine, United States of America, Uzbekistan
Ips typographus, European spruce bark beetle	19	Austria, Croatia, Czech Republic, Denmark, France, Georgia, Germany, Hungary, Latvia, Lithuania, Netherlands, Poland, Romania, Russian Federation, Serbia, Slovakia, Sweden, Switzerland, Turkey
Tortrix viridana, European oak leaf roller	10	Croatia, Czech Republic, Germany, Netherlands, Poland, Republic of Moldova, Romania, The Former Yugoslav Republic of Macedonia, Tunisia, Ukraine
Thaumetopoea pityocampa, pine processionary caterpillar	9	Albania, Algeria, Bulgaria, Croatia, Morocco, Syrian Arab Republic, The Former Yugoslav Republic of Macedonia, Tunisia, Turkey
Neodiprion sertifer, European pine sawfly	7	Belarus, Georgia, Latvia, Norway, The Former Yugoslav Republic of Macedonia, Turkey, Ukraine
Panolis flammea, pine beauty moth	7	Belarus, Germany, Latvia, Lithuania, Poland, Ukraine, United Kingdom
Pityogenes chalcographus, six-toothed spruce bark beetle	7	Austria, Croatia, Czech Republic, Germany, Serbia, Slovakia, Switzerland
Bupalus piniarius, pine looper moth	6	Estonia, Germany, Latvia, Poland, Ukraine, United Kingdom
Dendrolimus pini, pine lappet moth	6	Belarus, Georgia, Germany, Lithuania, Poland, Ukraine
Lymantria monacha, nun moth	6	Belarus, Czech Republic, Germany, Latvia, Lithuania, Poland

TABLE 4.6
Most prevalent pathogens reported

Pathogen	Number of reports	Countries
Armillaria spp., Armillaria root disease	10	Austria, Bhutan, Brazil, Croatia, Germany, Malawi, Mauritius, New Zealand, Peru, Slovakia
Cryphonectria parasitica, chestnut blight	6	Albania, Croatia, Georgia, Germany, The Former Yugoslav Republic of Macedonia, Turkey
Heterobasidion spp., annosum root rot	6	Austria, Belarus, Finland, Germany, Russian Federation, The Former Yugoslav Republic of Macedonia
Melampsora larici-populina, poplar rust	4	Belgium, France, Iceland, Uzbekistan
Mycosphaerella pini, red band needle blight	4	Belgium, Croatia, France, New Zealand
Sphaeropsis sapinea, diplodia tip blight	4	Austria, Croatia, France, Germany
Chalara fraxinea, ash dieback	3	France, Germany, Norway
Gremmeniella sp.	2	Finland, Sweden
Melampsora allii-populina, poplar rust	2	Albania, France

FOREST FIRES

Introduction

Fire is a major disturbance factor that has both beneficial and detrimental effects. Some forest ecosystems are adapted to fire and need it to retain their vigour and reproductive capacity. However fires often get out of control and destroy forest vegetation and biomass, which in turn results in considerable soil erosion by wind and water. Fires affect not only forests and their functions and services, but also other assets, human

lives and livelihoods. The damage extends to landscapes, and results in haze and deposited pollutants, as well as the release of greenhouse gases. Both uncontrolled expansion of agricultural land onto forested land and the increased use of forests for recreational purposes and tourism increase the risk of forest fires.

In relation to the loss of human lives recent examples include the forest fires in Victoria, Australia in 2009, which caused 173 fatalities (Teague, McClead and Pascoe, 2009), while fires in Greece in 2007 fires resulted in 80 dead (69 civilians, 9 seasonal fire fighters and 2 pilots) (Joint Research Centre, 2008). Many wilderness–urban interface fires (e.g. in Australia, Italy and the United States of America) have clearly shown how wildfires affect and threaten residential areas.

Status

Information on forest fires continues to be poor. Based on the data from 78 responding countries, representing 63 percent of the global forest area, an average of just under 60 million hectares of land (forests, other wooded land and other land) burned per year during the period 2003–2007 in these countries. The largest areas burnt were reported by Cameroon, Mali, Botswana, Chad, Namibia, United States of America, Ghana, Canada, Mongolia and Senegal.

