GLOBAL OUTLOOK FOR PLANTATIONS

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ABARE

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Foreword

Plantations are recognised as being significant in future global wood supply and in the development of forest and environmental policy. However, their exact role in these areas has not been well understood.

ABARE and Jaakko Pöyry prepared this report to provide input into the Intergovernmental Forum on Forests. The technical information here is intended to assist in the forum's policy deliberation on issues associated with the supply and demand for wood and nonwood forest products and services.

Previous research in this area has concentrated on two themes: trade in forest products and the characteristics of plantation development. The aim in this report is not to duplicate previous research, but to link the key findings from recent studies in a compatible and assessable format. The intention is to identify gaps in information and determine the potential role of plantations in future wood supply.

The main focus in this report is on the development of plantations for industrial roundwood, although the use of plantations for fuelwood is also briefly discussed.

It is hoped that the report will help raise the global profile of plantations by providing an information tool to assist governments, policy makers, industry and landowners in developing plantation strategies.

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Summary

Plantation forests (plantations) are playing an increasingly important role in meeting the world's growing requirements for wood and nonwood forest products. They represent less than 3 per cent of the world's forest resources, yet are estimated to supply around a third of industrial roundwood and 10 per cent of fuelwood. Plantations also supply a large range of nonwood products and services — including animal fodder, cork, nuts and fruit, latex, tannin and oils — and are used for recreation and environmental protection, such as soil and water protection. They are also increasingly important as a focus for international forest policy. However, despite the benefits, the exact role of plantations is not well understood.

The first meeting of the Intergovernmental Forum on Forests in October 1997 agreed to list new items under category II (d) (issues needing further clarification) of the forum's program of work. Category II (d) specifically includes consideration of 'future supply and demand of wood and nonwood forest products and services'.

Study objectives

This report provides technical information for the Intergovernmental Forum on Forests, rather than material addressing policy issues. Specifically, the main objectives in this study into the global outlook for plantations are to:

- collate information on current and expected rates of plantation establishment and expected trends in demand for plantation products;
- assess the likely implications of plantation expansion on the supply of wood;
- identify economic, social and environmental costs and benefits of plantations; and
- develop recommendations, in consultation with the study Steering Committee, to the Intergovernmental Forum on Forests.

It is not the intention in this report to duplicate existing work, but rather to link key findings of previous studies on trade in forest products and plantation development — such as the Norwegian report (Solberg 1996), the Global

Forest Products Outlook Report (FAO 1998a) and the Plantations Consultant Report to the Food and Agriculture Organisation (Brown 1998) — with other recent studies and information. The report identifies gaps in information, assesses the potential role of plantations, and recommends strategies for raising the global profile of plantations.

The main focus in this report is on the development of plantations for industrial roundwood, although the use of plantations for fuelwood and nonwood forest products is also briefly discussed.

Defining plantation forests

A continuum exists from highly protected conservation forests to productive, short rotation planted forests, and the interface between some planted and natural forests is indistinct. Thus, a clear definition of plantation forests is difficult to provide. Most definitions identify the degree of management as the determining factor between a plantation and a natural forest. Lund (1998), while reviewing definitions of forest, deforestation, afforestation and reforestation, observed seventeen definitions of plantation.

This report uses the definition developed by the Food and Agriculture Organisation (1998b) for the Temperate and Boreal Forest Resource Assessment 2000, which identifies plantations as:

> forest stands established by planting and/or seeding in the process of afforestation or reforestation. They are either: of introduced species (all planted stands), or intensively managed stands of indigenous species, which meet all the following criteria: one or two species at planting, even age class, regular spacing.

Location, species and ownership of plantations

Industrial plantations are the focus in this report, because data on fuelwood and nonwood products either are unavailable or were difficult to obtain in the available time. Much of the 115.9 million hectares of plantations established (62 per cent) is located in the traditional wood producing regions (as defined by the Food and Agriculture Organisation) of Europe and the former Soviet Union, and North and Central America (table 1).

