Global demand for wood products

Demand for wood products is one of the main drivers of investment in forest management. Although short-term market changes influence individual decision-making, long-term changes in demand have a greater influence on investments in forestry and forest industry at the aggregate level. This chapter projects some of the long-term changes in the demand for wood products (based on FAO, 2008c).

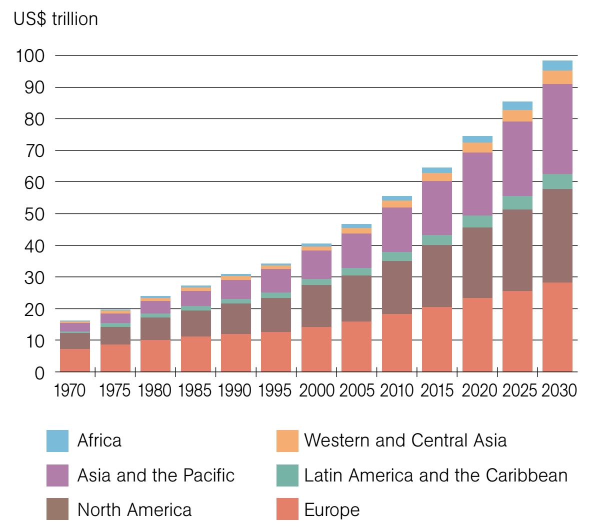
DRIVERS OF CHANGE

The main factors affecting long-term global demand for wood products include:

- Demographic changes: the world's population is projected to increase from 6.4 billion in 2005 to 7.5 billion in 2020 and 8.2 billion in 2030.
- Continued economic growth: global GDP increased from about US$16 trillion in 1970 to US$47 trillion in 2005 (at 2005 prices and exchange rates) and is projected to grow to almost US$100 trillion by 2030 (Figure 50).
- Regional shifts: developed economies accounted for most of the GDP in the period 1970–2005. The rapid growth of developing economies, especially in Asia, will swing the balance significantly in the next 25 years.
- Environmental policies and regulations: more forests will be excluded from wood production.
- Energy policies: the use of biomass, including wood, is increasingly encouraged.

Other important factors in the wood products outlook include a decline in harvesting from natural forests and the emergence of planted forests as the major source of wood supply (Box 31), and technological developments such as increased plantation productivity through tree improvement, reduced wood requirements owing to expanded recycling, higher recovery, wider use of new composite products and production of cellulosic biofuel (see the chapter "Developments in forest science and technology" in Part 2).

FIGURE 50 Global gross domestic product



NOTE: 2005 prices and exchange rates.
SOURCES: FAO, 2008a, 2008c.

OUTLOOK

Sawnwood

Long-term annual growth in sawnwood production and consumption was about 1.1 percent globally in the period 1965–1990, but declined drastically from 1990 to 1995, mostly as a result of reductions in Eastern Europe and the former Soviet Union (Table 21; Figure 51). Sawnwood production and consumption have also declined in Asia and the Pacific since 1995.

Europe and North America account for about two-thirds of global sawnwood production and consumption and are net exporters of sawnwood. Latin America and the Caribbean, the other net exporting region, accounts for almost 10 percent of production, while Asia and the Pacific accounts for slightly more than 15 percent of production and is the world's main net importing region. Production and consumption of sawnwood in Africa and in Western and Central Asia are modest, amounting to less than 5 percent of the global total between them.

BOX 31 Outlook for wood production from planted forests

The world's forest plantation area, as reported to the Global Forest Resources Assessment 2005 (FAO, 2006a), is 140.8 million hectares. The area of planted forests, defined more broadly to include the planted component of semi-natural forests, is estimated to be 271 million hectares (FAO, 2006b).

The outlook for global wood production from planted forests to 2030 was estimated based on a survey of planted forests in 61 countries, representing about 95 percent of the estimated global planted forest area (FAO, 2006b). The outlook was calculated based on predicted changes in planted forest area (mainly through new plantings) as well as opportunities for increased productivity from more efficient management practices, new technology and genetic improvements, following three scenarios:

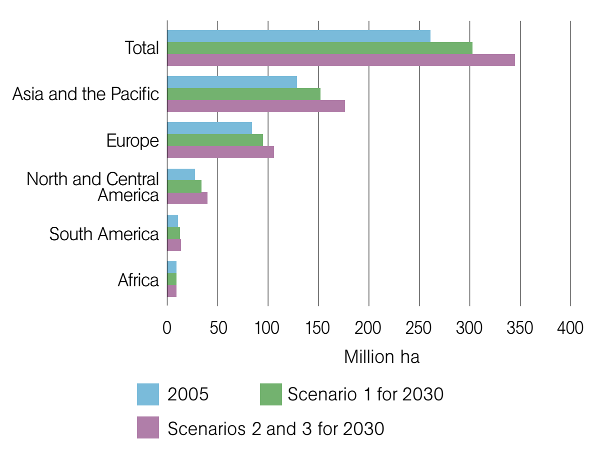
- Scenario 1: increase in planted forests slowing to half the pace of previous trends (owing to constraints including lack of suitable land and slow growth in demand), with no change in productivity;
- Scenario 2: area changes continuing at the current rate until 2030, without productivity increases;
- Scenario 3: area changes continuing at the current rate until 2030, with an annual productivity increase (for those management schemes where genetic, management or technological improvements are expected).

The model results indicate that the area of planted forests will increase in all scenarios in all regions except Africa, with the highest increase in Asia (figure on the left). Among species groups, the highest increase will be in pine forests.

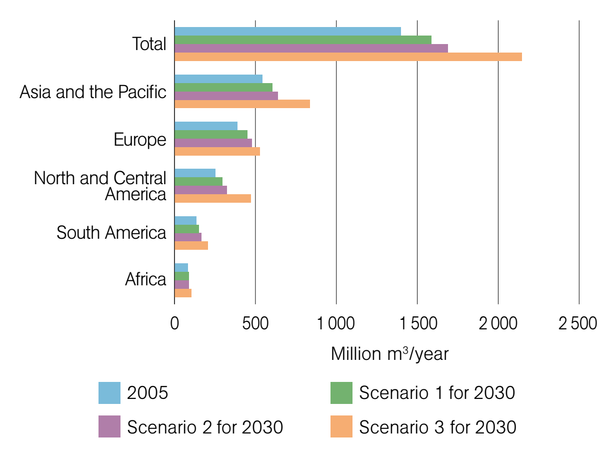
The total wood volume produced will increase across all scenarios from 2005 to 2030 (figure on the right). The widest variation among scenarios is in Asia and South America, where the higher-productivity Scenario 3 gives a considerable increase in wood production, mainly in eucalyptus and other hardwood species. The differences between Scenarios 1 and 2 are small, as additional planted area in Scenario 2 may not generate wood within the period of the projection.

Actual production could vary significantly from the projections. Often, planted forests are not harvested even on reaching maturity, particularly when they are established without considering access to markets and potential end uses.

Current and projected planted forest area in 61 countries



Current and projected wood production from planted forests in 61 countries



SOURCE: Carle and Holmgren, 2008.

Views from CPF partners

Timber and the future of tropical forests

From the International Tropical Timber Organization (ITTO)

Large-scale payments for ecosystem services (especially for climate-related services) offer the best prospect for generating funds to secure the tropical forest resource base. However, the main source of income from tropical forests remains timber and wood products. Annual exports of primary and secondary wood products from tropical forests have exceeded US$20 billion in recent years, with further increases foreseen as more countries focus exports on higher-valued secondary wood products.

Much of the raw material already comes from planted forests. The vast areas of degraded forest land in the tropics provide much scope for further increasing planted area, with potential benefits for the wood-processing sector and opportunities for capturing funds from emerging greenhouse gas markets. However, it is important to ensure that payments for ecosystem services do not lead countries to convert natural forest to fast-growing plantations.

Certification and public-purchasing policies are likely to become more important for exporters of tropical wood products in the future, especially as more countries begin to insist on evidence of sustainability, including China (in response to demands from its own export markets). Cellulosic biofuels are likely to provide economic alternatives for tropical countries, but technology transfer from developed countries will be required in order to realize this potential.

The main challenge in the future, as now, will be to add value to tropical forests so that deforestation becomes an economically unattractive option. Despite the potential of new funding mechanisms for tropical forests, it is highly likely that there will be less money available than required.

TABLE 21
Production and consumption of sawnwood

Region	Amount (million m^3)					Average annual change (%)			
	Actual			Projected		Actual		Projected	
	1965	1990	2005	2020	2030	1965–1990	1990–2005	2005–2020	2020–2030
Production									
Africa	3	8	9	11	14	3.7	0.5	1.6	1.9
Asia and the Pacific	64	105	71	83	97	2.0	−2.6	1.1	1.6
Europe	189	192	136	175	201	0.1	−2.2	1.7	1.4
Latin America and the Caribbean	12	27	39	50	60	3.3	2.5	1.7	2.0
North America	88	128	156	191	219	1.5	1.3	1.4	1.4
Western and Central Asia	2	6	7	10	13	4.6	1.5	2.6	2.2
World	**358**	**465**	**417**	**520**	**603**	**1.1**	**−0.7**	**1.5**	**1.5**
Consumption									
Africa	4	10	12	19	26	3.6	1.2	2.8	3.5
Asia and the Pacific	64	112	84	97	113	2.3	−1.9	1.0	1.6
Europe	191	199	121	151	171	0.2	−3.3	1.5	1.2
Latin America and the Caribbean	11	26	32	42	50	3.3	1.5	1.7	1.8
North America	84	117	158	188	211	1.3	2.0	1.2	1.2
Western and Central Asia	3	7	13	18	23	4.0	3.7	2.5	2.2
World	**358**	**471**	**421**	**515**	**594**	**1.1**	**−0.8**	**1.4**	**1.4**

NOTE: Data presented are subject to rounding.
SOURCES: FAO, 2008a, 2008c.

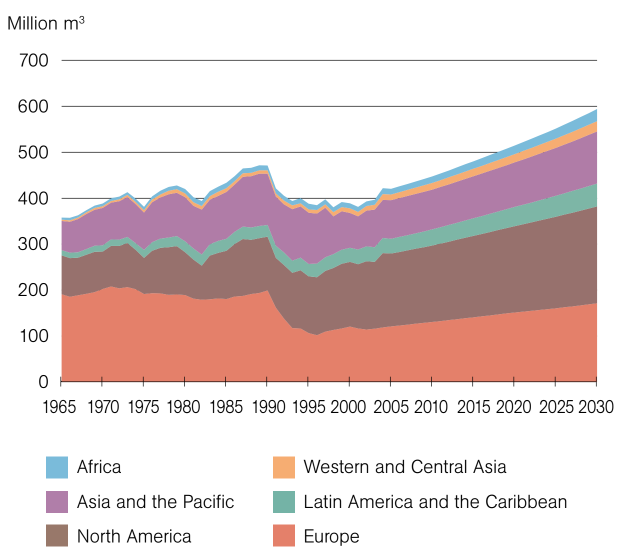
Projections suggest that the distribution of production and consumption among different regions will not change markedly before 2030, but that growth will increase at the global level. Production growth is expected to be highest in the Russian Federation, Eastern Europe and South America. High growth in consumption is expected in Africa and in Asia and the Pacific. These regions, together with Western and Central Asia, will remain dependent on imports to meet their demand. Consumption growth in developed countries is expected to be more moderate because of replacement by engineered (composite) wood products.

Wood-based panels

Although production and consumption of wood-based panels – including plywood, veneer sheets, particleboard and fibreboard – are currently only half those of sawnwood, their higher growth rates will bring them to the levels of sawnwood by 2030 (Table 22; Figure 52). However, future growth in production and consumption will be slightly slower than in the past in most regions, which suggests that the substitution of wood-based panels for sawnwood may be slowing.

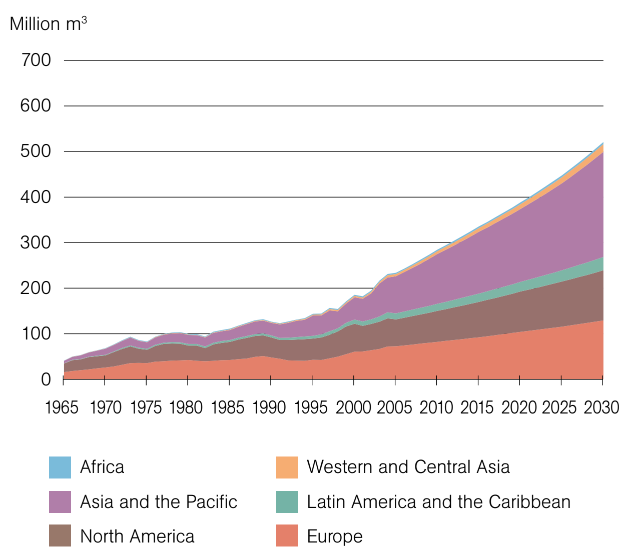
Production and consumption are currently evenly balanced among the three main markets (Asia and the Pacific, Europe and North America). Asia and the Pacific will account for a greater proportion of global wood-based panel production and consumption in the future.

FIGURE 51 Sawnwood production



SOURCES: FAO, 2008a, 2008c.

FIGURE 52 Global wood-based panel production



SOURCES: FAO, 2008a, 2008c.