Some 13 countries were able to provide information on the total area burnt, but did not specify the forest area burnt. Many of these were relatively small countries in Africa (6), Asia (2) and Central America (1), but the list also included such forest-rich countries as Brazil, Bolivarian Republic of Venezuela and Papua New Guinea.

Just over half the countries and areas included in FRA 2010 (118 out of 233) provided information on the area of forest burnt in the period 2003–2007. Based on the data from these 118 countries, which represent 65 percent of the global forest area, an average of 19.8 million hectares of forests were affected by fire annually. This area represents less than one percent of the total forest area in these countries (see Table 4.7). The highest percentages of forest area affected by fire were reported by Chad, Senegal, Ghana, Botswana and Portugal, while the largest areas of forest affected by fire were reported

TABLE 4.7
Average area of forest annually affected by fire by region and subregion, 2005

Region/subregion	Information availability		Area of forest affected by fire	
	Number of countries	% of total forest area	1 000 ha	% of forest area
Eastern and Southern Africa	8	29.3	452	0.6
Northern Africa	5	10.0	17	0.2
Western and Central Africa	8	19.7	7 849	11.9
Total Africa	**21**	**22.4**	**8 318**	**5.4**
East Asia	5	100.0	549	0.2
South and Southeast Asia	8	83.3	1 859	0.7
Western and Central Asia	16	51.7	50	0.2
Total Asia	**29**	**87.9**	**2 457**	**0.5**
Europe excl. Russian Federation	41	96.6	270	0.1
Total Europe	**42**	**99.4**	**1 262**	**0.1**
Caribbean	7	74.1	15	0.3
Central America	4	72.6	107	0.7
North America	4	100.0	3 437	0.5
Total North and Central America	**15**	**98.9**	**3 558**	**0.5**
Total Oceania	**6**	**82.5**	**3 903**	**2.4**
Total South America	**5**	**14.0**	**333**	**0.3**
World	**118**	**65.2**	**19 831**	**0.7**

by Chad, Australia, United States of America, India and Canada, which all reported an average of more than 1 million hectares of forest burnt annually (Figure 4.3).

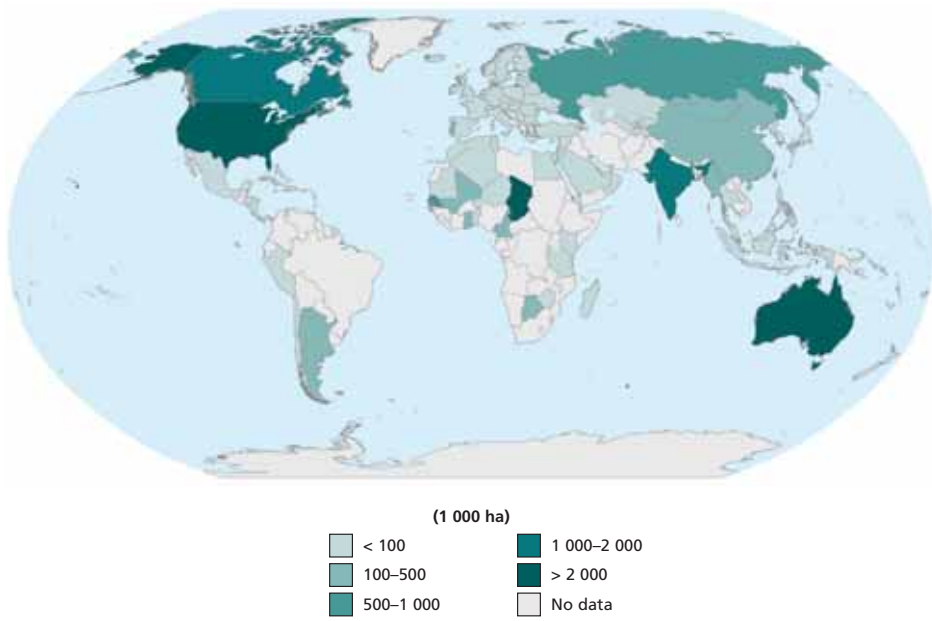
An additional 17.9 million hectares of other wooded land were significantly affected by fire each year during the period 2003–2007 in 105 countries. Although the reporting countries represent less than half the global forest area, there is a clear indication that a large proportion of fires are significantly affecting other wooded lands. This is especially the case in Africa, where large areas of other wooded land affected by fire were reported by Cameroon, Chad, Botswana, Ghana, Madagascar and Senegal. This phenomenon may be explained by the widespread use of fire as a land-use management tool.