However, significant planting has occurred in recent years in the temperate and subtropical areas of Africa, South America, Asia and Oceania.

Over 60 per cent of the plantations in Asia and Africa have been assessed as being unsuitable for commercial wood production as a result of low productivity, poor management and poor species selection. Some have been planted for fuelwood or environmental benefits. In contrast, most of the plantations in other regions are used for commercial wood production.

The total area of industrial plantations effectively available for commercial wood production is around 94 million hectares (table 1).

Over 70 per cent of plantation forests are softwood species (coniferous species). These species dominate plantations in North and Central America,

1 Global industrial plantations **a**

	Unit	Africa	North and Central America	South America	Asia
Industrial plantations area	million ha	3.9	24.2	7.8	30.1
Total effective area	million ha	1.4	24.2	7.5	11.2
Plantation area suitable for commercial wood production	%	36	100	96	37
Species planted – ratio of softwood to hardwood		50:50	98:2	53:47	31:69
Ownership levels – ratio of public to private		na	60:40	0:100	na
			Europe and former Soviet Union	**Oceania**	**World**
Industrial plantations area	million ha		47.1	2.8	115.9
Total effective area	million ha		47.1	2.5	93.9
Plantation area suitable for commercial wood production	%		100	89	81
Species planted – ratio of softwood to hardwood	%		88:12	90:10	71:29
Ownership levels – ratio of public to private			50:50	33:67	na

a By the Food and Agriculture Organisation's statistical regions. **na** Not available.
Source: Global Outlook for Plantations Database.

Europe and the former Soviet Union, and Oceania, and there are also significant softwood resources in the temperate regions of South America and Africa (mainly Chile and South Africa) (table 1). Hardwood species (non-coniferous species) dominate plantations in the tropical regions of Asia and the north of South America (mainly Brazil), and there are significant hardwood plantations in southern Europe (mainly Spain and Portugal).

The establishment of hardwood plantations is increasing in the temperate regions of South America, Africa and Oceania. Growth rates are influenced by factors such as the site, species and silvicultural management, and vary from less than 7 cubic metres per hectare a year to well over 30 cubic metres per hectare a year. Establishment costs (excluding land purchase) also vary, ranging from US$1500 to US$2500 per hectare for softwood plantations, and from US$1800 to US$4200 per hectare for hardwood plantations.

There is a trend, particularly in the southern hemisphere, away from government development and ownership of plantations toward ownership by processing companies, landowners or individual investors. The plantations in South America are mostly privately owned, and there is also a trend to private ownership in Oceania, where governments established most plantations. However, parts of Europe and the former Soviet Union and parts of Asia are likely to maintain high levels of public ownership, given their different political objectives.

Costs and benefits of plantations

Unlike many other land uses, plantation development is considered a long term venture (with rotation lengths ranging from five to over fifty years) and can result in economic, environmental and social costs and benefits. Plantation managers can improve the economic benefits by careful species and provenance selection and by using silvicultural regimes that increase wood production and improve rates of return.

The development of industrial plantations usually depends on factors such as the suitability of land and the proximity to markets and existing infrastructure. Industry usually develops in conjunction with the plantation resource. The development of industry and careful site selection have allowed greater specialisation in growing, harvesting, transporting, processing and marketing of wood. Technological advances in tree breeding and genetic improvement, site preparation, weed control and silviculture have resulted in improvements in commercial yield, health and vigor. Consequently, plan-

tations can now be established on a wider range of sites with varying silvicultural regimes, reducing the costs of management, harvesting and processing. *Eucalyptus globulus*, for example, was selected for breeding to improve its pulping and fibre characteristics, making it highly suitable for the production of fine writing papers.

