Ecosystem Goods and Services from Plantation Forests

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1
Plantation forests: global perspectives

Markku Kanninen

Introduction

Forest plantations now cover about 140 million hectares (Mha) globally, representing about 4 per cent of the global forest area (FAO, 2005a). In terms of wood production, plantations are much more important than their share of the forest area indicates, and their importance is expected to increase with time. In 2000, plantations supplied one-third of the total demand for industrial roundwood. According to some estimates, approximately half of the global industrial roundwood supply will be provided by plantations and planted forests by the year 2040.

Globalization of markets for forest products and services brings new opportunities and challenges for plantation-based forestry and forest enterprises. In addition to meeting the growing demands of the pulp and paper industry with fibre from fast-growing plantations, there are opportunities for value-added wood products for expanding international and domestic markets. However, in forest plantations that are managed sustainably and competitively, intensive silvicultural interventions are required in order to fully optimize the production of high-quality products.

In addition to production of wood and fibre, forest plantations provide several other ecosystem services, including carbon sequestration, clean water production, regulation of the hydrological cycle, and improvement in the connectivity of landscape mosaics for biodiversity conservation and the alleviation of desertification. It is expected that the relative importance of such services provided by forest plantations will increase in the future.

Basic concepts and definitions

Evolution of concepts and definitions

Forest-related definitions have been used to classify data and information on forest land use and vegetation. In global policy processes dealing with forests,

commonly agreed definitions are needed to reach common understanding among stakeholders on measures included in global policy agreements (Sasaki and Putz, 2009; Putz and Redford, 2010).

The concepts and definitions around forest plantations have undergone several changes since the first global plantation assessment by the Food and Agriculture Organization (FAO) in 1965. In the process of defining modalities for the implementation of the Kyoto Protocol in 1997, the issue of definitions has been full of contrasting views and controversies between the 'forestry' and 'climate change' communities in the definition of afforestation and reforestation (FAO, 2002). In addition, several environmental and social groups have strongly criticized FAO on the concepts and definitions related to planted forests and forest plantations – not mainly because of this broadening of the concept from forest plantations to include planted forests, but because they do not consider these as forests in the first place (World Rainforest Movement, 2007, 2009). The paper by Varmola et al (2005) gives a good overview of this historical development and evolution of concepts and definitions.

A major conceptual change in the definition was the introduction of the concept of 'planted forests' in the early 2000s (CIFOR, 2001; Carle and Holmgren, 2003). 'Planted forests' is a broader concept than 'forest plantations', thus creating a continuum of concepts and definitions based on forests characteristics. It was created to allow a distinction from the 'traditional', usually exotic and mono-specific forest plantations and forest plantings of native species, usually grown in mixed-species systems, mainly in temperate and boreal zones – earlier defined as 'semi-natural forests' (Varmola et al, 2005; Carle and Holmgren, 2008). Planted forests are defined as those forests predominantly composed of trees established through planting and/or after deliberate seeding of native or introduced species (Carle and Holmgren, 2008).

FAO (2006a) defines plantations as 'forests of introduced species and in some cases native species, established through planting or seeding, with few species, even spacing and/or even-aged stands'. This definition includes not only industrial plantations established for the production of biomass and timber, etc., it also includes small-scale home and farm plantations, agroforestry plantations and plantations established to achieve ecological objectives, such as soil protection and wildlife management. This broad definition of plantations is encapsulated in the typology of planted forests provided by the Center for International Forestry Research CIFOR, 2001) (see Box 1.1). The types of plantations are not only distinguished by their different purpose, but also by their spatial scale, management intensity, structure and ownership. In the typology provided by CIFOR (2001), the 'managed secondary forests' can be regarded as a transitional type between plantations and other forest types.

This evolution of concepts and definitions has had its pros and cons. On the positive side, experts argue that the introduction of 'planted forests' is a move towards a more inclusive concept allowing a better reflection on all the

Box 1.1 *Typology of planted forests*

Plantation type and purpose	Characteristics
Industrial plantation: timber, biomass, food	Intensively managed forest stands established to provide material for sale locally or outside the immediate region, by planting or/and seeding in the process of afforestation or reforestation. Individual stands or compartments are usually with even age class and regular spacing and of introduced species and/or of one or two indigenous species. Usually either large scale or contributing to one of a few large-scale industrial enterprises in the landscape.
Home and farm plantations: fuelwood, timber, fodder, orchards, forest gardens and other	Managed forest, established for subsistence or local sale by planting or/and seeding in the process of afforestation or reforestation, with even age class and regular spacing. Usually small scale and selling, if at all, in a dispersed market.
Agroforestry plantation: fuelwood, timber, fodder	Managed stands or assemblages of trees established in an agricultural matrix for subsistence or local sale and for their benefits on agricultural production; usually regular and wide spacing or row planting.
Environmental plantations: windbreaks, soil protection and erosion control, wildlife management, site reclamation or amenity	Managed forest stand, established primarily to provide environmental stabilization or amenity value, by planting or/and seeding in the process of afforestation or reforestation, usually with even age class and regular spacing.
Managed secondary forests with planting	Managed forest, where forest composition and productivity is maintained through additional planting or/and seeding.