TABLE 22
Production and consumption of wood-based panels

Region	Amount (million m³)					Average annual change (%)			
	Actual			Projected		Actual		Projected	
	1965	1990	2005	2020	2030	1965–1990	1990–2005	2005–2020	2020–2030
Production									
Africa	1	2	3	4	5	4.6	3.8	2.1	2.4
Asia and the Pacific	5	27	81	160	231	6.9	7.5	4.6	3.7
Europe	16	48	73	104	129	4.5	2.8	2.4	2.2
Latin America and the Caribbean	1	4	13	21	29	7.4	7.6	3.3	3.2
North America	19	44	59	88	110	3.4	2.0	2.7	2.2
Western and Central Asia	0	1	5	11	17	6.8	8.9	5.4	4.7
World	**41**	**127**	**234**	**388**	**521**	**4.6**	**4.2**	**3.4**	**3.0**
Consumption									
Africa	0	1	3	4	5	4.8	5.3	1.9	2.4
Asia and the Pacific	4	24	79	161	236	7.4	8.2	4.8	3.9
Europe	16	53	70	99	122	4.9	1.9	2.4	2.1
Latin America and the Caribbean	1	4	9	12	15	7.0	5.7	2.2	2.3
North America	20	43	70	96	115	3.1	3.3	2.1	1.8
Western and Central Asia	0	2	9	18	28	8.1	10.6	4.5	4.5
World	**42**	**128**	**241**	**391**	**521**	**4.6**	**4.3**	**3.3**	**2.9**

NOTE: Data presented are subject to rounding.
SOURCES: FAO, 2008a; FAO, 2008c.

Within the category of wood-based panels, there is an increasing shift from plywood (which accounted for most of the wood-based panel production and consumption in the 1960s) to particleboard and fibreboard. This shift, which has important implications for wood raw-material requirements, began in Europe (where particleboard and fibreboard accounted for 90 percent of the panel market in 2005) and has continued in North America (70 percent). It has only recently started to occur in Asia and the Pacific, where plywood still accounts for more than half of production and consumption, with two main producers (Indonesia and Malaysia) and two main consumers (China and Japan).

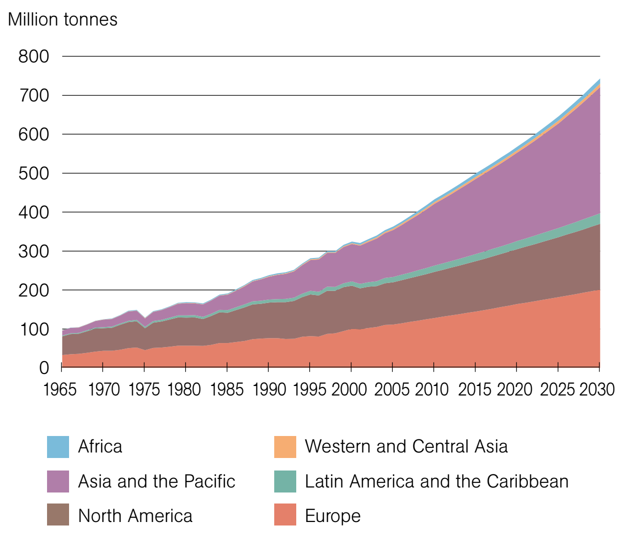
Asia and the Pacific, Europe and Latin America and the Caribbean are net exporting regions, while the others are net importers. Europe exports mainly particleboard and fibreboard, while the other two regions export plywood. These trends are expected to continue, with international trade accounting for about 26–27 percent of global production and consumption.

Paper and paperboard

As with panel products, global production of paper and paperboard is also expanding rapidly (although less so than in recent decades), with an annual growth rate of 3.7 percent between 1965 and 1990 and 2.8 percent between 1990 and 2005. Growth rates for consumption have been about the same as those for production (Table 23; Figure 53).

Historically, North America dominated global production and consumption, but because of rapid growth in Asia and the Pacific and Europe, all three major markets now account for a similar share. The rapid growth in Asia and the Pacific is a consequence of the high rate of economic growth in recent decades, first in Japan and a few other industrializing economies and more recently in China and India.

FIGURE 53 Global paper and paperboard production



SOURCES: FAO, 2008a, 2008c.

TABLE 23
Production and consumption of paper and paperboard

Region	Amount (million tonnes)					Average annual change (%)			
	Actual			Projected		Actual		Projected	
	1965	1990	2005	2020	2030	1965–1990	1990–2005	2005–2020	2020–2030
Production									
Africa	1	3	5	9	13	6.4	4.3	3.9	3.7
Asia and the Pacific	13	58	121	227	324	6.3	5.0	4.3	3.6
Europe	33	76	111	164	201	3.4	2.6	2.6	2.1
Latin America and the Caribbean	2	8	14	21	27	5.7	3.6	2.9	2.7
North America	48	91	109	141	169	2.6	1.2	1.8	1.8
Western and Central Asia	0	1	3	6	9	9.2	5.9	4.2	3.5
World	**96**	**238**	**363**	**568**	**743**	**3.7**	**2.8**	**3.0**	**2.7**
Consumption									
Africa	1	4	7	14	21	5.1	4.2	4.6	4.4
Asia and the Pacific	13	63	128	234	329	6.3	4.9	4.1	3.5
Europe	32	73	101	147	180	3.3	2.2	2.6	2.0
Latin America and the Caribbean	3	9	16	24	31	4.7	3.9	2.9	2.6
North America	46	87	106	138	165	2.6	1.3	1.8	1.8
Western and Central Asia	0	3	8	14	20	7.5	7.5	4.0	3.4
World	**96**	**237**	**365**	**571**	**747**	**3.7**	**2.9**	**3.0**	**2.7**

NOTE: Data presented are subject to rounding.
SOURCES: FAO, 2008a, 2008c.

In Europe, production growth has been driven partly by the expansion of exports; Europe is the largest exporter of paper products. On the supply side, European production has also benefited from high growth in wastepaper recovery.

The differences in past and future growth also reflect the structure of the paper and paperboard markets and industry in the three main regions:

- Currently, global newsprint production is divided roughly equally among Asia and the Pacific, Europe and North America, but growth is slowing because of the rapid spread of electronic media.
- Asia and the Pacific and Europe produce far more printing and writing paper than North America.
- Production of other paper and paperboard is highest in Asia and the Pacific.

Paper and paperboard is one of the most globalized commodity groups, with a high share of production exported and a high share of consumption imported. International trade expanded significantly in the 1990s, especially in Europe, and the globalization of paper and paperboard markets will continue in the future.

Industrial roundwood

Industrial roundwood demand is derived from growth in demand for end products – sawnwood, wood-based panels and paper and paperboard. Wood requirements for these products vary depending on the technology employed and the potential to use wood and fibre waste. Growth in sawnwood production requires more industrial roundwood, whereas a shift to reconstituted panel production (particleboard and fibreboard) increases the potential to use wood residues and fibre waste, reducing industrial roundwood requirements. Recycling policies have led to increased use of recovered paper and reduced pulpwood demand.

Increased use of wood residues and recycled materials will reduce the share of industrial roundwood in total wood and fibre use from almost 70 percent in 2005 to about 50 percent in 2030.

The total derived demand in wood raw-material equivalent (WRME) is higher than the consumption of industrial roundwood. In 2005, global derived demand amounted to about 2.5 billion cubic metres WRME, of which 1.7 billion cubic metres was industrial roundwood. Approximately 0.5 billion cubic metres WRME came from recovered paper and the remainder from wood-processing residues, recovered wood products and other sources.

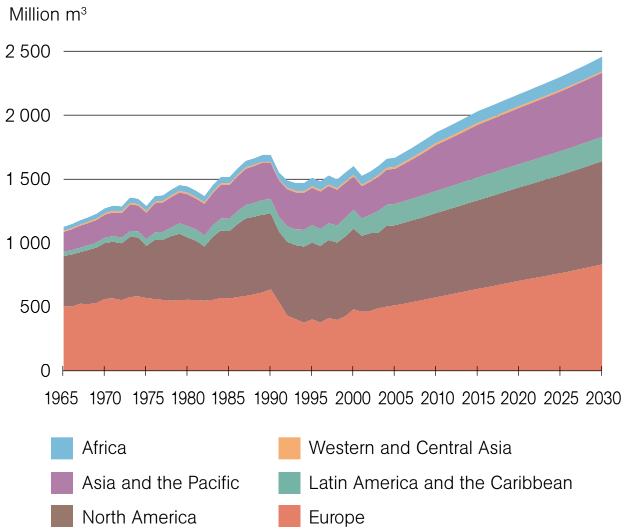
Global production of industrial roundwood is expected to increase by slightly more than 40 percent up to 2030 (Table 24; Figure 54). This is considerably less than the projected rise in total wood and fibre demand (which is expected to almost double) because the highest rates of production growth are expected in the paper and paperboard sector and a higher proportion of paper consumption will be recycled in the future.

TABLE 24
Production and consumption of industrial roundwood

Region	Amount (million m³)					Average annual change (%)			
	Actual			Projected		Actual		Projected	
	1965	1990	2005	2020	2030	1965–1990	1990–2005	2005–2020	2020–2030
Production									
Africa	31	55	72	93	114	2.4	1.8	1.8	2.0
Asia and the Pacific	155	282	273	439	500	2.4	−0.2	3.2	1.3
Europe	505	640	513	707	834	0.9	−1.5	2.2	1.7
Latin America and the Caribbean	34	114	168	184	192	5.0	2.6	0.6	0.4
North America	394	591	625	728	806	1.6	0.4	1.0	1.0
Western and Central Asia	10	9	17	15	11	−0.6	4.5	−0.8	−3.0
World	**1 128**	**1 690**	**1 668**	**2 166**	**2 457**	**1.6**	**−0.1**	**1.8**	**1.3**
Consumption									
Africa	25	51	68	88	109	2.9	1.9	1.8	2.1
Asia and the Pacific	162	315	316	498	563	2.7	0.0	3.1	1.2
Europe	519	650	494	647	749	0.9	−1.8	1.8	1.5
Latin America and the Caribbean	33	111	166	181	189	4.9	2.7	0.6	0.4
North America	389	570	620	728	808	1.5	0.6	1.1	1.0
Western and Central Asia	10	10	19	22	19	−0.2	4.4	1.1	−1.3
World	**1 138**	**1 707**	**1 682**	**2 165**	**2 436**	**1.6**	**−0.1**	**1.7**	**1.2**

NOTE: Data presented are subject to rounding.
SOURCES: FAO, 2008a; 2008c.

FIGURE 54 Global production of industrial roundwood



SOURCES: FAO, 2008a, 2008c.

Most of the growth will occur in the three main regional markets. The greatest production expansion will be in Europe (more than 300 million cubic metres), mostly because of increases in the Russian Federation. Production in Asia and the Pacific and North America will also expand, largely because of increased production from planted forests.

Asia and the Pacific will have a high deficit between production and consumption, increasing from about 43 million cubic metres in 2005 to 63 million cubic metres in 2030. Thus, the region will depend on potential surplus countries, especially the Russian Federation and possibly some countries in Latin America and the Caribbean.

In the 1990s, Europe, which had been a net importer of industrial roundwood, became a net exporter, largely because of exports from the Russian Federation. The opposite trend was observed in Asia and the Pacific. This situation is likely to continue in the future, although it could be influenced by recent changes in the Russian Federation's forest policies (see Box 10 on page 26).

Wood energy

Roundwood used in energy production is comparable in quantity with industrial roundwood. Energy production using wood includes traditional heating and cooking with fuelwood and charcoal, heat and power production in the forest industry (usually using processing wastes such as black liquor from pulp production) for own use or sale to others, and heat and power generation in specifically designed power facilities.

Statistics on energy production from wood are difficult to obtain because of this diversity of uses and the high share of informal production. Furthermore, the two main agencies that collect these statistics – FAO and the International Energy Agency (IEA) – present different figures because of different definitions and primary data sources. IEA presents biomass energy production figures that include other types of biomass besides wood (i.e. agricultural residues and dung). Its statistics also include heat and power generation in the forest industry and by commercial energy producers, which are not fully captured in FAO statistics.

Trends and projections for biomass energy production estimated from a combination of these two data sources reveal an increase in global production from about 530 million tonnes oil equivalent (MTOE) in 1970 to about 720 MTOE in 2005, projected to reach 1 075 MTOE in 2030 (Table 25; Figure 55).

Interpolation suggests that wood used for bioenergy production increased from about 2 billion cubic metres in 1970 to 2.6 billion cubic metres in 2005. This suggests that up to 3.8 billion cubic metres of wood could be required by 2030. However, some of the future demand may be satisfied by biomass produced from agricultural residues and energy crops (including short-rotation coppice and grasses).

Until 2005, global biomass energy production increased relatively slowly, at less than 1 percent per year. Most of the increase in production occurred in developing countries, where wood continues to be a major source of energy. The exception is Asia and the Pacific, where growth has declined considerably because of switching to other preferred types of energy as a result of increasing income.

The projections reflect a future marked increase in the use of biomass for energy production in Europe and, to a lesser extent, North America as renewable energy policies and targets take effect. Europe's per capita biomass energy use is projected to triple by 2020 in response to renewable energy targets, although some production will also come from energy crops and agricultural residues. Most developed countries have set renewable energy targets for 2020; hence, rapid growth in production is expected until that time, followed by a slower rate of growth.

Furthermore, future large-scale commercial production of cellulosic biofuel could increase the demand for wood drastically, beyond that shown in the projections.