Plantations are now a significant source of industrial wood, with South America and Oceania sourcing more than half of their wood supply from plantations. Over half the world's production of wood is used for fuel. Consumption of fuelwood is an estimated 1.7 billion cubic metres a year, although this figure may understate total consumption given that it is difficult to measure. Developing countries in Asia, Africa and South America consume almost 90 per cent of fuelwood. Plantation establishment for fuelwood began on a large scale in the late 1970s, largely in Asia and Africa. Plantation wood from these regions is estimated to supply around 10 per cent of the total fuelwood demand. However, given the difficulty of measuring total fuelwood consumption, this estimate varies: Brown (1998), for example, estimates that fuelwood production from plantations makes up 4.7 per cent of total fuelwood production.

Environmental benefits are harder to quantify. Plantations established for site rehabilitation on degraded land can increase biodiversity, provide improved soil structure, increased soil organic matter and fertility, and improve the local microclimate. Plantations of native species, in particular, can help achieve conservation goals and protect core conservation areas. They can be used to provide corridors between protected areas, control water runoff, provide shelter from wind, heat and sand storms, and lower watertables in saline areas. Wood production is not necessarily excluded from plantations developed for environmental protection, and the need for wood may even be the catalyst for planting.

Potential environmental costs can include the simplification of ecosystems, sedimentation, pollution from fertilisers and weedicides, and the rise of disease and pest incidence (with a potential impact on surrounding land uses). Problems can also arise if plantations reduce the availability of water for other uses.

The social benefits of plantations include employment, the generation of infrastructure (such as roads, communications, housing) and byproducts (such as fuelwood and other nonwood products to remote areas). Governments have encouraged the establishment of plantations to achieve a range

of economic and social objectives, including the development of rural economies. Grown as a woodlot or integrated into existing land uses, plantations can also provide a supplementary form of income to farmers and landholders.

Negative social impacts of plantations usually reflect reduced access to forests for local people and limited rights to use land for traditional activities. To minimise the potential for these social costs, plantation design and management needs to ensure the rights of landowners. Unacceptable economic, social and environmental costs are usually found to result from deficiencies in project design and/or management. Full consideration of economic, social and environmental factors in the planning and management of plantations can assist in maximising benefits and minimising costs.

Factors shaping plantation development

A number of economic, social and environmental factors have shaped plantation development in the past and will influence future plantations.

Government involvement

Governments can become involved in plantation development to overcome perceived market impediments created by the nature of plantation investments. The long term nature of plantation development presents issues that can make plantation investment unattractive to the private sector, for example: the high risk of investment; the high cost of financing the investment; the long period of investment, with high initial costs for establishment and revenue received only on harvest; the need for a critical mass of wood availability before processing facilities can be developed; lack of information on appropriate species, establishment and management techniques; lack of regional infrastructure to support plantation development; the high risk of marketing products especially small wood from thinnings; and the lack of secondary plantation markets to allow plantation sales before harvesting. The type and magnitude of risks with plantings can vary significantly between developed and developing countries and between regions.

Governments can also use plantation developments to meet specific economic, social or environmental policy objectives, such as assisting forest industry development, increasing regional infrastructure and employment, and overcoming forest product trade imbalances. Government policy has been a significant factor in the growth in planted areas over the past thirty years.

Large scale plantation development began largely as a government activity in most parts of the world, including the United Kingdom, Australia, Chile and New Zealand. Plantations were developed through direct government involvement or through government incentive schemes, including taxation incentives, loans against subsidised interest rates and other conditions, and grants.

The appropriate role of government in plantation forestry remains debatable, given the demand for forests to supply nonindustrial wood products and nonwood products. Many countries are divesting themselves of their public plantation assets, which may reduce access to many of the nonwood benefits of plantations, or place a cost on these assets that were traditionally provided free of charge.

Markets

Both changing and emerging markets influence plantation development. New markets in North Asia, for example, have resulted in expanded plantation development within and close to this region. Technological advances also affect plantation development. Tree breeding, for example, has improved yields and the quality of products harvested, while new processing technology — such as reconstituted panel boards (for example, medium density fibreboard) and glue laminated products (for example, laminated veneer lumber) — produces more product with fewer inputs and/or lower quality inputs.