Source: adopted from CIFOR, 2001

investments in man-made forests, as well as social and environmental concerns around forest plantations and planted forests (Carle and Holmgren, 2008). On the other hand, this broadening of the definition almost doubles the area of concern. According to FAO (2006a), the global area of planted forests was estimated to be around 270Mha, compared to around 140Mha reported as forest plantations.

Definition of forest plantations

Forest plantations, defined as 'forest or other wooded land of introduced species and in some cases native species, established through planting or

seeding', are divided into two sub-groups: productive plantations and protective plantations. In turn, they are defined by FAO (2005a) as:

- productive plantation: forest plantations predominantly intended for the provision of wood, fibre and non-wood products; and
- protective plantation: forest plantations predominantly for the provision of services such as the protection of soil and water, rehabilitation of degraded lands, combating desertification, etc.

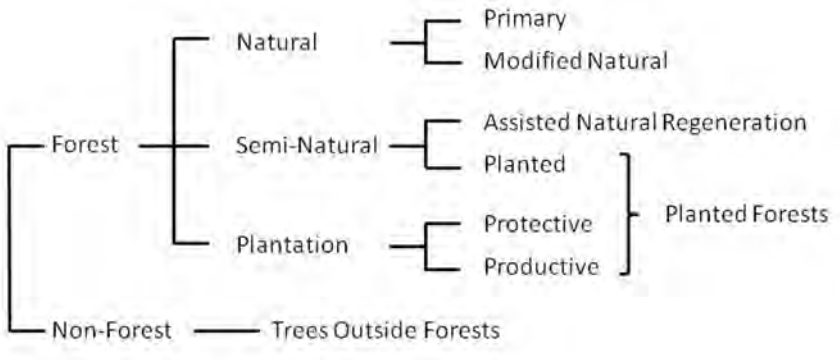

Figure 1.1 *Continuum of forest characteristics and definitions of different forest types according to FAO*

Source: Carle and Holmgren, 2008

Development of plantations

Area of productive and protective plantations

The planted forests thematic study, carried out by FAO, based on the results of the Forest Resources Assessment of 2005 and additional studies, indicated that the total plantation area has increased from 100Mha in 1990 to ca. 140Mha in 2005 (FAO, 2005a, 2006a) (Figure 1.2).

Of total plantation area, 109.3Mha are productive and 30.1Mha are protective plantations. Interestingly, the ratio of productive to protective plantations (3.6) was nearly the same as the ratio between the total area of production to protection forests worldwide (3.7), indicating similar functions. However, for the total forest area, there are other designated functions such as multipurpose or conservation use, not listed for plantations (FAO, 2005a).

China has the largest total area of forest plantations, 31.4Mha in 2005. It is followed by the US, the Russian Federation and Japan, with 17.1, 17.0 and 10.3Mha, respectively. The seven largest plantation countries (China, the US, the Russian Federation, Japan, Sudan, Brazil and Indonesia) account for about

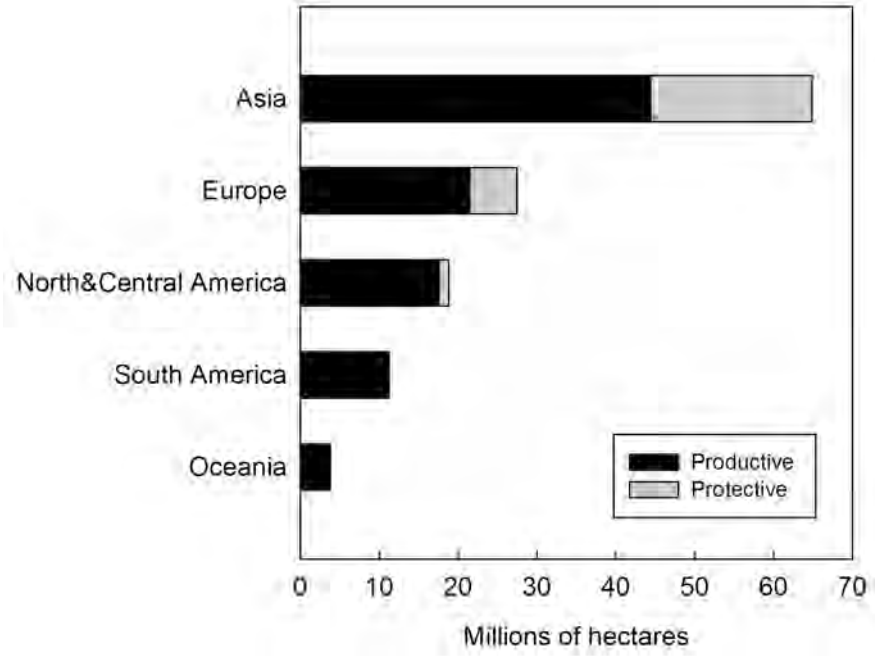

Figure 1.2 *Area of productive forest plantations 1990–2005*

Source: FAO, 2006a

64 per cent of the total plantation area, with a total of 90Mha in 2005. The ten largest plantation countries account for 71 per cent, and the 20 largest countries account for 84 per cent of the world's total plantation area. Productive plantations represented 79 per cent and protective plantations 21 per cent of the total area of plantations, respectively.