The projections for biomass energy production in developing countries also have interesting features:

- In Africa, the growth in biomass energy production will continue, but will slow significantly. With the region's relatively small processing sector and few renewable energy targets, most of its bioenergy production will continue to be from traditional woodfuel (fuelwood and charcoal). Following the trend in other regions (e.g. Asia and the Pacific), this

TABLE 25
Production of bioenergy

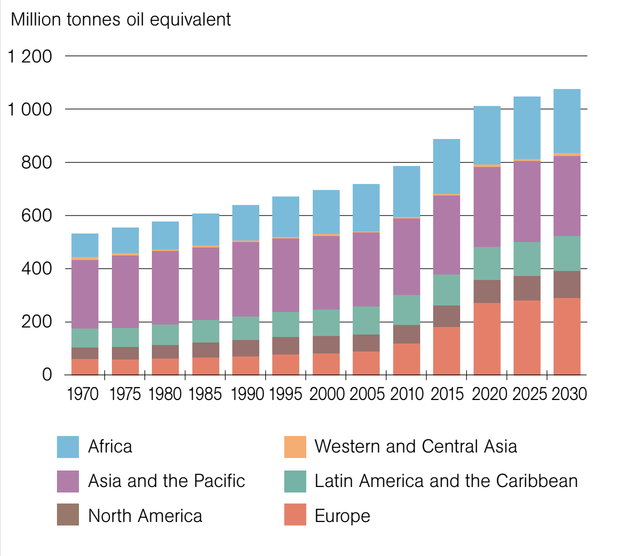
Region	Amount (MTOE)[1]					Average annual change (%)			
	Actual			Projected		Actual		Projected	
	1970	1990	2005	2020	2030	1970–1990	1990–2005	2005–2020	2020–2030
Africa	87	131	177	219	240	2.1	2.0	1.4	0.9
Asia and the Pacific	259	279	278	302	300	0.4	0.0	0.6	−0.1
Europe	60	70	89	272	291	0.7	1.6	7.7	0.7
Latin America and the Caribbean	70	88	105	123	133	1.1	1.2	1.1	0.8
North America	45	64	65	86	101	1.8	0.1	2.0	1.6
Western and Central Asia	11	7	6	8	10	−2.7	−1.0	2.4	1.9
World	**532**	**638**	**719**	**1 010**	**1 075**	**0.9**	**0.8**	**2.3**	**0.6**

[1] MTOE = million tonnes oil equivalent.
NOTE: Data presented are subject to rounding.
SOURCES: FAO, 2008a, 2008c.

growth is expected to decline as incomes rise and more people switch to other types of energy.

- In Asia and the Pacific, traditional woodfuel production is expected to decline, but this will be outweighed by increased production of bioenergy in the forest industry and, in a few cases (e.g. China), commercial bioenergy production in response to renewable energy targets.
- In Latin America and the Caribbean, biomass energy production is projected to increase in all dimensions, with a rise in traditional woodfuel production in the poorer countries of the region and increased bioenergy production by the forest industry and others in the more advanced economies.

FIGURE 55 Global production of energy from biomass



NOTES: 1 tonne of oil equivalent is equal to approximately 4 m³ of wood.
Figures include the use of black liquor, agricultural residues and dung in addition to wood.
SOURCES: FAO, 2008a, 2008c.

SUMMARY

The production and consumption of wood products and wood energy are expected to increase, largely following historical trends. One shift will be the higher growth in the production and consumption of wood products in Asia and the Pacific, mainly stemming from the rapid growth in demand from emerging economies such as China and India. The most dramatic change will be the rapid increase in the use of wood as a source of energy, particularly in Europe as a result of policies promoting greater use of renewable energy.

The Asia and the Pacific region is becoming the major producer and consumer of wood-based panels and paper and paperboard (although per capita consumption will remain higher in Europe and North America). The region's industrial roundwood production will be far short of consumption, increasing dependence on imports unless substantial efforts are made to boost wood production. However, it will be difficult to expand wood production in Asia and the Pacific given the high population density and competing land uses.

Changes in the use of wood for energy and particularly the potential for large-scale commercial production of cellulosic biofuel will have unprecedented impacts on the forest sector. Increasing transport costs could also influence these projections. Most of the growth in global forest products value chains has been founded on the drastic decline in transport costs in the past two decades. These factors and others, including changes in exchange rates, will influence the competitiveness of the forest sector and affect the production and consumption of most forest products.

Furthermore, the industrial roundwood that is used is increasingly likely to come from planted forests, as growth in production from planted forests is expected to keep up with demand growth for industrial roundwood. This presents interesting opportunities and challenges for management of the remaining forest estate.

Gross value added in forestry

In 2006, the forest industry contributed approximately US$468 billion or 1 percent of the global gross value added. Although this represents an increase in the absolute value of about US$44 billion since 1990, the share of the forestry sector has declined continuously because of the much faster growth of other sectors (see figure). Between 1990 and 2006, value addition increased significantly in the wood-processing subsector, rose marginally in roundwood production and remained stable in pulp and paper, which accounted for nearly 43 percent of the forestry sector's value added in 2006.

Asia and the Pacific registered the most significant increase in gross value added, a large part of it in the pulp and paper subsector (see table). Its share of roundwood production was relatively stable. Growth in Latin America and the Caribbean was also strong, mostly as a result of expansion in roundwood production. Roundwood production also accounted for the increase in Africa. The increase in North America was mainly in the wood-processing sector, while the pulp and paper sector remained stable. Forestry's value added fell only in Europe, mainly owing to a decline in the pulp and paper subsector. Value added in Western and Central Asia remained stable.

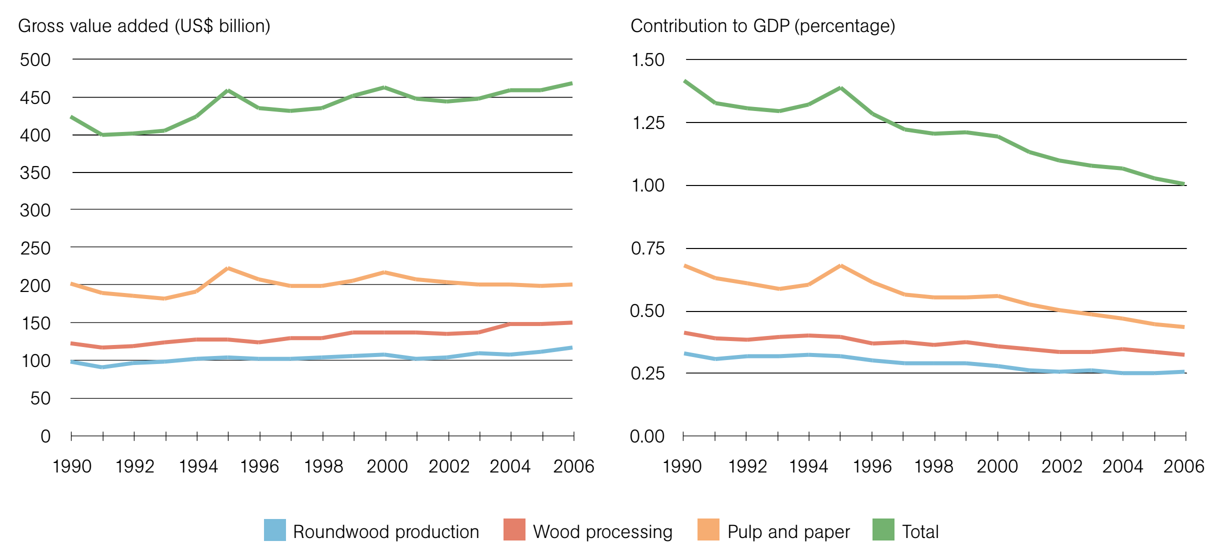
These trends are likely to continue in the next few years, especially as investments in wood production and processing increase in Asia and the Pacific and in Latin America and the Caribbean.

Gross value added

Region	Roundwood production (US$ billion)		Wood processing (US$ billion)		Pulp and paper (US$ billion)		Total (US$ billion)		Contribution to GDP (%)	
	1990	2006	1990	2006	1990	2006	1990	2006	1990	2006
Africa	6	9	2	2	3	3	11	14	1.7	1.3
Asia and the Pacific	29	33	21	30	40	56	90	119	1.4	1.0
Europe	27	25	57	57	74	60	159	142	1.4	1.0
Latin America and the Caribbean	13	21	6	7	11	12	30	40	2.0	1.9
North America	21	27	35	53	73	67	129	147	1.4	1.0
Western and Central Asia	2	2	1	1	2	2	5	5	0.5	0.3
World	**98**	**118**	**123**	**150**	**202**	**201**	**424**	**468**	**1.4**	**1.0**

NOTE: Data presented are subject to rounding.

Forestry sector's contribution to GDP



Meeting the demand for environmental services of forests

As the demand for food, fibre and fuel has increased, so has the demand for clean air and water, unspoilt landscapes and other environmental services provided by forests. Where forests are converted to other land uses, the services they supply are diminished. Maintaining such services poses challenges, especially where trade-offs between the production of goods and the provision of services must be addressed.

Publicly owned forests have been a major source of environmental services, provided mainly through regulatory, non-market approaches such as protected areas. With non-state actors playing an increasing role in resource management, a need for incentives for the provision of environmental services has become evident. This chapter discusses the outlook and challenges in the provision of environmental services from forests.

REGULATORY APPROACHES

Protected areas

Establishment of protected areas has been an important and widely adopted regulatory approach to protecting the environment. A main objective is to restrict or prohibit activities that undermine the supply of environmental services. Protected areas are grouped into different categories depending on the degree of protection afforded.

The extent of terrestrial protected areas (including but not only forest protected areas) has registered significant growth in the past three decades, although it seems to have been levelling off since 2000 (Figure 56). The total extent of protected areas is about 1.9 billion hectares, or about 14.5 percent of global land area. This represents an increase of 35 percent since 1990 (UN, 2008c). The area protected varies considerably among the regions. The outlook for protected area management depends on both the scope for increasing the extent of protected areas and the effectiveness of their management.

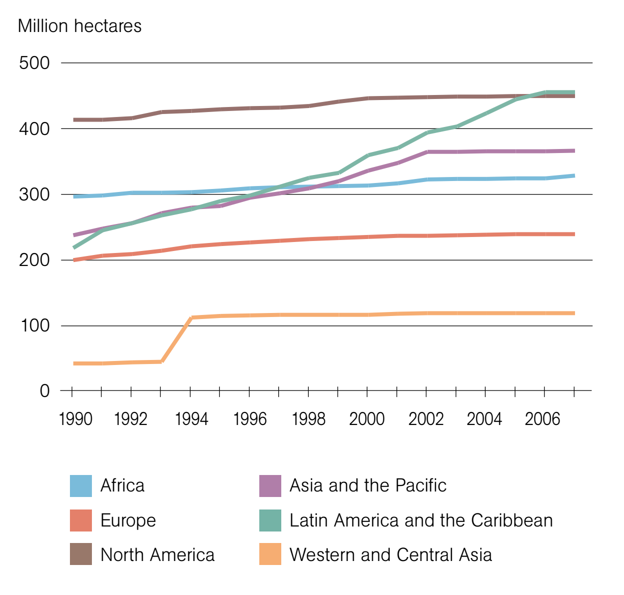
About 13.5 percent of the world's forests are in some category of protected area (Schmitt *et al.*, 2008). With the exception of some of the large forested regions where population densities are low – the Amazon Basin, the Congo Basin and the boreal forests of Canada and the Russian Federation – the scope for further expansion of protected areas is probably limited.

Effective management of protected areas poses enormous challenges. Much depends on the willingness and ability of society to meet the direct and indirect costs of their management.

In densely populated countries, protected areas are vulnerable to degradation caused by illegal logging, woodfuel collection, grazing and poaching. The ineffectiveness of excluding people has led to a shift in management approach, favouring people's participation in protected area management, including income-sharing arrangements with local communities. The success of such approaches depends on establishing appropriate trade-offs between conflicting objectives. This requires a robust institutional framework and good mediation skills to negotiate a lasting compromise.

Protected areas are often the last frontier for large-scale developments, especially involving mining, oil drilling, infrastructure and large-scale agriculture. Low-income

FIGURE 56 Growth in terrestrial protected areas



SOURCE: UN, 2008c.

countries dependent on land and other natural resources for their development often find it extremely difficult to resist such options.

Sustainable forest management

As less than one-seventh of the world's forests are set aside as protected areas, most forest environmental services are provided in conjunction with the production of wood and other products. Production can be compatible with provision of environmental services, but only up to a certain level. Thus, considerable attention has been devoted to developing wood production systems that minimize environmental damage and support continued provision of services. Implementation of sustainable forest management – which addresses the economic, social and environmental functions of forests – is an important approach to ensuring a balance between the objectives of production and conservation. Maintaining critical ecosystem functions is a key pillar of sustainable forest management. "Close-to-nature silviculture" and the "ecosystem approach" are essentially variants of sustainable forest management, giving greater emphasis to environmental services.

While the concept of sustainable forest management is accepted as the framework for managing forests in most countries, its implementation differs considerably among them. Barriers to its adoption are relatively few where institutions are well developed and society is able to meet the higher costs, as is the case in many developed countries. However, in low-income situations, sustainable forest management faces far more constraints, reflecting limited ability and willingness to pay for the additional costs involved in adhering to the social and environmental criteria. Consequently, in the tropics, the proportion of forests that are sustainably managed remains very low (ITTO, 2006).

Green public procurement

Public procurement policies that aim to ensure that wood products purchased have been produced legally have the potential to promote sustainable forest management and environmental protection. For example, Japan, New Zealand and several countries in Europe have operational timber procurement policies, and many regional and local governments have established restrictive rules for their procurement contracts (UNECE and FAO, 2006a). An increasing number of public- and private-sector players are also adopting green building and procurement policies (Metafore, 2007) (Box 32).

BOX 32 Green building in the United States of America

"Green building" is construction that conserves raw materials and energy and reduces environmental impacts. It includes consideration of future water use and energy demands, ecological site selection and the procurement of sustainably produced materials. In the United States of America, many public agencies and schools have adopted green building standards. Leadership in Energy and Environmental Design is a green building rating system developed in 1994 by the United States Green Building Council (a member of the World Green Building Council, which has members in more than ten countries). It is a national third-party certification programme for the design, construction and operation of high-performance green buildings. Green building legislation, policies and incentives are in place in 55 cities, 11 counties and 22 states.