The emergence of carbon markets has recently captured the attention of the plantation industry, with the possibility of selling the rights to carbon sequestered in plantations. The Kyoto Protocol (11 December 1997) and the subsequent Conference of Parties at Buenos Aires (November 1998) raised the possibility that countries may use carbon sequestered by plantations established since 1 January 1990 to meet their Kyoto Protocol targets (where certain conditions are met and where areas can be accurately measured and verified). International regulations and guidelines on the definitions of forests that could be counted are still under negotiation, but a few rights to carbon sequestered by plantations have already been traded in anticipation of the development of carbon sequestration markets.

Carbon markets could influence plantation development and associated wood processing if a trading system is implemented. However, the likely implications for the expansion of plantations are unknown.

Advances in the manufacture of wood products have allowed reconstituted wood products such as particleboard and medium density fibreboard to substitute for many solid wood products. Global production of solid wood products has not increased over the past decade, yet world production of wood based panels has risen by 80 per cent (FAO 1997a). Reconstituted and glue laminated products, which can use low grade, small diameter logs, favor plantation grown wood. The trend away from solid wood products is expected to continue, and reconstituted board products, although they may never replace some solid wood products (particularly those used in decorative and high quality furniture uses), can be expected to gain significant market share.

Land availability

Land availability is a key determinant of future plantation expansion. For environmental reasons, the majority of plantation development will occur on marginal agricultural land. Regional characteristics and insufficient information make it difficult to accurately estimate the global or even regional areas suitable for plantation, and such estimates vary greatly. Nilsson and Schopfhauser (1995) suggest that around 345 million hectares of land presently used for agriculture globally could become available for plantations and agroforestry. Grainger (1988) assessed degraded lands in the tropics, and estimates that about 758 million hectares are suitable for plantation development. Land availability is considered to be a major factor in the rising wood supply from the southern hemisphere.

Despite the likely increase in demand for forest products in the future, the supply from natural forests is not expected to increase and may even decrease. Thus plantations are expected to supply the bulk of any increase in supply. However, plantation expansion will require plantations to successfully compete for available land with agriculture and other land uses. Additionally, user rights will have a significant impact on the conversion of agricultural land to plantations.

Environmental issues

Society's perception of forests has changed over the past few decades. There is increasing focus on the way in which forests are managed and used, resulting in greater areas of natural forests being set aside as parks and reserves and only limited harvesting activities in natural forests. There is increasing community pressure to improve forest management and harvesting practices, and to ensure sustainability of all natural forest values. This has increasingly

limited the volume of wood harvested from natural forests. As a result, the cost of obtaining access to these forests has increased, creating market opportunities for wood substitutes and wood from plantations or intensively managed accessible natural forests.

To encourage sustainable management, the certification of forest products is being promoted in a number of markets, particularly in parts of Europe. Certification in plantation grown forests is likely to target poor management, which is the underlying cause of many of the environmental and social costs of plantations. Evans (1997) shows that plantation forestry is sustainable in terms of wood yield in most situations, if plantation managers maintain good management practices. Any problems with the potential loss of productivity between successive rotations could be overcome through adjustments to management practices and, in some cases, through the use of fertilisers.

Globalisation of the forest industries

The forest product economy is now global, with international trade in forest products quadrupling since the 1960s. Given improved transport systems and worldwide integration of markets for forest products, wood is shipped from one part of the world to another for processing or sale. World scale, cost efficient processing facilities require mills to be located close to large wood resources. Further, many of these facilities, such as pulpmills, often require wood fibre of a homogeneous quality. These factors favor the development of industrial plantations.