China has the largest area of productive forest plantations, about 29Mha in 2005, which is about 26 per cent of the world total. It is followed by the US, the Russian Federation and Brazil, with 17, 12 and 5Mha, respectively. In terms of protective forest plantations, Japan leads with 10Mha in 2005 (35 per cent of the world total), followed by the Russian Federation, China and India with 5, 2.8 and 2.2Mha, respectively. In terms of growth, the fastest growth in plantation area has recently taken place in Asia, where the plantation area has grown by 2.5 per cent per year in recent years.

Countries in which the relative importance of forest plantations corresponds to or approaches 100 per cent of their total forest area (Egypt, Libya, Cape Verde, Bahrain, Kuwait, Oman, United Arab Emirates and Malta) are typically those that have very little natural forest or where the forest area had been diminished in historical times. The latter also applies to countries such as Lesotho, Ruanda, Ireland, the UK, Denmark, Iceland, Israel, Syria and

Burundi, where forest plantation area covers more than 50 per cent of total forest area. The relative importance of plantations in these countries is indicative also of their importance for the selection of ecosystem goods and services, and the selection of these countries shows that plantations play this role in many different parts of the world such as Europe, North and East Africa and the Middle East. Although there is no tight relationship between the percentage forest cover and the percentage that plantations contribute to forest area (Figure 1.3a), it is obvious that countries with the highest plantation percentage have low forest cover. In addition, the highest proportions of protective plantations can be found in countries with low percentages of forest cover. Also, this can be seen as an indication of the substitutive role of plantations, where the cover of native forests has been lost or is naturally low. The absence of a tight relationship also indicates that the relative importance of protective plantations depends on many other factors, such as topography, land-use history and current land use, etc.

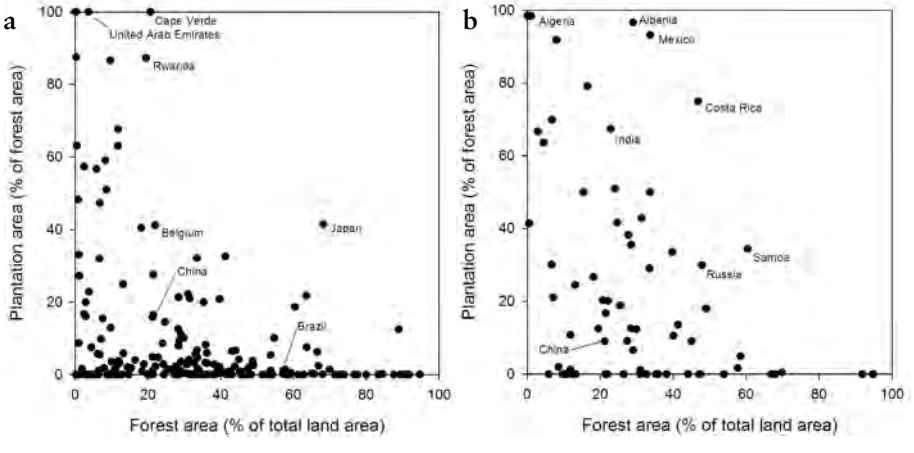

Figure 1.3 *(a) The relative importance of plantations by area in relation to the total forest area, and (b) the relative importance of protective plantations by area in relation to the percentage of total forest areas of countries that have reported protective plantations*

Source: FAO, 2005a

It is interesting to observe that large plantation countries, i.e. countries with large areas of plantations, like the Russian Federation, Brazil, Indonesia and the US, have large areas of natural forests as well, so that plantations represent only a small proportion (1–6 per cent) of their total forest area. In China, the country with the largest total plantation area, the share of plantations is 16 per cent of the total forest area in the country.

About 50 per cent of the total area of planted forests reported in the FAO thematic study (2006a) was under public ownership, whereas plantations owned by smallholders covered 32 per cent and corporations 18 per cent of the total plantation area, respectively. When compared to the situation in 1990, the area (both absolute and relative) of smallholder plantations has tripled, whereas the share of publicly owned plantations has decreased. This is mainly due to the increase in smallholder woodlots and village-scale plantations for the production of wood products for domestic and local use, including firewood and charcoal – a development that started in many developing countries in the 1980s (Evans, 2009).

In terms of the end-use of the products from the plantations, the production of sawlogs dominated with 67Mha (46 per cent of total area) in 2005. The area of plantations aimed for pulpwood and fibre have increased rapidly, covering 18 per cent (27Mha) of the total plantation area reported (Figure 1.4).