Countries were also asked to report on the number of fires. According to information from 64 countries, representing 60 percent of the global forest area, an average of 487 000 vegetation fires occurred per year during the period 2003–2007 in forests, other wooded land and other land. Mozambique, the United States of America, Madagascar, Poland, Portugal, the Russian Federation, Spain, Argentina and Hungary top the list – all with an average of over 10 000 vegetation fires per year.

In terms of the number of forest fires, 81 countries, representing 50 percent of the global forest area, reported an average of 156 000 forest fires per year during the period 2003–2007 (i.e. an average of around 1 900 forest fires per country per year). However, as would be expected, there was great variation between countries. The largest numbers of forest fires were reported by the United States of America, the Russian Federation, India, Poland and China, which all reported an average of more than 10 000 forest fires per year. The small proportion of global forest area represented by the reporting countries makes it difficult to estimate the global number of forest fires during this period.

Countries were asked to estimate how large a proportion of the area burnt was caused by wildfire as opposed to planned fires. Some 87 countries, accounting for 77 percent of the world's forests, provided this information for the period 2003–2007.

FIGURE 4.3
Average area of forest annually affected by fire by country, 2005



In these countries an estimated 94 percent of the total forest area affected by fire was due to wildfires and only 6 percent due to planned fires. Although these countries represent a high proportion of the global forest area, more information is needed to confirm this figure. In many cases the information seems to be based on expert estimates rather than on national registration systems.

Trends

A total of 96 countries, accounting for 59 percent of the total forest area in the world, provided information on the area of forest burnt for all three reporting periods (1990, 2000 and 2005). The total area burnt (forest, other wooded land and other land combined) for all three periods was reported by 52 countries, accounting for 58 percent of the forest area. Information on the area of other wooded land and other land burnt for all three periods was reported by 87 and 29 countries respectively, together accounting for 43 and 21 percent of the forest area.

Both the total area affected by fires and the forest area affected by fires are lower in recent years compared with the period around 1990. However, whether this can be interpreted as a consistent trend is debatable, given the lack of comprehensive information and the nature of fires, which are closely linked to climatic fluctuations such as the El Niño phenomenon in some countries and regions. It is an encouraging sign that countries such as Thailand and Indonesia have significantly reduced the area of forest burnt annually, although it is too early to tell the impact of fires in 2010 which is predicted to be another strong El Niño year.

Table 4.8 shows the subregional and regional figures for the three reporting periods for those countries that provided a complete data series.

The number of forest fires has decreased slightly over the years while the proportion of wildland fires has remained relatively constant for the reporting countries. Information was provided on the number of forest fires for all three reporting periods by only 61 countries (accounting for 45 percent of total forest area) and this variable may be considered less useful in future assessments. The proportion of the area burned

TABLE 4.8
Trends in area of forest annually affected by fire by region and subregion, 1990–2005

Region/subregion	Information availability		Area of forest affected by fire (1 000 ha)		
	Number of countries	% of total forest area	1990	2000	2005
Eastern and Southern Africa	6	25.0	88	50	53
Northern Africa	4	9.6	14	21	16
Western and Central Africa	4	9.2	12 141	8 462	7 157
Total Africa	**14**	**15.6**	**12 243**	**8 533**	**7 226**
East Asia	5	100.0	318	417	549
South and Southeast Asia	7	82.2	3 090	2 149	1 852
Western and Central Asia	13	48.7	19	79	47
Total Asia	**25**	**87.1**	**3 427**	**2 644**	**2 448**
Europe excl. Russian Federation	36	80.2	273	225	261
Total Europe	**37**	**96.2**	**896**	**1 387**	**1 252**
Caribbean	6	73.8	11	18	15
Central America	0	–	–	–	–
North America	4	100.0	2 781	3 112	3 437
Total North and Central America	**10**	**96.8**	**2 793**	**3 130**	**3 452**
Total Oceania	**5**	**4.2**	**0**	**0**	**0**
Total South America	**5**	**14.0**	**490**	**708**	**333**
World	**96**	**59.0**	**19 849**	**16 402**	**14 710**

that was caused by wildfire as opposed to planned fires was reported for all three periods by 73 countries (representing 56 percent of the total forest area) and showed no significant change over time.