Outlook for wood products

The long term demand and supply of wood has been the subject of a number of recent studies (for example, Sedjo and Lyon 1996; Solberg 1996; Sohngen et al. 1997; FAO 1998a). Some studies were conducted before the 1997-98 economic upheavals in Asia, although many analysts agree that the downturn will have only a moderate impact on economic growth in the longer term and thus will not necessarily affect the relevance of these studies. Average annual demand for roundwood is generally projected to increase by around 1 per cent a year over the coming decade. Sedjo and Lyon (1996) project that consumption will increase from 1.7 billion cubic metres in 1995 to around 2.3 billion cubic metres by 2045.

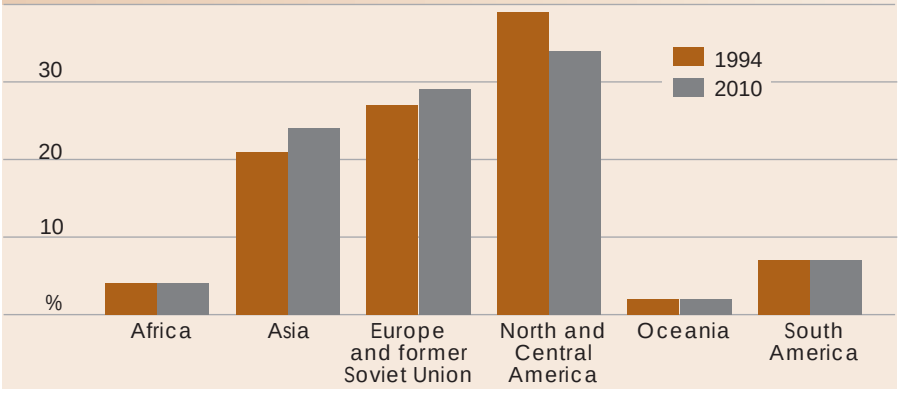
These projections also reflect an increasing trend in the consumption of pulpwood for reconstituted wood panels and paper. Pulpwood consumption is

projected to increase from 700 million cubic metres in 1995 (41 per cent of total industrial roundwood) to around 1.33 billion cubic metres by 2045 (58 per cent of total industrial roundwood).

Along with changes to the quantity and type of wood demanded, there are also changes to the regional demand patterns. Based on consumption projections to 2010 (FAO 1998a), Asia and Europe and the former Soviet Union are likely to increase their shares of global wood consumption; South America, Africa and Oceania are likely to retain their shares; and the North and Central America region is expected to decrease its share (figure A). These projections confirm the view of many analysts that Asia, driven by increasing economic development and population growth, is emerging as an important future market for wood products. In Europe and the former Soviet Union, much of the growth in consumption is likely to come from the developing economies of countries in the former Soviet Union, such as Russia and the Ukraine.

Similar changes are expected in the regional patterns of roundwood supply. Regional analysis (FAO 1998a) indicates that Asia and Europe and the former Soviet Union will increase their shares of global supply; South America, Africa and Oceania will maintain their shares; and the North and Central America region will decrease its share. Asia, despite experiencing some decline in supply from natural forests, will have increasing supplies from plantations. Much of the supply increases in Europe and the former Soviet Union are likely to come from the latter's natural forests, although the high costs of gaining access to these forests will constrain production. Increasing supply from South America, Africa and Oceania is expected from the increasing

A **Share of world consumption of industrial roundwood, by region**



plantation resource in these regions. Any increase in supply from North and Central America is likely to come from natural forests in Canada and a growing supply of plantation wood in the southern part of the region. The United States is unlikely to increase its wood supply from natural forests.

Potential supply from plantations

By assessing regional potential (including existing natural forests and plantations, suitable land, infrastructure, access to plantation technology, and political and economic stability), wood supply from plantations was estimated, by region, to 2040. Plantations will largely produce future increases in global supply of wood. Industrial wood supply from plantations is projected to increase by 67 per cent — up from 624 million cubic metres in 2000 to 1043 million cubic metres by 2040. Thus plantations are expected to meet 35 per cent of projected global demand for industrial wood by 2000, rising to 44 per cent by 2020 and 46 per cent by 2040 (table 2). This level of production would require a significant increase in plantation area and/or substantial gains in plantation productivity in all regions.