While green building provides healthier work environments at both the environmental and human levels, the high costs involved are frequently a disincentive. However, the initial costs are often mitigated over time by gains in overall efficiency.

SOURCE: USGBC, 2008.

MARKET MECHANISMS: THE DEMAND SIDE

Certification for green products

A major condition for the adoption of sustainable forest management is a demand for products that are produced sustainably and consumer willingness to pay for the higher costs entailed. Certification represents a shift from regulatory approaches to market incentives to promote sustainable forest management. By promoting the positive attributes of forest products from sustainably managed forests, certification focuses on the demand side of environmental conservation.

In 2008, more than 300 million hectares, or almost 8 percent of the world's forests, were certified by independent third parties, a significant increase since third-party certification was introduced in 1993 (Figure 57). The two major certification systems are those of the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification Schemes (PEFC). In addition, many countries have national certification systems, often affiliated with PEFC (UNECE and FAO, 2006b; ITTO, 2008).

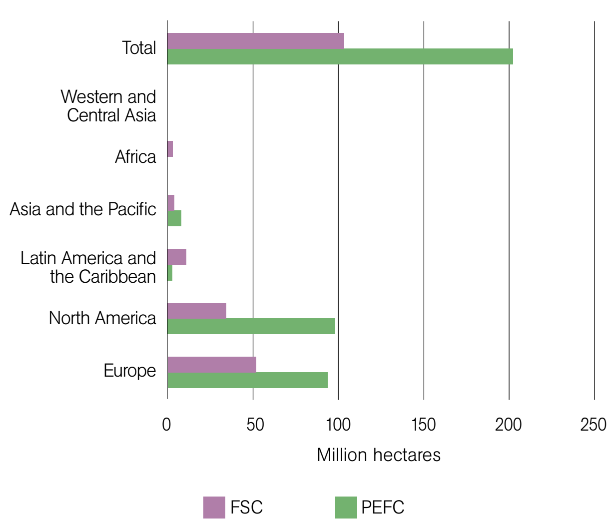
In 2006, certified forests supplied about 24 percent of the global industrial roundwood market (UNECE and FAO, 2006b). FSC (2008) estimates annual sales of FSC-labelled products at US$20 billion. PEFC estimates that 45 percent of the world's roundwood production will come from certified forests by 2017 (Clark, 2007). In addition to wood, other products are increasingly being certified, including woodfuel and NWFPs (UNECE and FAO, 2007).

Both major certification systems now allow non-certified wood to be sold together with certified wood under a "mixed sources" label, provided it meets certain basic requirements of acceptable forest management (World Resources Institute, 2007).

The following are key issues and trends in certification:

- Although certification started with the objective of encouraging sustainable forest management in the tropics, only 10 percent of the certified forest area in 2008 was in the tropics. The rest was in Europe and North America, reflecting economic and institutional advantages in adopting certification in developed countries.
- Certification provides access to markets where consumers prefer green products, but no price premium to cover the costs of certification. For many producers, access to the green market is insufficient incentive for seeking certification, especially when there is demand for comparable uncertified products produced at a lower cost.
- Major expansion in certification will depend on the response of consumers in rapidly growing markets (especially China and India). While the desire for market access may encourage the growth of certification, the main constraints could be on the supply side, especially the investments required to reach the minimum threshold level of management allowing certification.

FIGURE 57 FSC- and PEFC-certified forest area, 2008



SOURCES: FSC, 2008; PEFC, 2008.

MARKET MECHANISMS: THE SUPPLY SIDE

Encouraging the supply of environmental services through appropriate payments to forest owners has received considerable attention as a means of supporting forest conservation. While such payments have long existed for recreational services (for example, through entry fees to recreational sites), they are being adopted for other services such as watershed protection, biodiversity conservation and carbon sequestration (Box 33). The idea is to place environmental services on a par with other marketed products, correcting the bias against their supply.

Payments for environmental services (PES) have been developed mainly for watershed services, carbon sequestration and to some extent biodiversity conservation. The growth of ecotourism has also facilitated the development of markets for scenic and nature values, especially through access fees and permits.

Watershed protection

Watershed protection is one of the most important environmental services involving forests and has received considerable attention for payment schemes. These schemes involve payments to upstream land users for improving water quality and quantity through appropriate land-use practices. Such arrangements tend to be most effective in small watersheds, where service providers and beneficiaries are able to interact and the information flow is relatively smooth. At larger scales, more complex arrangements become necessary. In most cases, the payments are from utility companies to land users.

As water is indispensable and tangible, users are generally willing to pay for improving the quality, quantity and regularity of its supply. Moreover, it is easy geographically to identify the providers and beneficiaries of the service.

BOX 33 Key lessons on developing payment for environmental services schemes

- An operational PES scheme can take years to develop. The crucial step is finding willing buyers.
- Most voluntary, private-driven PES schemes have been small, have high transaction costs and deliver modest rural incomes and modest conservation gains.
- Government-driven PES schemes have tended to be larger and deployed faster, and they have resulted in improved forest practices in some instances.
- Regulation-driven PES with private buyers (e.g. markets for carbon credits) have generated high expectations that have yet to be fully realized.
- PES schemes require supportive legal and institutional frameworks, clear property rights and assistance to small farmers and rural communities.
- National governments remain the most important source of funding for PES programmes, with the international community acting as a catalyst.
- Ecosystem service payments may be insufficient to provide incentives for forest conservation where there are high opportunity costs for land.

SOURCE: FAO, 2007d.

Views from CPF partners

Forests and synergies among multilateral environmental agreements

From the Global Mechanism of the United Nations Convention to Combat Desertification (UNCCD)

The UNCCD promotes synergies offered by forests among multilateral environmental agreements. Sustainable forest management, sustainable land management and climate change adaptation strategies are interrelated; solutions for forest degradation and deforestation overlap with those for land degradation. The Global Mechanism uses national policy processes for coordination and reconciliation, with the aim of increasing investments and financial flows in forests and agriculture. It supports efforts to increase resource allocations in national budgets, to take full advantage of innovative financial mechanisms and to obtain "vertical funds" focused on specific themes.

From a financing perspective, the potential for increased financial flows to address land degradation and degraded forests in the future climate regime is interesting but demands careful preparation. A responsible pro-poor policy framework would provide equitable compensation to smallholder farmers that offer environmental services to the country and climate change resilience to the world. Subsistence farmers in fragile ecosystems could become key players in the international market.

Although forests in arid and semi-arid lands have comparatively low carbon values, they are being degraded at relatively high rates in some regions and, therefore, are targets of national and international schemes. In addition, low-carbon-density forest lands may act as buffer areas between agricultural lands and more dense forests. Their protection is particularly important in preventing encroachment, conversion, further land degradation and eventual desertification.

Views from CPF partners

Valuing ecosystem services

From the United Nations Environment Programme (UNEP)

Climate change poses a major challenge to forests. Its impacts on the supportive and regulating processes of forests and on how people use forest resources are difficult to predict. The best response to the uncertainty climate change presents is to maintain or increase the functioning and resilience of all forests as a matter of urgency. This challenge provides opportunities for forest stakeholders at the national and international levels to increase cooperation.

UNEP promotes an ecosystem approach that considers lessons learned from the past and seeks preparedness for challenges such as climate change. The services that forests provide need to be part of development strategies and incorporated into financial decision-making. Climate regulation is just one of the services for which a monetary value urgently needs to be established. Others include hydrological regulation, protection from natural hazards, nutrient cycling, energy, waste treatment and freshwater provisioning.

As population growth persists and the decline of forest ecosystem services continues, UNEP will promote equitable distribution of ecosystem services across socio-economic groups as an important measure for increasing human well-being and for mitigating conflicts and disasters.

Nevertheless, developing a system of payments for watershed services entails a number of challenges, such as:

- lack of clarity about the hydrological processes involved and, in particular, the impact of different land uses on the quantity, quality and regularity of water flow;
- public opposition related to privatization, perceptions that access to water is a fundamental right and concerns about the potential for increased inequities (i.e. that payment systems might impede poor people's access to water);
- high transaction costs for the development of PES, especially for large watersheds with many providers and users of watershed services.

Consequently, market mechanisms for the provision of watershed services are still in the early stages of development. Most of the existing arrangements are either between small groups of users and providers that can interact efficiently, or established by large electricity or water utilities that can levy the necessary charges and channel the funds to those undertaking watershed conservation.

Carbon markets and forestry

Payment for carbon sequestration to mitigate climate change is one of the fastest-growing environmental markets. Under the Kyoto Protocol, three flexible mechanisms were created: the Clean Development Mechanism (CDM), joint implementation and emission trading. Under the CDM, Annex I (industrialized) countries may offset a certain part of their emissions through investment in carbon sequestration or substitution projects in non-Annex I (developing) countries and thus acquire tradable certified emission reductions. Under joint implementation, Annex I countries may jointly execute carbon sequestration or substitution projects. Emission trading permits the marketing of certified emission reductions.

Carbon markets comprise the compliance market (which follows stringent rules under the Kyoto Protocol) and the voluntary market. In 2007, the total carbon market (including all voluntary and compliance markets) amounted to US$64 billion, more than double the 2006 total (Hamilton *et al*., 2008). The voluntary carbon market, where a sizeable share of carbon credits comes from forest activities, also doubled in terms of emissions traded (65 million tonnes of carbon dioxide equivalent in 2007), and tripled in terms of value (US$331 million) (Box 34).

While the appeal of afforestation and reforestation as a climate change mitigation strategy is considerable, forest-based carbon offset projects face several challenges, including setting baselines, permanence, leakage and monitoring constraints. The problems are particularly severe in countries with high deforestation rates, which usually also have major policy and institutional constraints. These issues have hindered a more prominent role for forests in climate change mitigation under the CDM (one reforestation project out of 1 133 registered projects as of August 2008).

Following the thirteenth session of the Conference of the Parties to UNFCCC in Bali, Indonesia, in 2007, many high hopes were generated on the inclusion of REDD in the post-Kyoto climate change mitigation efforts. The economic

Views from CPF partners

Reducing emissions from deforestation and forest degradation

From the United Nations Framework Convention on Climate Change (UNFCCC)

Reduction in emissions from deforestation and forest degradation is generally recognized as a relatively low-cost greenhouse gas mitigation option. About 65 percent of the total mitigation potential of forest-related activities is located in the tropics, and about 50 percent of the total could be achieved by reducing emissions from deforestation (IPCC, 2007) – which would also provide other benefits and complement the aims and objectives of other multilateral environmental agreements while addressing some of the needs of local and indigenous communities.

At the Climate Change Conference in Bali, Indonesia, in December 2007, countries adopted a decision on reducing emissions from deforestation in developing countries. Governments are encouraged to seek to overcome the barriers to implementation (lack of effective institutional frameworks, adequate and sustained financing, access to necessary technology and/or appropriate policies and positive incentives) through capacity building, provision of technical assistance, demonstration activities and mobilization of resources.

Several governments have already announced their willingness to support such activities, to provide funds and to address outstanding methodological issues (related to assessment of changes in forest cover and associated forest carbon stocks and greenhouse gas emissions, reference emission levels, estimation of emissions from forest degradation, implications of national and subnational approaches, etc.). Several organizations have also launched initiatives to assist developing countries in these efforts. Opportunities for collaboration should be explored to ensure that efforts are complementary and to maximize the benefits for all countries involved.

and scientific rationale for REDD has been well articulated in that the forest sector (mainly deforestation) accounts for more than 17 percent of greenhouse gas emissions and that addressing deforestation and degradation would be a more cost-effective mitigation option than bringing about changes in energy use. However, providing incentives to desist from deforestation involves complex policy, institutional and ethical issues (Martin, 2008).

Biodiversity conservation

Biodiversity conservation has largely been in the public domain, primarily through establishment and management of protected areas. However, as public funding becomes insufficient to support biodiversity conservation, many countries have made efforts to identify alternative ways to finance it, including through systems of payment for the services provided. Such systems are compatible with objectives of increased community participation in biodiversity conservation. Examples include private protected areas, which depend on visitor fees as the main source of income.

Payment systems for conservation are diverse (Jenkins, Scherr and Inbar, 2004), including:

- outright purchase of high-value habitat;
- payment for access to potentially commercial species or habitat;
- payment in support of management that conserves biodiversity;

BOX 34 Forests and voluntary carbon markets

Voluntary carbon markets, or the exchange of offsets by entities not subject to greenhouse gas emission caps, have two components:

- the structured and monitored cap-and-trade system of the Chicago Climate Exchange (CCX);
- the more disaggregated over-the-counter (OTC) system, which is not driven by an emissions cap and does not typically trade on a formal exchange.

In 2007, 42.1 million tonnes of carbon dioxide equivalent (CO_2e) were transacted on the OTC market and 22.9 million tonnes on the CCX, representing a tripling of transactions for the OTC market and more than a doubling for the CCX since 2006.

Within the larger OTC voluntary market, forestry projects (which include afforestation and reforestation of both planted and natural forests and avoiding deforestation efforts) accounted for 18 percent of transactions in 2007, down from 36 percent in 2006. Projects for avoiding deforestation increased from 3 percent of the volume in 2006 to 5 percent in 2007. Forestry projects and particularly those involving afforestation or reforestation remained among the highest-priced project types in 2006 and 2007, with weighted average prices of US$6.8–8.2 per tonne of CO_2e.

SOURCES: Gorte and Ramseur, 2008; Hamilton *et al.*, 2008.