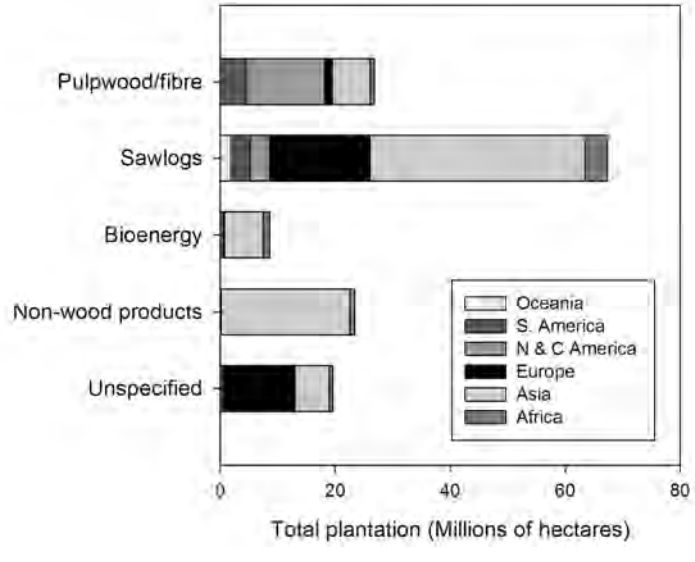

Figure 1.4 *Plantation area (Mha) by the intended end-use 1990–2005*

Source: FAO, 2006a

Species planted

According to the planted forests thematic study of FAO, *Pinus* is the most commonly used genus in plantations, with a total area of 54Mha, representing 29 per cent of the total area planted. The ten most commonly planted genera in plantations, (*Pinus*, *Cunninghamia*, *Eucalyptus*, *Populus*, *Acacia*, *Larix*, *Picea*, *Tectona*, *Castanea*, *Quercus*) represent about 70 per cent of the total

area planted (Figure 1.5). In productive plantations, the share of the top ten genera of the total area planted is 77 per cent, whereas in protective plantations the top ten genera represent 60 per cent of the total area planted.

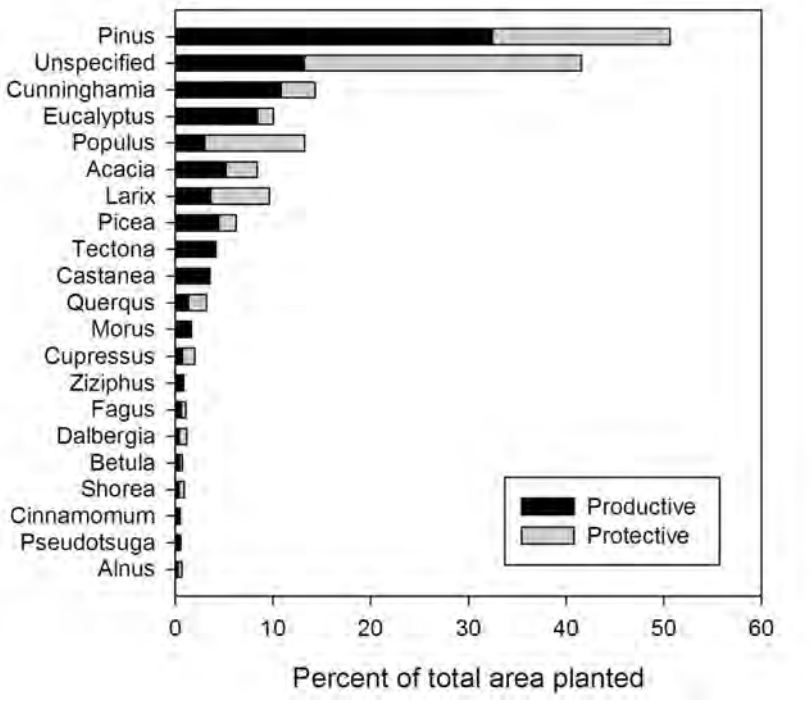

Figure 1.5 *Most commonly used species in plantations*

Source: FAO, 2006a

The pool of species differs to some extent between these two purposes of plantations. The fast-growing plantation species belonging to the genera *Eucalyptus* and *Acacia*, as well as the valuable tropical hardwood teak (*Tectona*) or the *Castanea* grown for non-wood forest products are much less important for protective plantations. Some species that produce litter promoting fires or suppress development of understorey such as eucalypts or teak, are in many situations not particularly suitable for protective functions. In contrast, genera such as *Cryptomeria*, *Chamaecyparis*, *Populus* and *Larix* are relatively more important in protective plantations. However, this difference cannot be attributed to the fact that these species are more suitable for protection purposes than other species. In fact, it may be contested that they are not. The large share of these particular species can be attributed to the country-specific classification of species for productive and protective

purposes, which also depends very much on the respective legislation. The importance of the above-listed species for protective plantations is to a large extent attributable to their share of the plantation estate in Japan and China. Particularly in the latter country, large areas of protective plantations were established, or they were established as productive plantations and later declared protection forest (Wenhua, 2004).