The future expansion of plantations and their role in supplying wood products will largely reflect the competitiveness of plantation wood against other sources of wood and product substitutes, and the competitiveness of plantations against agriculture, urban use and other uses. Location, ease of harvest, fibre quality and so on — leading to improved efficiency and lower delivered cost of wood — are important factors in this competitiveness. Natural forests have traditionally maintained a competitive advantage over plantation forests, given the high cost of intensively managing plantations. However, this gap is narrowing as a result of improvements in the productivity and

2 Predicted contribution of plantation wood to regional wood supply

	2000	2020	2040
	%	%	%
Africa	20	39	40
Asia	32	46	48
Europe and former Soviet Union	46	53	55
North and Central America	22	29	31
Oceania	55	66	67
South America	63	65	66
World	35	44	46

Recommendations

Definition of plantations

1. Call on countries to adopt an internationally agreed definition of plantations.

Global and regional plantation expansion

2. Call on countries to work with the Food and Agriculture Organisation to improve the accuracy of data on plantation areas.
3. Call on countries and relevant international organisations such as the International Tropical Timber Organisation and the Food and Agriculture Organisation to develop and implement forest product statistics databases which clearly segregate wood products derived from natural forests from those derived from plantations.
4. Call on countries and international organisations to support a study on the supply of, demand for and value of fuelwood and nonwood forest products, as called for in Proposals for Action by the Intergovernmental Panel on Forests.

Emerging issues

5. Call on countries and international organisations to conduct research studies on the long term (over several rotations) sustainability of plantations from economic, social and environmental perspectives.
6. Call on countries to implement appropriate codes of practice and guidelines for plantation management, and criteria and indicators of sustainability. It is expected that some form of voluntary certification of sustainability will be required.
7. Call on countries to contribute to assessing the likely impact of developing carbon markets on plantation development and forest product markets.
8. Call on countries and international organisations to undertake studies to identify and report on the availability of land for plantation expansion from biophysical and economic perspectives, accounting for relevant economic, social and environmental constraints.

Costs and benefits of plantations

9. Support the work of international organisations and countries, with the Food and Agriculture Organisation, to develop a better understanding of, and methods of quantifying, the social and environmental costs and benefits of plantations (including those developed for fuelwood), and the exchange of relevant information.
10. Call on countries to identify and remove obstacles to plantation development and to trade, in the context of the emerging importance of plantations in supplying wood and nonwood requirements.

efficiency of plantations, the decreasing availability of wood from natural forests, and also the increasing cost of gaining access to these forests.

Markets are recognising the increasing competitiveness of plantations. Japan (the world's largest importer of hardwood woodchips), for example, has increased its use of wood from plantations. The major Japanese companies using woodchip have set targets to source from plantations a significant amount of their woodchip imports (currently around 10 million bone dry tonnes of hardwood and 3 million bone dry tonnes of softwood). The main aim is to reduce costs and ensure uniformity of the wood fibre.

Recommendations

An objective in this study is to identify proposals for action that will help raise the global profile of plantations. The recommendations listed opposite have been developed in consultation with the Australian Steering Committee of the Intergovernmental Forum on Forests.

1 Introduction

Plantation forests (plantations) are playing an increasingly important role in meeting the world's growing requirements for wood and nonwood forest products. This is resulting from a combination of economic, social, political and environmental factors. Plantations represent less than 3 per cent of world forest, yet make up 20 per cent of total wood supply, including fuelwood (Sutton 1999). An estimated 34 per cent of industrial wood — comprised of industrial timber cut for sawntimber, veneer and pulp — was sourced from plantations in 1997 (Sedjo and Botkin 1997).