Views from CPF partners

Primary forests, planted forests and biodiversity objectives

From the Convention on Biological Diversity (CBD)

The year 2010 will be celebrated the world over as the International Year of Biodiversity. This occasion should be used as a starting point for a more sustainable relationship with our forests.

Forests are home to two-thirds of all terrestrial species. If we are to achieve the 2010 target to reduce the loss of biodiversity significantly, all governments and relevant organizations must redouble their efforts to halt deforestation and to manage forests sustainably. For example, market failures that stand in the way of appreciating the real value of forests need to be addressed. Biodiversity and the numerous ecosystem services that forests provide must be properly accounted for, and they must be marketed. Forest governance must be improved and the management of forests must become a matter of societal choice. In addition, information about the importance and value of forests must reach key decision-makers. The CBD programme of work on forest biodiversity (which was reviewed by the ninth meeting of the Conference of the Parties in Bonn, Germany, in May 2008) addresses all of these issues.

In a context of rising demand for wood products, planted forests will meet a greater part of timber needs in the future. Hence, it is important to ensure that planted forests increasingly fulfil biodiversity objectives, for example by forming ecological corridors between protected areas. New methods and technologies will make it possible to establish planted forests exclusively on degraded lands, without damage to primary forests. Primary forests will serve mostly as reservoirs for biodiversity and as storage space for carbon.

- tradable development rights;
- support for enterprises that adhere to conservation principles in their business practices.

Each of these requires a specific policy and institutional framework.

The market for biodiversity conservation is still nascent. Most of the purchases of high-value habitats (often under debt-for-nature swaps) are by international agencies including non-governmental organizations (NGOs) and foundations. Conservation easements, under which private landowners surrender certain development rights to provide environmental benefits in perpetuity in return for compensation (including tax exemptions), are widely adopted in the United States of America (TNC, 2004).

Other compensation arrangements

Some countries, when unable to avoid the development of forests or other habitats, compensate for the loss by supporting conservation in other locations. Such arrangements involve transfer payments that are not necessarily linked to the quantity or quality of the service delivered and are not true markets for the provision of environmental services in the conventional sense. A typical example is wetland mitigation banking in the United States of America, in which unavoidable impacts on aquatic resources are compensated by establishing, enhancing or conserving another aquatic resource area (US EPA, 2008).

Another example is the compensatory afforestation programme in India under which any diversion of public forests for non-forestry purposes is compensated through afforestation in degraded or non-forest land. Funds received as compensation are used to improve forest management, including afforestation, assisted natural regeneration, management and protection of forests, and watershed management. A government authority has been created specifically to administer this programme (SME Toolkit India, 2008).

SOCIO-ECONOMIC ASPECTS

Support for provision of environmental services and the appropriateness of regulatory and other measures need to be considered in the larger socio-economic context. Countries and societies with higher incomes tend to be more willing to pay for environmental services. Low-income countries may have difficulty giving priority to provision of environmental services, especially when they face more economically attractive development options (Box 35).

This raises the question of the potential role of PES in poverty alleviation (FAO, 2007e). There are some indications that the poor may not benefit particularly from ecosystem markets (FAO, 2004). The concern is to ensure that the payments for the environmental services actually go to the farmers who provide the services by adopting appropriate land use. However, their ability to provide the services depends largely on rights to and ownership of the land, as well as other policy and institutional factors that determine the transaction costs. Consequently, it is often the large landowners that are able to take advantage of PES arrangements.

An additional concern is that, given the social and economic inequities that exist in most countries, when markets develop and profits can be made by selling ecosystem services, the access of poor people to these services may be reduced.

A chief impediment to the provision of environmental services through existing approaches is the high transaction cost. Environmental markets are more sophisticated and complex than commodity markets, requiring substantial information on technical aspects of provision of services and well-developed institutional and legal arrangements. This again suggests the enormous effort required to develop effective measures to provide environmental services in most developing countries.

BOX 35 Willingness and ability to pay for conservation

Conversion of biodiversity-rich delta to sugar-cane plantations

Kenya has recently embarked on a large-scale sugar plantation, converting about 2 000 km^2 of the pristine Tana River Delta, which provides habitat for a large number of species and a source of livelihood to local communities. The objections of conservationists and local communities have led to judiciary intervention, delaying project implementation.

Closure of sugar-cane plantations for wetland restoration

The United States Sugar Corporation, the largest producer of cane sugar in the United States of America, has agreed to close down about 750 km^2 of sugar-cane plantations to help in the restoration of the Everglades wetlands. The State of Florida will pay the company an estimated US$1.75 billion in order to purchase the land.

SOURCES: *Environment News Service*, 2008a, 2008b.

OUTLOOK

The outlook for the provision of environmental services is mixed. Growth in income coupled with greater awareness will usually strengthen demand for environmental services as well as the ability of a society to meet the costs of environmental protection. However, increased income often reduces environmental services as more goods and services are produced. In particular, countries with rapidly growing economies often go through a period when forest resources are exploited or converted to other uses, resulting in a decline in environmental services.

There is no single solution appropriate to all contexts. Both market and non-market approaches have their strengths and limitations. It is often assumed that economic growth is a prerequisite for improving the environment, but the reality is more complex. Many factors, including institutions and legal frameworks, will have an impact on the ability of a country to manage its forests in such a way as to provide stable or increasing environmental services.

Changing institutions

Institutions are key to sustainable resource management and societal adaptation to social, economic and environmental changes. As in other sectors, the overall trend in forestry is towards a pluralistic institutional environment, attributable to two divergent trends: globalization and localization. Increased cross-border movement of capital, labour, technology and goods resulting from globalization has necessitated adaptation by existing institutions and the establishment of new ones. At the same time, local communities have become more involved in resource management through decentralization and devolution of responsibilities. While there are considerable differences across countries and regions, this chapter summarizes how institutions in the forest sector are responding to the emerging developments outlined in Part 1.

INSTITUTIONAL CHANGE IN FORESTRY: AN OVERVIEW

Before the 1990s, the forest sector was dominated by government forestry agencies, several large enterprises, a multitude of small and medium enterprises (many operating outside the formal system) and a few international organizations largely focused on providing technical support to public forestry agencies. Today, the forest sector is characterized by a greater number of institutions addressing a wider array of issues (Box 36).

The private sector and civil-society organizations have experienced significant growth since the 1990s, particularly as a result of:

- the political and economic changes following the collapse of the Soviet Union, especially the shift from centralized planning to market-oriented economic policies and globalization;
- growth in environmental awareness and concerns and the proliferation of related initiatives following the United Nations Conference on Environment and Development (UNCED) in 1992;
- changes in funding for forestry, i.e. increases in foreign direct investments and private-foundation support (Box 37) alongside decreases in official development assistance.

Developments in information and communication technologies have further catalysed institutional changes, challenging hierarchical structures and calling for institutions to respond to the demands of a more informed public (see Box 45 on page 88).

BOX 36 Types of institutions dealing with forest issues

Public forestry agencies and enterprises

- National policy formulation, legislation and planning, including national forest programmes
- Management of forests and forest industries and all related activities, including trade in forest products
- Regulatory and enforcement functions – providing a level playing field to other institutions involved in forest and tree resources management

Private sector

- Management of forests and other resources, including planted forests
- Production and processing of, and trade in, wood and non-wood products

Civil-society organizations

- Environmental and social advocacy in policy and market development and awareness generation

Informal sector

- Production and processing of, and trade in, wood and non-wood products

International and regional organizations and initiatives

- Intergovernmental forest policy, environment- and trade-related processes and conventions
- Financing, development and technical assistance, including technology transfer
- Regional collaboration arrangements
- Science and technology development and networking

PUBLIC AGENCIES

Government forestry agencies remain the dominant force in the sector. More than 80 percent of global forests are under public jurisdiction (FAO, 2006a).

Government forestry departments are often among the oldest of the civil services. Many originally focused on enforcing regulations, with the main objective of protecting and managing the forests to supply forest products and generate revenue for government. They traditionally integrated multiple functions from wood production to processing and trade as well as forestry research (see Box 38), education, training and extension.

BOX 37 Growth of private foundations in the United States of America

The United States of America has the largest segment of private foundations supporting development activities. In 2005, they provided grants of an estimated US$3.8 billion (US$1.6 billion in 1998). Almost half of the support is in the field of health (largely because of the huge support provided by the Bill & Melinda Gates Foundation). Environment accounted for about 10.4 percent of the number of grants in 2004.

SOURCE: Renz and Atienza, 2006.

Challenges of reduced public expenditure, mounting expectations of different stakeholders and increasing conflicts over the use of forest resources are stirring public agencies to rethink their management objectives, functions and structures (FAO, 2008h). The evolution in focus can be loosely described as moving from policing the forests to managing them to facilitating management by others (Table 26).

BOX 38 Declining public forestry research

In most countries, the public forestry administration has traditionally had a research arm, but institutional arrangements for research are changing. Research is increasingly carried out by government-funded independent organizations, universities and the private sector, often through collaborative networks. It is increasingly demand-driven rather than supply-driven. However, these changes raise concerns about imbalances in investments. Support for basic and strategic research has been declining, with more attention focused on applied and adaptive research that yields immediate returns. Furthermore, the results of private-sector research are often not publicly available.

TABLE 26
Progression in the development of public forestry agencies

Stage	Objectives of resource management	Functions and structures
Protecting	To utilize what grows under natural conditions (e.g. to log natural forests) To safeguard future timber supplies for strategic reasons	Policing of the forest estate Hierarchical structure
Managing	To improve the state of resources by investing in improved management To create assets, including planted forests	Production and resource management Emphasis on technical and managerial skills
Enabling others to manage	To support or empower other players (private sector, communities, farmers, etc.) to manage resources and regulatory functions	Creation of enabling conditions Negotiation, facilitation and conflict resolution Emphasis on diversity of skills and quick response to needs of various stakeholders

In some cases, reform has been superficial; for example, limited to changes in ministerial responsibility (in particular shifting between agriculture and environment ministries) or to structural but not functional change. Many public agencies are unable to develop the human resources needed in order to manage forest resources in an increasingly complex environment (Nair, 2004; Temu, 2004), and many lack sufficient capacity for long-term strategic planning or open sharing of information, with a tendency to be reactive to short-term pressures and concerns (often mirroring the larger public administration).

Strategies used in more successful transitions to an enabling role have included:

- separating policy and regulatory functions from management functions;
- entrusting wood production and processing to an independent commercial government entity or privatizing all commercial activities, usually as part of a larger policy of economic liberalization, often triggered by government budgetary crises (as in the case of New Zealand [O'Loughlin, 2008]);
- decentralizing and devolving management responsibility to the local level (Box 39), usually as part of a larger programme of political and administrative decentralization – with widely different results.

BOX 39 Elements of successful decentralized forest governance

External to the forest sector

- Significant transfer of power and responsibilities to democratically elected and accountable lower levels of government
- Fair and clear enforced property rights and an appropriate regulatory framework
- Respect of the law by governments, the private sector and civil society
- Effective linkages between government, the private sector and civil-society institutions

Internal to the forest sector

- Effective and balanced distribution of responsibilities and authority among different levels of government
- Adequate resources and institutional effectiveness at each level of government
- Sufficient participation of civil society and the private sector at all levels

SOURCE: Contreras-Hermosilla, Gregersen and White, 2008.

PRIVATE SECTOR

Private enterprises range from individual and household microenterprises and small farms, often operating on a minimal budget, to large transnational corporations, whose annual turnover in some cases exceeds the GDP of a small country.

Corporate sector

The corporate sector accounts for a large segment of logging concessions, planted forests and wood industries. Profitability remains its primary objective. Corporations operate in an extremely competitive environment with constant pressures to cut costs and improve market share. The following are some of the sector's major challenges and opportunities:

- Rapid growth of emerging economies in Asia is resulting in a regional shift in the demand for wood products (see the chapter "Global wood products demand" in Part 2). Investments in new capacity are taking place in countries where demand and profitability are perceived to be high and the costs of production – especially of fibre, energy and labour – are low. In particular, the pulp and paper industry has seen a spate of mergers and acquisitions and the closure of less-competitive mills.
- Pressure for industry to adhere to tenets of corporate social responsibility is expected to mount as society becomes more concerned about environmental and social issues (Box 40). "Green" values will influence procurement of goods and services along the whole supply chain. Consumer preference is shifting in favour of certified products, but this is not always reflected in higher prices.
- Climate change concerns are expected to provide new opportunities for wood products (which store carbon and require relatively little energy to produce) and industrial wood energy. Major related challenges include increasing transport costs owing to the rapid expansion of global value chains and increasing demand for wood.

Strategies for adaptation to the above challenges include:

- Focus on core business and divestment of non-core activities: The traditional model of large integrated industrial units is giving way to highly networked global supply chains, linking firms and affiliates across countries, including subcontractors and home workers operating outside the formal system. Components of production may be relocated abroad for improved profitability. Wood production may be outsourced to farmers through partnership arrangements. Forest product companies increasingly recognize that tying up large stocks of capital in forest ownership affects their short-run cash flow

BOX 40 Corporate social responsibility

The overarching focus on profitability in the private sector often results in high social and environmental costs. As society's awareness of these costs increases, pressures mount on the private sector to abide by environmental and social regulations. Industry may also find it advantageous to project a green image, especially among environment-conscious consumers. Industry organizations have developed a number of criteria relating to corporate social responsibility, and green auditing is becoming mandatory. In Rome in 2006, chief executive officers from 61 companies belonging to the International Council of Forest and Paper Associations signed a commitment to global sustainability. The World Business Council for Sustainable Development has prepared guidelines on sustainable procurement of wood and paper products that address environmental and social aspects (WBCSD and WRI, 2007). Increasing environmental awareness and easy access to information will help to ensure that industry no longer neglects its responsibilities through superficial "greenwashing".