Box 4.2 illustrates the type of analysis that can be undertaken for countries where information on forest fires is more readily available.

BOX 4.2

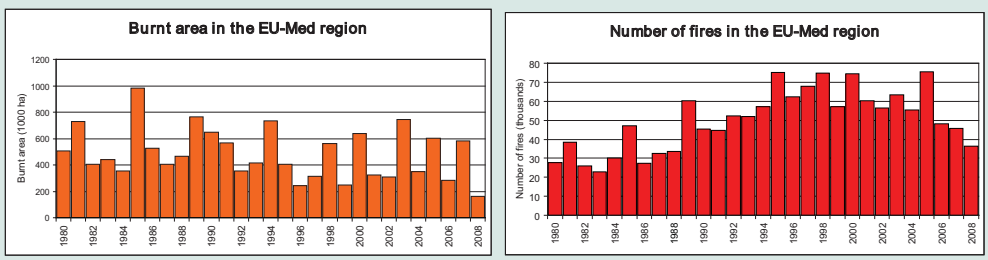
Trends in forest fires in Europe

Although forest fires are an integral part of forest dynamics in Europe, trends in fire frequency and fire impact have changed throughout the years. The data for this analysis were extracted from the European Fire Database in the European Forest Fire Information System (EFFIS). These data include single fire records provided by the individual European countries in the EFFIS network. Currently, data from 21 countries are available in this database, although the network is made up of 26 countries. The number of years for which data are available differs between countries, with the time series for the Mediterranean region being the longest.

Fire frequency is determined by the annual number of fires in a country. A derived measure of fire frequency is fire density, which is estimated as the number of fires by area (in this case 10 square km). Due to the fact that most of the fires in Europe take place in the Mediterranean region, fire figures are presented for the Mediterranean region, and separately for the rest of Europe. Figure 4.4 presents the number of fires and the total burnt area in the Mediterranean region in the last decades. The figure shows a slightly decreasing trend in the number of fires during recent years. However, the trend in the burnt areas is not obvious. Years with a large fire impact are next to years with minor fire effects.

FIGURE 4.4

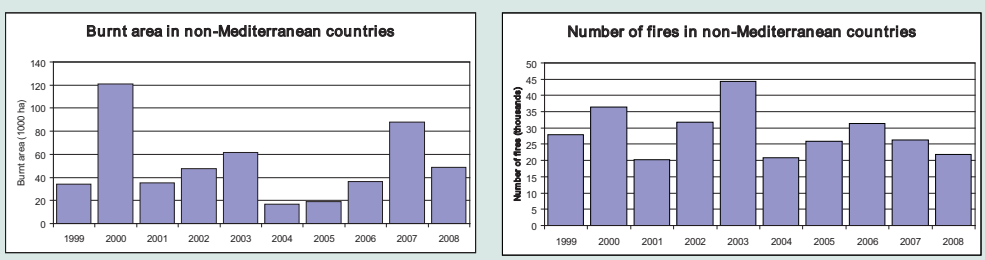
Number of fires and burnt area in the EU-Mediterranean region



The non-Mediterranean countries do not show clear trends in the number of fires or the total burnt area. The number of fires and the total burnt area in this part of Europe are presented in Figure 4.5.

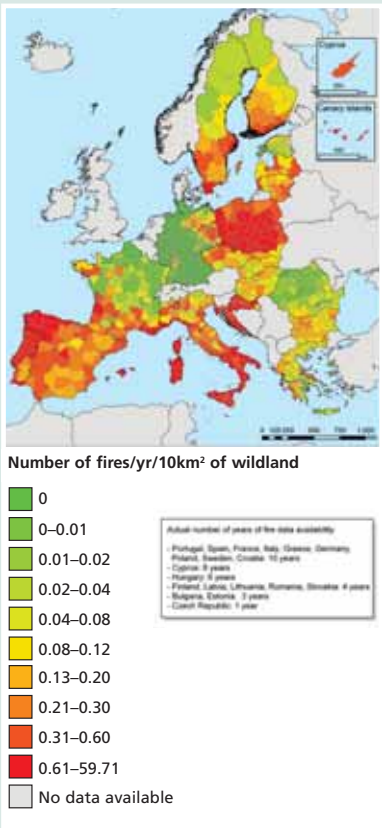
FIGURE 4.5

Number of fires and total burnt area in the non-Mediterranean region



Fire frequency expressed as average forest fire density provides information on the spatial distribution of forest fires. Fire density in Europe and total burnt area by country and forest area (burnt fraction) in each country are shown in Figure 4.6.