The larger proportion of unspecified species in protective plantations may indicate that the species is of lesser importance and/or that the areas under protective plantation may be smaller and more diverse and therefore more difficult to report on. The genus *Pinus* is of great importance for both protection and production plantations.

While fast-growing exotic monocultures dominate plantations aimed at wood or fibre production in the tropics (see Table 1.1), the importance of native species plantations either in pure or mixed stands is gaining importance, particularly for the rehabilitation and restoration of degraded lands (Lamb, 1998; Carnevale and Montagnini, 2002; Gunter et al, 2009). If managed properly, mixed stands offer higher productivity and ecological gains in terms of the provision of multiple ecosystems services compared to pure stands (see Chapter 5; Erskine et al, 2006; Petit and Montagnini, 2006; Piotto, 2008).

The importance of species planted for the provision of biodiversity and hydrological services are discussed in Chapters 4 and 5 of this book. For carbon sequestration services (Chapter 3), short-rotation timber species have high internal rates of return and high carbon benefits. However, the risks to local communities can be lower if long-rotation mixed plantations are used (Hooda et al, 2007). It is interesting to note that of the current 14 A/R CDM projects (afforestation and reforestation project activities under the Clean Development Mechanism) registered (UNFCCC, 2010), about half of the projects use fast-growing trees species, mainly exotics, to achieve maximum carbon sequestration rates, whereas the other half includes several native tree species in their projects; this is to diversify the ecosystem services produced and to maximize benefits to local communities by increasing access to non-timber forest products such as fruits, resins and honey (Ellis, 2003).

Fast-growing plantations

Fast-growing plantations are a sub-group of productive plantations aimed at industrial use with special characteristics in terms of their management. Typically, they are short-rotation plantations with single-species blocks of a high-productive species, usually exotics. They are usually owned by a single company, and they dominate the landscape, constituting the dominant (or only) land use in their area. The dominant objective pursued with these plantations is to produce large volumes of fibre for the pulp industry.

Cossalter and Pye-Smith (2003) estimated that in the early 2000s the total area of fast-growing plantations was about 10Mha (Table 1.1), growing at the pace of about 1Mha per year.

Although the land area covered by fast-growing plantations is relatively

small – less than 10 per cent of the total plantation area – these plantations have created a lot of controversy in terms of the social and environmental issues related to them (Cossalter and Pye-Smith, 2003; World Rainforest Movement, 2007, 2009; Evans, 2009).

Table 1.1 *Fast-growing plantations*[1]*: main species and countries involved*

Species	Mean annual increment (m^3/ha/year)	Rotation length (years)	Estimated extent as fast-growing plantation only (1000ha)	Main countries (in decreasing order of importance)
Eucalyptus grandis and various eucalypt hybrids	15–40	5–15	± 3700	Brazil, South Africa, Uruguay, India, Congo, Zimbabwe
Other tropical eucalypts	10–20	5–10	± 1550	China, India, Thailand, Vietnam, Madagascar, Myanmar
Temperate eucalypts	5–18	10–15	± 1900	Chile, Portugal, NW Spain, Argentina, Uruguay, South Africa, Australia
Tropical acacias	15–30	7–10	± 1400	Indonesia, China, Malaysia, Vietnam, India, Philippines, Thailand
Caribbean pines	8–20	10–18	± 300	Venezuela
Pinus patula and *P. Elliottii*	15–25	15–18	± 100	Swaziland
Gmelina arborea	12–35	12–20	± 100	Costa Rica, Malaysia, Solomon Islands
Paraserianthes falcataria	15–35	12–20	± 200	Indonesia, Malaysia, Philippines
Poplars	11–30	7–15	± 900	China, India, USA, C and W Europe, Turkey

Fast-growing plantation forests are broadly defined as having average growth rates ranging from ≤10 to ≥40 m^3/ha/year, with shorter rotations from ≤6 years to around 35 or 40 years.

Source: Cossalter and Pye-Smith, 2003

Other types of plantations

There are other types of 'tree plantations' that are very common in the everyday life of rural communities in many developing countries, and they are important in terms of their economic value and the ecosystem goods and services they provide. However, they may not be considered to be 'forest

plantations' or are not otherwise adequately captured by FAO or by national statistics. These include home gardens (e.g. Méndez et al, 2001; Kumar and Nair, 2006) and other types of agroforestry and silvopastoral systems (e.g. Beer et al, 2000), individual trees grown in rows as wind breaks (e.g. Harvey et al, 2000; Wilkinson and Elevitch, 2000).

The study carried out by FAO on 'trees outside forests' (FAO, 2001, 2005b) gives a good overview of the importance of these plantations. It indicates that it is almost impossible to assess the economic, social or environmental value of these plantations because national statistics do not exist (FAO, 2001). However, since these tree plantings are directly shaped and managed by local people and they grow in their immediate environment, they are particularly important for the provision of ecosystem goods and services.