BOX 41 Institutional investors: TIMOs and REITs

Most investments in planted forests have traditionally been made by government, smallholder or industrial forest owners. However, management arrangements such as timber investment management organizations (TIMOs) and real estate investment trusts (REITs) have created a significant shift in forest ownership from industries to institutional investors, primarily in North America but also in Australia, Finland, New Zealand, South Africa and Sweden. Investment by institutions in planted and managed native forests increased worldwide from less than US$1 billion in 1985 to more than US$30 billion in 2007. The number of TIMOs grew from two or three in the 1980s to more than 25 in 2007. About 20 million hectares of private forest land are under TIMO control. In the United States of America, forest landownership by integrated forest companies (those involved in both production and processing) declined from 19.5 million hectares in 1994 to 4 million hectares in 2007 (Neilson, 2007).

Some observers are concerned that the increase in forest ownership by wholly profit-seeking institutional investors could undermine long-term investments in forest management and research and also accelerate commercial development of private forest lands. However, the growth of TIMOs appears to be slackening because of the limited area available for sale.

SOURCES: FAO, 2007f; Sample, 2007.

BOX 42 Sovereign wealth funds: an emerging player in forestry investment

Since 2001, foreign exchange reserves have grown rapidly, far beyond the established benchmarks of adequacy. The sovereign wealth fund (SWF) is a vehicle established by some governments to channel these reserves into investments. In the first quarter of 2008, the total assets held by 51 SWFs were estimated at US$3.5 trillion, and these assets are projected to grow to about US$5 trillion by 2010 and US$12 trillion by 2015. SWFs invest in many asset classes including real estate, plantations and government bonds. Four SWFs have already invested in timber lands.

SOURCES: FAO, 2007f; *Friday Offcuts*, 2008.

and stock market values. Divestment has led to the emergence of new players (Boxes 41 and 42).

- Investment in R&D: The corporate sector leads investment in R&D, focusing on applied and adaptive research and on the development of new products and processes to establish competitive advantage and to meet consumers' environmental demands. The sector often takes advantage of results from public research. Planted forests managed by the corporate sector are among the most productive.

Other private and community-based enterprises

Globalization provides new opportunities for small and medium enterprises, but they will need to adapt continuously to survive intensifying competition. Issues affecting the long-term performance of this vibrant institutional segment include:

- Ownership, legal framework and level playing field: Ownership and security of tenure are necessary for the development of any enterprise. Policies and legislation vary in the extent to which they provide land rights to local communities. In many countries, rules and regulations are crafted to the needs of large enterprises, leaving small and medium enterprises and community institutions at a disadvantage.
- Constraints on economic viability: Local communities often have access to only the most degraded and least productive land, which cannot provide benefits commensurate with the investments required. They often lack access to inputs (including credit) and markets. Many small enterprises focus on production of low-value-added products, which seldom help to enhance income. Local markets face increasing competition from global suppliers. The inadequacy of entrepreneurial skills to deal with changing opportunities and challenges remains the most critical constraint.

- Governance and distribution of benefits: In some local community enterprises, power imbalances lead to inequitable distribution of benefits, undermining long-term sustainability. This problem is particularly severe where democratic transparent systems of management and accountability are lacking and local vested interests dominate.

Factors that have helped small and medium enterprises cope successfully with the challenges include:

- improved access to information and opportunities created by the Internet, e-trading and other tools;
- upscaling of business activities through associations and federations and improvement of access to markets, inputs and services;
- increased efforts to develop technologies appropriate to the needs of small and medium enterprises;
- rapidly rising transport costs, making local value chains more competitive.

Stronger institutional arrangements are critical to the scaling up of operations and improved bargaining power. Moreover, they enable communities to take advantage of new technologies, which are vital to making community-based resource management economically viable.

BOX 43 A federation of forest communities in Nepal

The Federation of Community Forest Users Nepal (FECOFUN), a forest-user advocacy organization founded in 1995, provides national representation of local people's rights in resource management. Comprising rural farmers – men and women, old and young – from almost all of Nepal's 75 districts, FECOFUN exemplifies the evolution and maturation of a community-based group into an important rural institution. Indeed, it is Nepal's largest civil-society organization.

FECOFUN and community forestry in Nepal owe their success to recognition of rural people's dependence on forests and to institutional incentives structured in accordance with rural realities.

SOURCE: FECOFUN, 2006.

CIVIL-SOCIETY ORGANIZATIONS

In recent decades, civil-society organizations have become major players in forest-related issues in most countries, often challenging established positions and increasing transparency. They have emerged as one of the main forces reshaping the future of forestry at all levels – local, national and global.

Indigenous peoples' groups have risen from local levels to become effective actors and advocates at the global level through coalitions presenting a unified front and delivering consistent messages in international meetings and processes. Their organized efforts have led to progress in recognizing and restoring the rights of indigenous peoples to forest land. The adoption in 2007 of the United Nations Declaration on the Rights of Indigenous Peoples, although non-binding, was a milestone.

Community forestry and community conservation organizations include: federations (Box 43); networks of local community organizations, advocacy and networking organizations, such as the Forest Peoples Programme; and coalitions, such as Friends of the Earth International, the World Rainforest Movement and the Global Forest Coalition. Reflecting the growth of community forestry around the world, these groups stress the connection between forests and livelihoods.

International environmental NGOs, such as the World Wide Fund For Nature, Conservation International, The Nature Conservancy, the Wildlife Conservation Society and the International Union for Conservation of Nature (IUCN) (an umbrella group of which all the others are members), are the most well-funded and perhaps the most effective civil-society actors in forestry. Although differing in perspectives and approach, these groups focus attention on conserving biological diversity, extending protected areas, driving forest certification and improving forest governance to reduce illegal logging and trade in endangered species.

A related group consists of civil-society organizations that promote market-based approaches to conservation and sustainable forest management, such as certification, fair trade, organic and sustainable agriculture, ecotourism and green investments. Some of these organizations, including FSC and PEFC, have brought about changes in the behaviour of producers and consumers of forest products.

A number of international environmental NGOs, for example the International Institute for Environment and Development (IIED) and the World Resources Institute (WRI), function as "think tanks", enhancing knowledge in key areas.

In addition, complex webs of national, regional and global networks, many still relatively informal, link farmers, forest-dependent communities, small traders and local activists. These alliances are no longer strictly the domain of large international conservation organizations and major development groups.

Overall, civil-society organizations form a strong counterforce against powerful players such as governments and the corporate sector. Their effectiveness stems largely from:

- close contact with grassroots and understanding of local issues;
- multidisciplinary approaches to resource management issues;

- effective communication with stakeholders and funding sources;
- skilful use of networks and associations and development of strong linkages with other players;
- their detailed research on key issues and its use in support of local action.

Increasing awareness and concern about social and environmental issues imply an increasing role for civil-society organizations in forestry.

The shift towards institutional and economic complexity should mirror more effectively the ecological and cultural diversity of forests and peoples. Such complexity is needed in order to help forests fulfil their integrating role in a dispersed, diversified and distributive forest economy. Civil-society actors inject much-needed disorder into intentionally neat power equations (J. Campbell, personal communication, 2008).

INFORMAL SECTOR

The dividing line between the formal and informal sectors is sometimes blurred, especially as many small and medium enterprises operate outside the formal realm. Players outside the formal sector range from traditional local forest management arrangements that have been pushed into the informal realm by restrictive government regulations to illegal logging networks that exploit weak institutional arrangements in many countries.

Although it is difficult to define the extent of its reach, the informal sector continues to be significant worldwide. The International Labour Organization estimates that for every job in the formal sector in forestry there is another one (or two) in the informal sector (ILO, 2001). Most of these are in production or collection of woodfuel and NWFPs. Unpaid subsistence work, primarily in woodfuel harvesting, is estimated to employ about 14 million workers (full-time equivalents), of whom 90 percent are in developing countries. Informal sector employment is often dominated by women.

Many small forest enterprises operate informally, largely because of ill-defined property rights and an unfavourable business environment with high barriers to entry and concomitant transaction costs. The informal sector dominates in countries where regulations are cumbersome and inflexible (World Bank, 2006). Increasing pressure by the formal sector to reduce costs is encouraging the growth of the informal sector. Work is often outsourced to firms outside the formal sector that cut production costs by failing to abide by social and environmental norms.

The key issue is whether governments will make significant efforts to create a favourable business environment by removing barriers restricting entrepreneurship. Improved access to credit, markets and technology could potentially move some players from the informal to the formal sector.

Also key are concerted efforts to address illegal logging, which currently include intergovernmental forest law enforcement and governance processes, tracking and verification systems and anti-money-laundering measures.

INTERNATIONAL ORGANIZATIONS

Although less quick to adapt than private-sector or civil-society organizations, international forest-related organizations have evolved in the past two decades. Before 1990, the United Nations (UN) and other intergovernmental organizations, international research and financing organizations and bilateral donor agencies provided mainly technical support, primarily focused on production of wood products. The priority areas were silviculture and forest management, forest industries, research, education, training and extension.

Since the UNCED in 1992, under the overarching objective of sustainable forest management, international organizations have broadened their agenda to address a wider array of social, economic and environmental issues. New types of international institutions have emerged (UN forest policy processes, environmental conventions and agreements and regional intergovernmental processes) and initiatives and partnerships have multiplied. Programmes place more emphasis on support to policies and institutions, with increased focus on governance, poverty alleviation and more recently on integrating forestry in the framework of the Millennium Development Goals. With growing concern about climate change, the pursuit of mitigation and adaptation measures is an emerging priority.

The proliferation of institutions and initiatives has necessitated substantial efforts to minimize fragmentation and avoid duplication. Duplication is a hazard because constituents commonly ask organizations to take up the latest "hot" issue – and organizations need to work where there is funding, which again tends to be available for these hot issues. Fragmentation at the international level accentuates problems at the country level, especially where development efforts are compartmentalized in different sectors. The capacity to coordinate is in short supply in countries where problems are most acute.

Efforts to address fragmentation and duplication include the "One UN" approach (UN, 2006b), which aims to coordinate the disparate activities of the various UN agencies at the country level, and the Collaborative Partnership on Forests (CPF) – an example of coordinated support for the international forest policy process (Box 44).

The accelerating pace of globalization and the emergence of a host of transboundary economic, social and environmental issues need to be addressed by effective international institutional arrangements. Some of the likely changes in the next few years may be:

- consolidation of institutions, in response to resource constraints and pressure to see concrete results on the ground;
- a shift from processes to tangible outputs and results, as demanded by a more informed society;
- increasing emphasis on regional, subregional and other group initiatives to enable countries with similar views and perceptions to address shared problems, and increased attention to forestry issues by regional and subregional economic blocks.

BOX 44 Collaborative Partnership on Forests

The Collaborative Partnership on Forests (CPF), a voluntary arrangement among 14 international organizations and secretariats with substantial programmes on forests, aims to enhance coordination of support to the international forest dialogue and to country-level implementation of sustainable forest management. Initiatives on streamlining forest-related reporting and harmonizing definitions have aided global, regional and national forest processes. Recent initiatives include a joint strategic response to the global climate change agenda and consolidation of scientific knowledge in support of international policy processes.

OUTLOOK

With the emergence of new players, the institutional landscape in the forest sector has become more complex and the balance among players is shifting. In general (although not in all countries), the playing field is more level, partly as a result of new information and communication technologies. The much-needed pluralism provides new opportunities for small and medium enterprises and community organizations. Civil-society institutions, usually focusing on social and environmental issues, and private-sector institutions, usually emphasizing economic aspects, are gaining in strength and number; funding and investments increasingly favour them over the public sector and international institutions. If the government forestry agencies that historically dominated the scene fail to adapt to these changes, they could fade into irrelevance. With the increasing pace of globalization, new players such as TIMOs, REITs, sovereign wealth funds and carbon trading institutions could alter the global institutional map. Institutions will face tremendous pressure to balance fragmentation and to consolidate efforts.

Views from CPF partners

The Non-Legally Binding Instrument and future priorities for forests

From the United Nations Forum on Forests (UNFF)

The Non-Legally Binding Instrument on All Types of Forests (NLBI) adopted by the UN General Assembly in December 2007 embodies a global consensus on sustainable forest management and outlines future priorities in the form of four Global Objectives on Forests:

- reverse the loss of forest cover worldwide through sustainable forest management;
- enhance forest-based economic, social and environmental benefits, including by improving the livelihoods of forest-dependent people;
- increase significantly the area of protected forests and other areas of sustainably managed forest worldwide;
- reverse the decline in official development assistance for sustainable forest management.

With the NLBI and its new multiyear programme of work, UNFF is poised to deliberate on some of the most pressing issues related to forests in the coming years. In 2009, UNFF will discuss the contribution of forests to addressing challenges of climate change as well as the role of forests in protecting biodiversity and reducing desertification. In this regard, issues such as governance and sound participatory decision-making will be crucial to ensuring that the benefits of forests are secured and that long-term planning takes precedence over short-term gains. ■

Developments in forest science and technology

The science and technology system involves basic and strategic research, applied and adaptive research, and adoption of the results. Broadly speaking, technology in forestry generally relates to two areas:

- management of forest and tree resources for the production of goods and provision of environmental services;
- harvesting, transport and processing of wood and non-wood products.