FIGURE 4.6
Average forest fire density and average burned forest fraction in Europe, 1998–2007



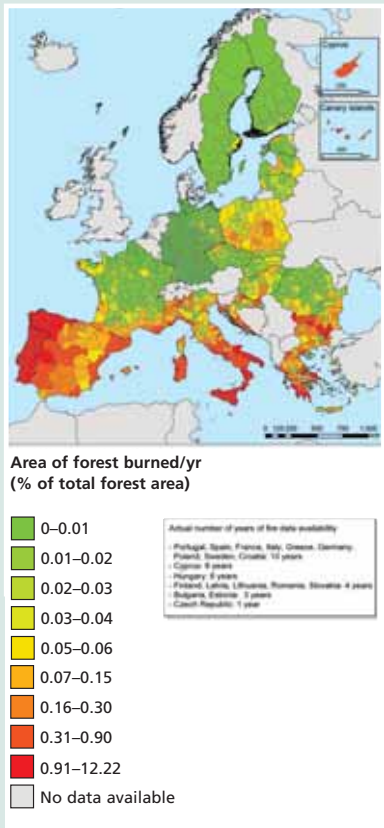


Figure 4.6 shows that fires are not confined to the Mediterranean region, although the largest impact in terms of burnt areas occurs in this region. Fire density in the northern and eastern regions of Europe can also be high; however, the extent of these fires is not large due to the weather conditions under which they occur. Analysis of the data in EFFIS showed a very close correlation between fire danger, which represents the weather conditions, and the total burnt area for the overall Mediterranean region.

Source: European Commission, 2009

Notes:
Mediterranean countries included in this study: Cyprus, France, Greece, Italy, Portugal and Spain.

Non-Mediterranean countries included in this study: Bulgaria, Croatia, Czech Republic, Estonia, Finland, Germany, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Sweden, Switzerland and Turkey.

Conclusions

On average, 1 percent of all forests were reported to be significantly affected each year by forest fires. However, the area of forest affected by fires was severely underreported, with information missing from many countries, especially in Africa. Less than 10 percent of all forest fires are reported as prescribed burning; the rest are classified as wildfires.

Data on the extent of forest affected by fires contribute to our understanding of fires, and thus to the development of appropriate risk management strategies. Even when data on fire frequency and areas burned are available, disaggregation of this data into different kinds of vegetation (forests, other wooded land and other land) is often lacking. Additional information is needed on the ecological dynamics of fire, direct and underlying causes, impacts and the desired long-term ecosystem condition (e.g. structure, species composition and health).

The use of remote sensing for forest fire monitoring should be encouraged, particularly for countries in Africa, which seems to be the continent most affected by wildfires. Yet reporting on the extent of fires and their impacts on forests and other wooded land is missing for many counties in this region.

OTHER DISTURBANCES

Introduction

For the purposes of the FRA 2010 report, other disturbances include a range of biotic and abiotic factors, as well as the spread of invasive (woody) species.

Disturbance by biotic factors includes damage by biotic agents other than insects or diseases, such as wildlife browsing, bark stripping, grazing or other physical damage by animals. In general, information on disturbances attributed to these factors is highly erratic and open to interpretation, with a broad range of causative agents. Problems reported include possums, camels, beavers, deer, rodents (particularly squirrels and rats), lagomorphs (hares and rabbits), plus mites and nematodes (especially the quarantine pest, the pine wood nematode, *Bursaphelenchus xylophilus*).

The impact of mammalian browsing (as noted with possums in the New Zealand country report for FRA 2010) can vary within plant populations, communities and ecosystems, and is influenced by a range of biotic and abiotic factors, which may predispose plant communities to browsing damage. Selective browsing on some species may have a gradual effect on forest composition, with some species disappearing from certain areas.