Plantations and ecosystem services

Increasing role of plantations in wood supply

The share of wood from forest plantations in the total production of industrial roundwood was 5 per cent in 1960, 22 per cent in 1995 and 30 per cent in 2005 (Varmola et al, 2005; Seppälä, 2007). Although the plantations represent only a very small share of the current global forest area, the intensity of management is high. If all industrial wood came from effectively managed planted forests, only some 73Mha, i.e. less than 2 per cent of the world's forest area, would be enough to satisfy the current global need of industrial wood (Seppälä, 2007).

Global industrial wood supply from plantations is increasing rapidly as substantial areas of tree plantations mature. Over the past two decades, most new plantation development has occurred in tropical and subtropical regions and in temperate zones of the southern hemisphere. Industrial timber production from natural forests has begun to decline in the leading tropical forest wood-producing countries of Asia, as supplies of commercially accessible large-diameter timber have fallen sharply in recent years. A report by Spek (2006) on investments in the pulp industry indicates that whereas South America (mainly Brazil and Chile) and Indonesia accounted for more 70 per cent of new investments in the pulp industry in the 1990s, Asian countries (mainly China) dominate the new investments.

Future trends

Global demand for forest products has grown at a rapid pace over the past decade and this is expected to continue in the foreseeable future. In the Asia-Pacific region alone, annual consumption of hardwood pulp is expected to increase by 73 million cubic metres (Mm^3) and annual consumption of softwood pulp by $32Mm^3$. There is a shift in the consumption and production of forest products. Recent studies show that current demand for forest industry products will grow less than before in Organisation for Economic Co-operation and Development (OECD) countries, while at the same time the demand will continue to increase considerably in many developing countries

and in countries in transition. This means a shift in the consumption of forest products from Western Europe, North America and Japan to the rest of Asia, Eastern Europe and Russia (Barr and Cossalter, 2004; Seppälä, 2007)

A recent study by Carle and Holmgren (2008) estimated that the area of planted forests will increase from its current level (261Mha) to about 303–345Mha in 2030, depending on the scenario. This increase is 16–32 per cent for the whole 25-year period, or 0.6–1.2 per cent per year. This would mean that the total volume of wood produced annually by planted forests would increase from 1.4 billion m^3 per year in 2005 to a level between 1.6–2.1 billion m^3 per year in 2030.

The above figures are for planted forests and not for forest plantations, which makes it difficult to compare them with earlier results. A study by ABARE-Jaakko Pöyry (1999), reported by Varmola et al (2005), estimated that the industrial wood supply from forest plantations would be 970Mm^3 per year in 2020 (44 per cent of the total) and 1.1 billion m^3 per year in 2040 (46 per cent of the total).

In recent years, the voluntary carbon markets have accounted for the bulk of forest carbon transactions: 95 per cent in 2008 and 72 per cent in first two quarters of 2009. In 2008, the total amount of credits traded in the voluntary markets was 5Mt CO_2 and the value US$37 million (Hamilton et al, 2009). Although the share of afforestation and reforestation of the total amount of Certified Emission Reductions (CERs) generated in the Clean Development Mechanism (CDM) is negligible, recent approval of new project methodologies has led to the registration of ten new A/R CDM projects in 2009.

The projections described above both on the supply of wood and carbon credits show that plantations will become a more important part of many landscapes. This development is not uniform in all parts of the world, and an increasingly higher percentage of new plantations will be established in East and South-East Asia and to a lesser extent in South America.

Challenges for the future

The success of forest plantations as sources of industrial roundwood supply has been obvious. In the past 25 years, their share of total industrial roundwood production has increased from 5 per cent to over 30 per cent. In the next 25 years, it is expected to reach 50 per cent of total industrial roundwood production.

This success is often contrasted with social and environmental problems that large-scale plantation schemes have repeatedly caused. In many cases, most smallholders and forest inhabitants have had limited participation – or no engagement at all – in the profitable business developed by large or medium size companies, and they have not shared significant benefits (direct income or other) in the planting, tending and logging operations performed by these companies. In other cases, companies have planted in large uniform blocks of land and this has led to the displacement of local people from the rural villages

or small holdings where they have traditionally lived. To improve the situation, certification schemes and other safeguards have been introduced. The voluntary guidelines for the responsible management of planted forests established by FAO (2006b) and ITTO (1993), and by various certification schemes are moves in the right direction. However, there is much still left undone to ensure their general application in practice.

One of the negative impacts of large-scale plantations has been on biodiversity (see Chapter 5). However, this has depended very much on the land use that was replaced by the plantations. If properly planned and managed, plantations can play a role in building connectivity in fragmented landscapes (Kanowski et al, 2005; Marjokorpi, 2006; Marjokorpi and Salo, 2007), or acting as catalysts for native species (Kuusipalo et al, 1995; Keenan et al, 1997; Parrotta and Turnbul, 1997; Otsamo, 2000). But as biodiversity continues to be lost, fixed, single-objective plantation management is likely to be a less attractive option in the future (Lamb, 1998). The plantation management paradigm has to move towards the management of multi-functional landscapes by incorporating multiple ecosystem services as an integral part of the overall production function of forest plantation schemes.