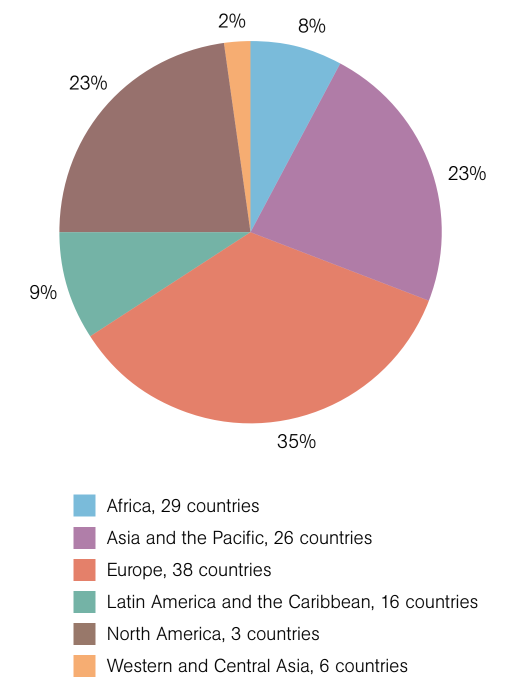
Within these areas, development tends to focus on one or more of the following objectives:

- reducing costs and increasing productivity;
- developing new products and services;
- conserving resources and reducing adverse environmental impacts;
- improving energy efficiency.

In meeting these objectives, newer fields, such as biotechnology, nanotechnology and information and communication technologies (Box 45), are having a notable impact.

A growing area of research deals with enhancing the scientific base for the provision of environmental services. This usually involves study of ecosystem processes and the implications of different degrees of human intervention. For

FIGURE 58 IUFRO membership by region, 2008



SOURCE: IUFRO, 2008.

BOX 45 Information and communication technologies in forestry

The growth of information and communication technologies (ICTs) has had significant direct and indirect impacts on forestry and has been central in accelerating the pace of globalization. The Internet and mobile communications have created unprecedented opportunities for those who were traditionally outside the global information loop, including small and medium-sized enterprises. ICTs have increased labour productivity, reduced costs and increased returns. Online stores provide marketing opportunities for wood product and service suppliers.

ICTs have also fostered institutional change in forestry. The increased ease of information sharing and global networking diminishes the power of vertically structured organizations and fosters the development of small organizations. ICTs have helped to promote transparency and accountability on an unprecedented scale, as very little information can be kept away from public access and scrutiny. ICTs have also facilitated awareness-raising about forest-related issues such as deforestation, biodiversity loss, forest fires and the marginalization of indigenous communities.

SOURCES: Hetemäki and Nilsson, 2005; Nyrud and Devine, 2005.

example, climate change mitigation and adaptation will require substantial efforts to understand carbon fluxes under different land uses and how ecosystems and species respond to changes.

Science and technology capacity differs significantly between developed and developing countries, mostly reflecting differing abilities to invest in education, training and infrastructure. Although a simplification, the geographical distribution of the members of the International Union of Forest Research Organizations (IUFRO) reflects the differences in research capacity among regions (Figure 58).

Translating scientific knowledge into technologies and then applying these remain major challenges, partly because of fragmented institutional arrangements. Adoption of technologies is context-specific. Often, a choice must be made among a wide array of technologies available for the same task.

Historically, public-sector forestry agencies led the development of forest science and technology. Today, there are many more players; in general, the public sector's role has diminished (Table 27) and its capacities have declined sharply in many countries.

SCIENCE AND TECHNOLOGY IN SELECTED AREAS

Forest management

For most of the twentieth century, natural forests were the main source of wood and other products, and forest research focused on managing them sustainably. Various silvicultural systems were developed (e.g. selection and shelterwood systems), taking into account the density of important species, their growth rates, light and moisture requirements, their ability to regenerate naturally and competition between marketable and non-marketable species. Low-intensity harvesting was adopted to avoid undermining forest environmental services. Vulnerable areas were excluded from logging.

Views from CPF partners

Research challenges of the future

From the International Union of Forest Research Organizations (IUFRO)

IUFRO is the central global network for forest researchers. It has three strategic goals:

- strengthen research for the benefit of forests and people;
- expand strategic partnerships and cooperation;
- strengthen communication and links within the scientific community and with students as well as with policy-makers and society at large.

To provide independent scientific expertise and information to its potential users, IUFRO periodically identifies emerging key issues and assesses its activities.

The forest research challenges of the future identified by IUFRO involve:

- the increased global demand for wood and non-wood goods and services;
- bioenergy;
- impacts of climate change;
- competition for land and how to reverse deforestation;
- the role of genetically modified trees and plantation forestry;
- invasions of alien pests and pathogens;
- biodiversity conservation;
- social and behavioural processes;
- the impact of global economic developments on local economies and livelihoods.

Society is placing greater pressure on scientists to explain their research publicly and to demonstrate its positive impacts. Moreover, the users of scientific information, including policy-makers and practitioners, increasingly want to be involved in the development of research agendas. Networking can help both the scientific community and its actual and potential beneficiaries to enhance research uptake and impact.

TABLE 27
Key players in forest science and technology

Key players	Research focus	General trends
Public-sector forest research institutions	Basic and applied research in all aspects of forests and forestry A significant share of research is not demand-driven, but provides the foundation for downstream applied and adaptive research	With few exceptions, declining because of reduced funding and concomitant reduction in human resources Fragmentation of research agenda and weak linkages between research areas
Universities	Mostly focused on the science of forestry and to a limited extent on applied research leading to technology development	Declining public-sector funding compelling shifts in favour of more applied and adaptive research in collaboration with industry
Industry	Demand-driven research primarily undertaken by large enterprises Focused on applied and adaptive research leading to the development of new processes and products that can be patented	Increased investments to raise competitiveness Collaborative arrangements with public institutions and universities, largely to benefit from capacity in basic research
International public-sector research institutions and networks	Global and regional issues and research networking (but very few in number)	Shift in focus from technical aspects of forestry to policy issues, with increasing emphasis on social and environmental dimensions
Independent think tanks and civil-society research institutions	Mostly policy issues, with particular emphasis on environmental and social issues Focused on supporting advocacy initiatives	Expanding influence, especially in policy processes at national and international levels
Manufacturers of equipment and machinery	Production of machinery and equipment that draws on many technologies for specific tasks	Intense competition and the constant need to upgrade machinery and add new features

With a shift to the sourcing of wood from planted forests and the exclusion of large tracts of natural forests from wood production, these low-intensity management systems have been abandoned in many countries. The development of technologies that made it possible to process wood irrespective of its natural qualities and size has also contributed to shifting attention away from these systems.

Research in natural forests now focuses more on integrating environmental, social and economic objectives according to the principles of sustainable forest management. A number of national, regional and international initiatives focus on the development of criteria and indicators for measuring progress towards sustainable forest management, outlining the nature of technology to be adopted. Implementation of sustainable forest management requires substantial strengthening of the science and technology base. To this end, much research focuses on ecosystem structure and functioning, the spatial and temporal linkages among ecosystem components and processes, and their relation to the immediate and larger social and economic context. However, implementation of such research remains a challenge (CIFOR, 2004), especially in developing countries.

Technologies that increase the speed at which vast amounts of spatial and temporal data can be analysed and synthesized are revolutionizing forest management in some countries and are expected to spread. Improvements in the resolution of satellite imagery and the development of software to interpret it will contribute to real-time monitoring of deforestation, pests and diseases, fires and other potentially devastating events. Geographic information systems (GISs) and global navigation satellite systems provide forest managers with increasingly precise information on the nature and condition of forest resources, which can be processed and transmitted rapidly (Box 46). This information is also valuable as evidence for public consultation, verification of legality and third-party certification.

New modelling and visualization software linking GISs and remote sensing provides high-quality digital simulations of future forest landscapes to reveal changes that might result from natural processes, such as climate alterations, or human interventions, such as planting, thinning and harvesting. Such simulations facilitate community engagement in forest management decision-making (Sheppard and Meitner, 2005).

An increasingly urgent area of research relates to the adaptation of forests to climate change. For example, genetic and environmental variation in tree growth and health is being studied in order to predict potential impacts of climate change on ecosystems and species ranges, to predict adaptive responses of tree populations to climate and to formulate new strategies to help forest trees adapt to the changing climate (Wang *et al.*, 2008).

Planted forests and wood production

Planted forests have received most investment in forestry, and also in forestry technology development. Research aims primarily to enhance productivity through faster growth rates and to improve wood quality and the ability

BOX 46 Remote-sensing applications in forestry

Remote-sensing techniques (including aerial photography and satellite imagery) have been used successfully for forest mapping and monitoring and make it possible to cover large areas consistently and cost-effectively. New technologies address technical challenges such as the variable height, structure, density and composition of forests. Airborne light detection and ranging using lasers can provide highly accurate estimates of tree cover and height; it can even assess the shape of individual trees. Space-borne radar (radio detection and ranging) is a promising new way to obtain estimates of stand volume and biomass and can penetrate clouds, overcoming some of the limitations of optical satellite sensors. New spectral sensing systems can measure a wide array of land and vegetation characteristics, making it possible to assess a range of forest attributes – helping to improve mapping of forest pests and diseases, for example.

SOURCE: R. Keenan, personal communication, 2008.

of forests to withstand adverse environmental conditions, pests, diseases and other hazards.

Enormous productivity increases have been obtained for fast-growing, short-rotation species such as eucalypts, tropical pines and poplars. For example, eucalypt plantings in Brazil have reached productivity levels exceeding 50 m^3 per hectare. Productivity increases have primarily been a consequence of the cumulative impact of improved planting material, nursery practices, site/species matching and intensive site management. Substantial efforts have also been directed at improving the quality of management, for example through integrated pest management.

The focus on short-rotation, fast-growing species is directly related to demand from processing industries (producing pulp and paper and reconstituted fibreboard). Industry has been one of the main drivers encouraging innovation in wood production technologies. The new developments are mainly applied by the corporate sector – which, however, only accounted for about 18 percent of the world's productive planted forests in 2005. Thus, governments and smallholders (which hold 50 and 32 percent of planted forests, respectively) have not been able to adopt many of the improved technologies, suggesting considerable scope for enhancing productivity on the global scale.

Tree improvement programmes aim to accelerate the development and mass multiplication of progeny with desirable characteristics. Molecular techniques make it possible to characterize genetic diversity in trees, insects and soil and plant microbes. While traditional improvement techniques rely on natural genetic variation, increasing but controversial efforts are also under way to develop genetically modified trees (Box 47).

Completed genome mapping of *Populus trichocarpa* has enhanced the understanding of genetic functioning in trees. A recently initiated effort to map the genome of *Eucalyptus grandis* (International *Eucalyptus* Genome Network, 2007) will further develop this capacity. Forest biotechnology can also improve the knowledge of cell function, allowing a greater understanding of processes such as wood formation, stress tolerance and carbon fixation and sequestration.

Soil and water depletion and biodiversity loss are other issues raised in the context of planted forest expansion. FAO's voluntary guidelines for the responsible management of planted forests (FAO, 2006f) propose a holistic approach that gives due attention to economic, social and environmental dimensions.

Agroforestry

Research on agroforestry, which comprises varied practices integrating crops, livestock and trees, aims to optimize these components in order to meet the economic, social, cultural and environmental needs of communities and households, while taking advantage of site-level variation in soils, topography and light and moisture availability.

Agroforestry technologies are generally ecologically and culturally site-specific. They have traditionally been developed through "hands-on" experience and transmitted through the generations. Successful agroforestry systems and practices include alley cropping, silvipasture, windbreaks,

BOX 47 Genetically modified trees: blessing or curse?

Advances in gene transfer technologies and tree genomics are providing new avenues for genetic modification of trees. Traits considered for genetic modification include herbicide tolerance, reduced flowering or sterility, insect resistance, wood chemistry (especially lower lignin content) and fibre quality, which could all boost economic potential. Increasing interest in cellulosic biofuels is focusing greater attention on genetic modification, in particular on reducing the lignin content in wood. However, research and deployment, including field trials of genetically modified trees, remain a contentious issue. Concerns have been raised about impacts on ecosystems, especially potential invasiveness, impacts on biodiversity and the transfer of genes to other organisms.

SOURCES: Evans and Turnbull, 2004; FAO, 2006f.

hedgerow intercropping, parklands, home gardens and relay cropping. Some have been in existence for centuries, evolving in response to needs and constraints both on and off the farm. Formal agroforestry research applies the tools and techniques of modern science to help improve the traditional practices and enable their wider application. It generally takes a holistic perspective in that economic and other benefits are assessed with consideration given to the links among the different components.

Agroforestry is currently responding to new market opportunities. Planting of trees on farms to supply wood to forest industries has increased significantly in many countries. Accordingly, new research issues have emerged, including for example interactions between tree crops and food crops and long-term sustainability of production with a focus on maintaining and improving productivity of land.

Harvesting and processing of wood products

Improving economic efficiency and minimizing environmental damage have been the primary objectives of harvesting innovations. Shortages and increasing costs of labour have encouraged significant mechanization of logging and transport. Sophisticated harvesting, conversion and transportation technologies have been deployed in a number of countries, especially in industrial forest plantations.

Reduced-impact logging was developed in response to concerns about the long-term sustainability of wood production from natural forests. It involves measures to minimize damage to the remaining vegetation, enabling rapid recovery after logging. FAO has developed global and regional codes for sustainable forest harvesting and supports countries in developing national codes and guidelines. While the importance of reduced-impact logging is understood and its long-term commercial feasibility has been demonstrated, its adoption depends on the objectives of the resource owners or logging concessionaires and their willingness and ability to comply with market and non-market signals.

New techniques have been developed to identify the source of logs using tags, paints and chemical compounds that can be read by detection devices. New-generation radio-frequency identification tags and bar codes can easily track the movement of logs from forests to markets, helping to distinguish legally from illegally sourced wood.