Abiotic disturbances, including climatic events such as storms, drought, wind, snow, ice and floods, have always influenced forest ecosystems and are considered important for maintaining biological diversity and facilitating forest regeneration. However, global climate change, primarily the result of human activities, is reportedly making forest ecosystems more prone to damage by altering the frequency, intensity and timing of fire events, hurricanes, storms, landslides, and insect and disease outbreaks. Climate-related shifts in the range of pest species, many of which are forest-dependent, can further exacerbate abiotic impacts on forest health.

In European forests where timber production is a major objective, heavy storms can create significant economic, ecological and social problems and together with fire are likely to be the most important, large-scale disturbance to stands of both natural and managed forests. Catastrophic storms tend to occur every five to ten years in Europe; however due to the effects of climate change, change in wind patterns or oceanic currents and general increased variability in meteorological events, the period between destructive storms could change in the coming years or decades. These storms are becoming of such concern that the Directorate-General for the Environment of the European Commission is preparing a study on destructive storms entitled *Destructive Storms in European Forests: Past and Forthcoming Impacts*.

To supplement the information in FRA 2010, and in acknowledgement of the increasing importance of abiotic influences on forest health, FAO will prepare a more detailed study in 2011.

Several disturbance factors such as illegal logging, encroachment, overharvesting and other unsustainable management practices were not included in the reporting for FRA 2010 because of a lack of quantitative information in most countries. However, some countries did report on disturbances caused by human interference. For instance, several countries commented on overharvesting through illegal cutting, encroachment and habitat degradation from excessive hunting and tourism as significant causes of disturbance to forest and other wooded land.

Status

Reporting of other biotic and abiotic disturbances was more detailed in FRA 2010 than in FRA 2005. However, in general, information on disturbances attributed to these factors was highly sporadic, with a broad range of causative agents. While some categories have broad relevance (e.g. storms and wind), other data have relevance to relatively isolated areas (e.g. specific animal species). Furthermore, there may only be occasional reporting after a major storm or other major weather event and most often the volume of wood that is damaged is reported (e.g. through salvage felling reports) but not the area affected. Thus few of the data are comparable and it has not been possible to carry out a separate analysis for each of the disturbances caused by biotic and abiotic influences.

For the 2005 reporting period 60 countries, accounting for only 13 percent of the total forest area, reported that biotic agents affected close to 30 million hectares of forest, and 60 countries (together representing 27 percent of the world's forest area) reported that abiotic factors affected 8 million hectares of forest. However, there appears to be a wide range of interpretations of the term 'significantly affected by' with some countries reporting on the total area in which one of the factors has been recorded, regardless of the severity of the impact, while others have applied a more strict definition of damage.

In Asia, India recorded some 25.5 million hectares of forests as being affected by grazing by domestic animals and 4.4 million hectares by abiotic disturbances. China reported approximately 0.75 million hectares of forests affected by rat damage. The UK noted that present mammal damage was likely to have been persistent for many years so the presence of new damage did not necessarily imply that the area was newly affected. There may also be overlaps between the areas recorded with mammal bark stripping and mammal browsing.

Since the last assessment (FRA 2005) there have been some major catastrophic events including the Indian Ocean tsunami in December 2004 (not fully reported in FRA 2005). The tsunami took over 200 000 lives and destroyed livelihoods and infrastructure all around the Indian Ocean. Among other damage, trees were snapped, uprooted and undermined by waves and strong currents associated with the tsunami. In addition to the physical damage, some trees – particularly planted trees – were affected by soil salination. Reports that intact coastal forest (including mangroves) provided protection against the tsunami prompted the affected countries to call for the establishment of coastal buffer zones or greenbelts (FAO, 2006c). For the FRA 2010 assessment, the Maldives reported considerable destruction of trees and forest vegetation caused by the tsunami, but neither Thailand nor Indonesia reported damage.

In Europe, Sweden recorded 1.8 million hectares affected by biotic factors and 1.2 million hectares affected by abiotic factors including a major storm in January 2005 which caused severe windthrow in the south of the country, especially affecting middle-aged and old spruce stands. The same storms that contributed to extensive windthrow in 2005 (and 2007) resulted in increased populations of some insects,

notably *Ips typographus.* The Russian Federation reported that abiotic factors affected 1.3 million hectares of forests and Italy reported snow, storm and drought affecting 0.5 million hectares of forest.