Ecosystem services markets are growing fast and forest plantation will have an important role to play in global carbon markets and, more locally, in payments for ecosystem services schemes for managing water resources. Both of these areas are expected to gain increasing importance in the future, when the actions to combat climate change – both through adaptation and mitigation – become part of the new paradigm of sustainable plantation management.

References

Barr, C. and Cossalter, C. (2004) 'China's development of a plantation-based wood pulp industry: government policies, financial incentives, and investment trends', *International Forestry Review*, vol 6, pp3–4

Beer, J., Ibrahim, M. and Schlönvoigt, A. (2000) 'Timber production in tropical agroforestry systems of Central America', in B. Krishnapillay, E. Soepadmo, N. L. Arshad, A. Wong, S. Appanah, S. Wan Chi, N. Manokaran, H. Lay and K. Kean (eds) *Forest and Society: The Role of Research*, vol 1, pp777–786. 21st IUFRO World Congress, Kuala Lumpur, 7–12 August 2000. Kuala Lumpur, IUFRO World Congress Organizing Committee

Carle, J. and Holmgren, P. (2003) 'Definitions related to planted forests', UNFF Intercessional Expert Meeting on the Role of Planted Forests in Sustainable Forest Management, Wellington, New Zealand, pp329–343

Carle, J. and Holmgren, P. (2008) 'Wood from planted forests: a global outlook 2005–2030', *Forest Products Journal*, vol 58, pp6–18

Carnevale, N. J. and Montagnini, F. (2002) 'Facilitating regeneration of secondary forests with the use of mixed and pure plantations of indigenous tree species', *Forest Ecology and Management*, vol 163, pp217–227

CIFOR (2001) 'Typology of planted forests', *CIFOR InfoBrief*, Center for International Forestry Research (CIFOR), Bogor, Indonesia

Cossalter, C. and Pye-Smith, C. (2003) 'Fast-wood forestry: myths and realities', *Forest Perspectives*, Center for International Forestry Research, Bogor, Indonesia

Ellis, J. (2003) 'Forestry projects lessons learned and implications for CDM modalities', OECD and IEA Information Paper, Paris

Erskine, P. D., Lamb, D. and Bristow, M. (2006) 'Tree species diversity and ecosystem function: can tropical multi-species plantations generate greater productivity?', *Forest Ecology and Management*, vol 233, pp205–210

FAO (2001) 'Trees outside forests: towards rural and urban integrated resources assessment. elements for consideration', Contribution to Forest Resource Assessment 2000 report, Working Paper, Rome

FAO (2002) *Proceedings: Expert Meeting on Harmonizing Forest-related Definitions for Use by Various Stakeholders*, Food and Agriculture Organization, Rome

FAO (2005a) *Global Forest Resource Assessment 2005: Progress Toward Sustainable Forest Management*, FAO Forestry Paper 147, Food and Agriculture Organization, Rome

FAO (2005b) *Trees Outside Forests: Annotated Bibliography*, Food and Agriculture Organization, Rome

FAO (2006a) 'Global planted forests thematic study: results and analysis', by A. Del Lugo, J. Ball and J. Carle, Planted Forests and Trees Working Paper 38, Rome (also available at www.fao.org/forestry/site/10368/en)

FAO (2006b) 'Responsible management of planted forests: voluntary guidelines', Planted Forests and Trees Working Paper 37/E, Rome

Gunter, S., Gonzalez, P., Alvarez, G., Aguirre, N., Palomeque, X., Haubrich, F. and Weber, M. (2009) 'Determinants for successful reforestation of abandoned pastures in the Andes: soil conditions and vegetation cover', *Forest Ecology and Management*, vol 258, pp81–91

Hamilton, K., Sjardin, M., Shapiro, A. and Marcello, T. (2009) *Fortifying the Foundation: State of the Voluntary Carbon Markets 2009*, New Carbon Finance, New York

Harvey, C., Guindon, C. F., Haber, W. A., Hamilton DeRossier, D. and Murray, K. G. (2000) 'The importance of forest patches, isolated trees and agricultural windbreaks for local and regional biodiversity: the case of Costa Rica', in B. Krishnapillay, E. Soepadmo, N. L. Arshad, A. Wong, S. Appanah, S. Wan Chi, N. Manokaran, H. Lay and K. Kean (eds) *Forest and Society: The Role of Research*, vol 1, pp787–798, 21st IUFRO World Congress, Kuala Lumpur, 7–12 August 2000, Kuala Lumpur, IUFRO World Congress Organizing Committee