Technological developments in wood processing largely focus on:

- economic competitiveness, with an emphasis on reducing costs, improving quality and developing new products;
- energy efficiency and production of energy during wood processing;
- compliance with environmental standards, for example by reducing effluents and reusing water through "closed-loop processing" in the pulp and paper industry (Natural Resources Canada, 2008b).

Many technological developments in wood processing have been consumer driven, as processing is near the end of the forest products value chain, close to consumers and, thus, compelled to respond to changing demands. Intense competition has also encouraged innovation.

Traditional wood use was largely based on physical properties, especially strength, durability, working quality and appearance. Wood-processing technologies have improved mechanical and chemical properties, expanding uses and making it possible to employ species that were once considered less useful – for example, to use rubberwood (*Hevea brasiliensis*) for furniture and medium-density fibreboard. Biotechnology in the wood products sector has the potential to improve wood preservation properties.

New sawmilling technologies include laser and X-ray scanners combined with high-power computing, which make it possible to scan and store information on log diameter, length and shape and to produce optimal sawing patterns for each log to maximize sawnwood recovery (Bowe *et al.*, 2002). Picture analysis to determine surface properties (e.g. knots and colour) has improved the sorting and grading of sawnwood. New methods have been introduced to control the drying process and to measure physical strength, revealing possible defects (Baudin *et al.*, 2005).

Other technological developments in wood processing include:

- improved rate of recovery and the use of small-dimension timber, largely through improvements in sawmilling technologies and production of sliced veneer and reconstituted panels;
- recycling, for example use of recovered paper;
- the use of micro-organisms to bleach pulp and treat effluents in the paper industry, reducing costs and environmental impacts;
- total use of wood through biorefineries producing a range of biomaterials and energy (Box 48).

Nanotechnology, defined as the manipulation of materials measuring less than 100 nanometres (with 1 nanometre equalling one-billionth of a metre), is expected to revolutionize all aspects of production and processing, from production of raw materials to composite and paper products, permitting major advances in energy and material efficiency (Roughley, 2005; Reitzer, 2007). Most leading wood-product-producing countries are working on nanotechnology applications. Potential uses (Beecher, 2007) include:

- lighter-weight stronger products developed from nanofibres;
- coatings to improve surface qualities;
- production that uses less material and less energy;

BOX 48 Biorefineries and production of new-generation biomaterials

Initiatives in Europe and North America are transforming pulp and paper units into biorefineries – integrated industries that produce ethanol, starch, organic acids, polymers, oleochemicals, bioplastics and several food and feed ingredients from wood-processing residues. The biomass components are converted using a combination of technologies including novel enzymes, biocatalysts and micro-organisms. Biorefineries could become a cornerstone of a "green economy", sharply reducing dependence on fossil fuels. Some products, such as bioplastics and thermoset resins, would be easily recycled and degraded at the end of the product life.

SOURCES: US DoE, 2006; van Ree and Annevelink, 2007.

- "intelligent" products with nanosensors for measuring forces, loads, moisture levels, temperatures, etc.

Non-wood forest products

NWFPs are diverse and many different technologies are used in their production and processing. Although most NWFPs are subsistence products, collected from the wild and consumed locally with minimal processing, some have been domesticated and are cultivated and processed using sophisticated technologies to meet the demand from global markets. Science and technology development for these products has focused largely on more organized systems of production, while subsistence production has relied almost entirely on indigenous knowledge.

Natural-resource degradation coupled with increasing demand has been the main driver of organized cultivation of many NWFP-yielding species – much as wood production has shifted from natural to planted forests. Research on domestication and cultivation has also been encouraged by the complexity and uncertainty of managing production in the wild. For many products, such as natural rubber, rattan, bamboo and some medicinal and aromatic plants, organized production and chemical substitution of natural components have virtually replaced collection from the wild, except for products intended for niche markets paying a high premium.

Scientific research has focused on:

- understanding the composition, properties and potential uses of different products;
- low-cost technologies for the extraction and isolation of marketable components and for the addition of desirable characteristics, e.g. to facilitate storage and transportation;
- improving processing technologies and developing new products, e.g. new plant-based pharmaceuticals and health and beauty products (the areas where most technological advances are taking place).

Technological developments, for example in biotechnology, present new opportunities and challenges for many NWFPs. While new uses and markets have emerged, so have substitute products that undermine existing markets. Petrochemicals and new technologies for processing glass and metals have significantly changed the markets for a number of plant-based products. NWFPs with limited end uses are particularly vulnerable to such developments. In contrast, bamboo has been developed for diverse end uses and has become a widely distributed material and an important source of income (FAO, 2007g).

Wood for energy

Woodfuel is (and is likely to remain) the main source of domestic energy for cooking and heating in most developing countries. Although increasing income and availability of more convenient fossil fuels have reduced wood energy use, this situation seems to be changing as a result of high fuel prices, perceived risks of fossil fuel dependence and growing concern about greenhouse gas emissions from the use of fossil fuels (FAO, 2008d).

Traditional wood energy systems rely on low-cost technologies affordable to low-income consumers. The technologies used vary in cost and in production and conversion efficiency. For example, charcoal is produced using a range of kiln types, from traditional mud to metal. Modern wood energy production using cofiring (combustion of biomass together with other fuel such as coal) or wood pellets involves considerably higher investments, but is also much more energy-efficient.

Substantial investments are being made to develop and commercialize technologies for producing biofuel from cellulose. How cellulosic biofuel will develop depends on its cost-competitiveness with fossil fuels and other alternatives. If high energy prices persist, cellulosic biofuel production is expected to become a major source of commercial energy. The impact on the forest sector remains uncertain, especially considering that other high-productivity feedstocks could be used rather than wood (e.g. switchgrass, *Panicum virgatum*).

Provision of environmental services

Scientific knowledge is essential for timely and appropriate decision-making to ensure the provision of environmental services by forests. As this knowledge is frequently incomplete, enhancing it needs to be a priority area for research. Examples include: the limited information on the economic consequences of changes in ecosystem services; the lack of quantitative models linking ecosystem change to environmental services; and the poor understanding of ecosystem structure and dynamics that determine thresholds and irreversible changes.

Breakthroughs will be necessary in order to address the drastic degradation of dryland ecosystems, which will be aggravated by decreased rainfall expected as a consequence of climate change. Many affected countries do not have the capacity to undertake the scientific programmes required, and international support will be necessary.

Natural and planted forests offer significant greenhouse gas mitigation potential. However, there are large gaps in knowledge of the role of trees and forest ecosystems in climate change processes and the effect of changes in forest cover on forest carbon stocks and greenhouse gas emissions.

Research on the protective role of coastal forests has intensified since the December 2004 tsunami in Southeast Asia but is still not conclusive. In more than 20 studies carried out in the two years following the tsunami, some researchers found that coastal forests reduce adverse impacts significantly, while others discovered that forests can also be a liability by adding to the debris that can damage human settlements (FAO, 2007h).

Forest hydrology research addresses areas such as the relationship between land use and water yield, an area where myths and misconceptions often dominate decision-making.

Because of the complexity and breadth of issues involved in non-marketed environmental services, it is difficult for scientists to influence direct drivers of change – policy-makers and development actors – in their decisions and practices (and to gain their support for research activities to obtain new relevant knowledge). However, the Intergovernmental Panel on Climate Change (IPCC) has shown that concerted, holistic scientific efforts at the global level can effectively raise awareness and improve understanding of important complex issues, identify key areas where uncertainties need to be reduced and support the research activities needed to make this happen.

INDIGENOUS KNOWLEDGE

The advances in modern science and technology outlined above have had significant impacts on the forest sector. However, for vast populations these technologies remain inaccessible. Many continue to depend on indigenous or traditional knowledge in managing forests and other natural resources (Parrotta and Agnoletti, 2007). Traditional knowledge is defined as "a cumulative body of knowledge, practice and belief, handed down through generations by cultural transmission and evolving by adaptive processes, about the relationships of living beings (including humans) with one another and with their forest environment" (UNFF, 2004). Such knowledge, developed long before the advent of formal forest science, is the mainstay of many forestry practices (Asia Forest Network, 2008).

Indigenous knowledge is of growing interest to forest science as it is increasingly recognized that indigenous resource-management systems can help to improve the

Views from CPF partners

CIFOR's new strategy: a focus on climate change

From the Center for International Forestry Research (CIFOR)

CIFOR has a vision of a world in which forests remain high on the world's political agenda and people recognize the real value of forests for maintaining livelihoods and ecosystems services. In this vision, decision-making that affects forests is based on solid science and reflects the perspectives of developing countries and forest-dependent people.

Stakeholders surveyed for input to CIFOR's new strategy for 2008–2018 cited climate change as the most significant forest-related environment and development challenge today, followed by forest governance, deforestation and the impact of fast-growing economies on forests (CIFOR, 2008b). Thus, CIFOR's research agenda focuses on six domains:

- enhancing the role of forests in climate mitigation (with a focus on reducing emissions from deforestation and forest degradation);
- enhancing the role of forests in adaptation to climate change;
- improving livelihoods through smallholder and community forestry;
- managing trade-offs between conservation and development at landscape scale;
- managing the impacts of globalized trade and investment on forests and forest communities;
- sustainable management of tropical production forests.

An additional cross-cutting theme addresses the gap between changing societal demands from the forest sector and current institutional arrangements and capacities.

In analysing issues and communicating results, CIFOR will include the perspectives of less powerful stakeholders such as women, forest-dependent communities and developing countries.

framework for sustainable forest management. Low-input traditional land-use practices are particularly attractive in the context of declining energy supplies and increasing impacts of climate change. Traditional knowledge provides alternatives to modern science, especially in health care. For example, South Asian Ayurveda and Chinese indigenous medicine are increasingly practised throughout the world, and the use of plant-based pharmaceuticals is growing rapidly.

In efforts to improve the livelihoods of poor marginalized indigenous communities, it is essential to understand their traditional knowledge – their values, perceptions and knowledge of their local ecological conditions. With social, economic, political and institutional change, indigenous knowledge provides opportunities but also faces challenges (Box 49). Several scenarios are evolving:

- Domination, marginalization and assimilation: Despite increasing recognition of their rights, indigenous people are systematically marginalized in many countries, including by narrowly focused development programmes. As vast tracts of forests that sustained indigenous communities are converted to other uses, forest-based livelihoods and the associated knowledge are soon lost.
- Selective appropriation: Realization of the economic potential of traditional knowledge (particularly in the rapidly expanding pharmaceuticals and health and beauty care markets) has led to systematic efforts to identify and commercialize it – taking the knowledge out of its social and cultural context and raising issues of intellectual property rights and fair compensation for knowledge holders.
- Rediscovery: Increasing emphasis on protecting the rights, cultures and technologies of indigenous communities can create a favourable environment for the natural evolution of traditional knowledge. Developments in the international policy arena, such as the passage of the UN Declaration on the Rights of Indigenous Peoples, specifically recognize the need to respect traditional knowledge and practices.

Indigenous knowledge and community-based innovation are dynamic. Options for action include creating incentives to improve the capacity of formal research organizations to work with local and indigenous people and encouraging collaboration in conservation (IAASTD, 2008).

OUTLOOK

Visualizing the future of forest science and technology is difficult in a context of rapid change. Innovation has significantly improved the capacity of the forest sector to meet the changing demands of society and will continue to do so. However, many developing countries have little or no credible science capacity, and this lack hinders

BOX 49 Strengths, weaknesses, opportunities and threats for the survival of traditional forest knowledge

Strengths
- Adapted to local environmental, social, economic and cultural context
- Holistic, with focus on community welfare
- Integrated, avoiding artificial barriers of formal scientific disciplines
- Less resource-demanding and consequently more sustainable

Weaknesses
- Often not codified or widely disseminated – hence, not easily transferred and vulnerable to erosion over time
- Inadequately nurtured and developed
- Limited in ability to meet demands of increasing populations or large areas

Opportunities
- Increasing focus on sustainable management of resources adapted to local conditions and emphasizing social, environmental and cultural dimensions
- Emergence of pluralistic institutional arrangements and increasing emphasis on local community empowerment
- Increased interest in cherishing cultural diversity and growing niche market for unique products and services
- New information and communication technologies improving interaction and collaboration among indigenous groups

Threats
- Globalization and mass production undermining markets for goods and services produced locally using indigenous knowledge
- Marginalization and impoverishment of indigenous communities through appropriation of their land and other resources and consequent loss of culture and knowledge
- Ill-defined rights permitting appropriation of knowledge for commercial interests (bioprospecting) without appropriate compensation
- High investment in mainstream science and technology overshadowing traditional knowledge

their long-term developmental potential. Even in many developed countries, forest science and technology capacity has eroded.

The growth of commercially driven private-sector research and the declining capacity of public-sector research raise a number of issues. Most private-sector efforts are driven by the objective of maintaining competitiveness. As a result, it is often restricted in access, it may neglect environmental and social dimensions and it does not tend to nurture more open-ended upstream basic research. Vast populations that cannot afford to pay for improved technologies are excluded from the benefits. This accentuates disparities in access to knowledge, with consequences for income and living standards.

More concerted efforts are needed to address the imbalances and deficiencies in scientific and technological capacity. Challenges to governments include:

- reducing barriers to the flow of technologies among and within countries;
- ensuring that social and environmental issues are mainstreamed;
- transcending traditional sectoral boundaries to take advantage of science and technology developments outside the forest sector;
- setting a clear policy framework indicating the objectives, priorities and strategies for developing forest science and technology.

Finally, while this chapter has addressed biophysical aspects of forest science, the study of human behaviour, including economics and sociology, is equally important. Countries need to address both areas in a balanced way. Indeed, inadequate attention to the social-science dimension may be one of the reasons for the weak links between science and policy in many countries.