Storms and blizzards in January 2008 caused great damage to 18.6 million hectares of forest in eight provinces in China including Hunan; 1 781 state-owned farms and 1 200 nurseries were severely damaged, while 760 tonnes of tree seed and 10 billion seedlings were frozen (State Forestry Administration, 2008). In addition to a catastrophic loss of human life and destruction of towns and villages, the earthquake in Wenchaun, Sichuan Province, China in 2008 caused forest fragmentation and severely damaged ecosystems that support some of the last remaining giant panda (*Ailuropoda melanoleuca*) populations in the wild (Xu *et al.*, 2009). No reference to either of these extreme events was made in China's country report.

Disturbances in Africa were generally not quantified. The disturbance caused by cyclones remains irregular and thus unpredictable, particularly for small islands such as Mauritius. The severe drought of the 1970s and 1980s which affected the mangrove ecosystem in the Gambia was reported but again no quantitative data were available.

The impact of woody invasive species on forest health and vitality is causing increasing concern and 48 countries listed up to five invasive species each. Several species may be found in more than one country and in more than one region (see Table 4.9). Some countries included data on the area of forest affected. The United States of America recorded 34 million hectares of forest affected by five woody invasive species (including shrubs and vines). Sudan recorded 1.6 million hectares affected by *Prosopis chilensis*. In relative terms, small island states and territories such as French Polynesia, Réunion and Mayotte recorded the largest proportion of their forests affected by invasive woody species (from 35 to 65 percent of the total forest area).

It should be noted that methodologies for monitoring invasive species may not exist in some countries, may not be applicable, or may only be suitable for one genus (e.g. acacias in Portugal which are recorded through an individualized area evaluation in the national forest inventory). Herbaceous weeds may also be included and the area of invasiveness may include overlapping species.

TABLE 4.9
Most prevalent woody invasive species reported

Species	Number of reports	Countries
Acacia spp. including: *Acacia* sp. (3 reports) *A. mangium* (3) *A. dealbata* (2) *A. auriculiformis* (2) *A. cyanophylla* (1) *A. farnesiana* (1) *A. salicina* (1) *A. saligna* (1) *A. victoriae* (1)	10	Cook Islands, Cuba, Cyprus, Israel, Liberia, Portugal, Réunion, South Africa, Spain, Trinidad and Tobago
Ailanthus altissima	6	Bulgaria, Cyprus, Hungary, Italy, Spain, United States of America
Prosopis juliflora	6	Chad, Ethiopia, Mauritania, Niger, Saudi Arabia, Yemen
Acer negundo	5	Austria, France, Hungary, Poland, Spain
Lantana camara	5	Bhutan, New Caledonia, Réunion, Swaziland, South Africa
Leucaena leucocephala	5	Barbados, Bhutan, Jamaica, Liberia, New Caledonia
Prunus serotina	5	Belgium, France, Luxembourg, Netherlands, Poland
Robinia pseudoacacia	5	Croatia, Italy, Poland, Slovenia, Switzerland
Amorpha fruticosa	3	Bulgaria, Croatia, Hungary

Trends

Of the 233 countries and areas included in FRA 2010, 45 countries reported on the area of forest affected by biotic factors other than insects and diseases for all three reporting periods (i.e. 1990, 2000 and 2005), representing a mere 10 percent of the total forest area. A further 15 countries reported for the 2005 reporting period only. Data were provided by 45 countries on the area of forest affected by abiotic factors other than fire for all three reporting periods, together accounting for 24 percent of the total forest area. A further 15 countries provided data for the 2005 reporting period only.

At this point in time, there is insufficient quantitative information for a trend analysis.

Conclusions

Information on disturbances caused by biotic and abiotic factors other than insects, disease and fire was very sporadic and included a broad range of causative agents – some of them very localized – making an aggregation and comparison between countries and regions virtually impossible.

Major factors reported included storms, domestic animals and damage by wildlife including rats. The impact of woody invasive species on forest health and vitality is causing increasing concern – particularly in SIDS, where they threaten the habitat of endemic species.

An international agreement on what constitutes a disturbance and how best to obtain and analyse data would assist with future data collection and reporting.