Hooda, N., Gera, M., Andrasko, K., Sathaye, J., Gupta, M., Vasistha, H., Chandran, M. and Rassaily, S. (2007) 'Community and farm forestry climate mitigation projects: case studies from Uttaranchal, India' *Mitigation and Adaptation Strategies for Global Change*, vol 12, pp1099–1130

ITTO (1993) 'ITTO guidelines for the establishment and sustainable management of planted tropical forests', ITTO Policy Development Series, issue 4

Kanowski, J., Catterall, C. P. and Wardell-Johnson, G. W. (2005) 'Consequences of broadscale timber plantations for biodiversity in cleared rainforest landscapes of tropical and subtropical Australia', *Forest Ecology and Management*, vol 208, pp359–372

Keenan, R., Lamb, D., Woldring, O., Irvine, T. and Jensen, R. (1997) 'Restoration of plant biodiversity beneath tropical tree plantations in Northern Australia', *Forest Ecology and Management*, vol 99, pp117–131

Kumar, B. M. and Nair, P. K. R. (eds) (2006) *Tropical Home Gardens. A Time-Test Example of Sustainable Agroforestry*, Springer Verlag

Kuusipalo, J., Adjers, G., Jafarsidik, Y., Otsamo, A., Tuomela, K. and Vuokko, R. (1995) 'Restoration of natural vegetation in degraded *Imperata cylindra*

grasslands: understorey development in forest plantations', *Journal of Vegetation Science*, vol 6, pp205–210
Lamb, D. (1998) 'Large-scale ecological restoration of degraded tropical forest lands: the potential role of timber plantations', *Restoration Ecology*, vol 6, pp271–279
Marjokorpi, A. (2006) 'Biodiversity management in fast-growing plantations: a case study from West Kalimantan, Indonesia', *Annales Universitatis Turkuensis*, Serie AII, Part 200
Marjokorpi, A. and Salo, J. (2007) 'Operational standards and guidelines for biodiversity management in tropical and subtropical forest plantations: how widely do they cover an ecological framework?', *Silva Fennica*, vol 41, pp281–297
Méndez, V. E., Lok, R. and Somarriba, E. (2001) 'Interdisciplinary analysis of homegardens in Nicaragua: micro-zonation, plant use and socioeconomic importance', *Agroforestry Systems*, vol 51, pp85–96
Otsamo, R. (2000) 'Secondary forest regeneration under fast-growing forest plantations on degraded *Imperata cylindra* grasslands', *New Forests*, vol 19, pp69–93
Parrotta, J. and Turnbull, W. (eds) (1997) 'Catalysing native forest regeneration in degraded tropical lands', *Forest Ecology and Management* (Special Issue), vol 99, pp1–290
Petit, B. and Montagnini, F. (2006) 'Growth in pure and mixed plantations of tree species used in reforesting rural areas of the humid region of Costa Rica, Central America', *Forest Ecology and Management*, vol 233, pp338–343
Piotto, D. (2008) 'A meta-analysis comparing tree growth in monocultures and mixed plantations', *Forest Ecology and Management*, vol 255, pp781–786
Putz, F. E. and Redford, K. H. (2010) 'The importance of defining "forest": tropical forest degradation, deforestation, long-term phase shifts, and further transitions', *Biotropica*, vol 42, pp10–20
Sasaki, N. and Putz, F. E. (2009) 'Critical need for new definitions of "forest" and "forest degradation" in global climate change agreements', *Conservation Letters*, vol 2, pp226–232
Seppälä, R. (2007) 'Global forest sector: trends, threats and opportunities', in Freer-Smith, P. H., Broadmeadow, M. S. J. and Lynch, J. M. (eds) *Forestry and Climate Change*, CAB International, pp25–30
Spek, M. (2006) *Financing Pulp Mills: An Appraisal of Risk Assessment and Safeguard Procedures*, Center for International Forestry Research (CIFOR), Bogor, Indonesia
UNFCCC (2010) 'Registered A/R CDM projects' http://cdm.unfccc.int/Projects/registered.html, accessed 12 February 2010
Varmola, M., Gautier, D., Lee, D. K., Montagnini, F. and Saramäki, J. (2005) 'Diversifying functions of planted forests', in Mery, G., Alfaro, R., Kanninen, M. and Lobovikov, M. (eds) *Forests in the Global Balance – Changing Paradigms*, IUFRO World Series Volume 17, International Union of Forest Research Organizations (IUFRO), Helsinki, pp117–136
Wenhua, L. (2004) 'Degradation and restoration of forest ecosystems in China', *Forest Ecology and Management*, vol 201, pp33–41
Wilkinson, M. K. and Elevitch, C. R. (2000) *Multipurpose Windbreaks: Design and Species for Pacific Islands*, Permanent Agriculture Resources, Holualoa, Hawaii, USA
World Rainforest Movement (2007) *WRM Bulletin*, no 117 www.wrm.org.uy/bulletin/117/Bulletin117.pdf
World Rainforest Movement (2009) *WRM Bulletin*, no 146 www.wrm.org.uy/bulletin/146/Bulletin146.pdf