Future plantation wood supplies are projected to increase to 46 per cent of all industrial wood used in 2040. This increase in plantation development is likely to result in significant global changes to wood production and processing activities and to trade in forest products.

Plantation development has also emerged as a key element in the formulation and implementation of forest and environmental policy at the local, national and international level. A number of studies have addressed the importance of plantations as a wood source, but the likely regional and global implications of plantation expansion have not been well understood. In this report, summaries are provided of the key findings from recent studies, such as the Norwegian Report (Solberg 1996), the Global Forest Products Outlook Study (FAO 1998a) and the Plantations Consultant Report to the Food and Agriculture Organisation (Brown 1998), to determine the potential role of plantations in future wood supply.

The main focus in this report is on the development of plantations for industrial roundwood. The role of plantations in supplying fuelwood and nonwood forest products is of growing importance. However, these products are not largely traded between regions, and information on these products is scarce and incomplete at the global level. More information is needed before a comprehensive analysis of regional demand and supply of these products is possible.

The aim in this report is to help improve understanding of the implications of plantation expansion. Another objective is to raise the global profile of plantations by providing an up-to-date assessment of plantation information

to assist governments, policy makers, industry and landowners in developing plantation strategies.

The intention here is to provide technical information for the Intergovernmental Forum on Forests, rather than to address policy issues. Specifically, in this report:

- information on current and expected rates of plantation establishment and expected trends in demand for plantation products is collated;
- economic, social and environmental costs and benefits of plantations are identified;
- the likely implications of plantation expansion on the supply of wood are assessed; and
- recommendations to be considered by the Intergovernmental Forum on Forests are made.

Background information on plantations is provided in chapter 2, including regional information on area, establishment rates, species composition, growth rates and ownership. The economic, social and environmental costs and benefits of plantation development and uses are outlined in chapter 3. Case studies of the costs and benefits of planting are included in chapter 4. Issues that have influenced plantation development in the past and that are likely to influence future development are discussed in chapter 5. The outlook for world timber is examined in chapter 6, which includes an overview of regional demand, supply and trade in industrial roundwood, as well as a brief discussion on fuelwood. The potential role for plantations in future global wood supply is assessed in chapter 7. Finally, some conclusions and recommendations are made in chapter 8.

Differentiating between ‘natural’ and ‘plantation’ forests

The distinction between *natural forests* and *plantations* has complicated previous assessments of plantations and wood supply. It is widely recognised that a continuum exists from highly protected conservation forests to productive, short rotation planted forests, and that the interface between some planted and natural forests is indistinct. Thus, a clear definition of plantation forests is difficult to provide. Most definitions identify the degree of management as the determining factor in distinguishing a plantation from a natural forest. These two categories can be clearly distinguished in most

tropical and subtropical countries (Pandey 1995). However, there is a general view that this distinction is not appropriate to all forest growing regions with varied establishment and management practices, such as in Europe. Further, such a distinction suggests that products from plantations are easily discernible from those sourced from natural forests, which is often not the case.

Lund (1998) reviewed definitions of forest, deforestation, afforestation and reforestation, and reports seventeen definitions for forest plantations. These delineations can be separated into three main groups based on: physical characteristics (that is, the absence of key elements of a native ecosystem); planting only; and planting and sowing. Organisations such as the Food and Agriculture Organisation of the United Nations and the International Tropical Timber Organisation have identified this problem in collecting and collating forest information. They continue work to develop definitions that recognise the regional variations in establishment and management intensity, and that guide the uniform collection of forest information.

This report uses the definition developed for the Temperate and Boreal Forest Resource Assessment 2000 (FAO 1998b). It defines plantations as:

> forest stands established by planting or/and seeding in the process of afforestation or reforestation. They are either:
>
> - of introduced species (all planted stands), or
> - intensively managed stands of indigenous species, which meet all the following criteria: one or two species at plantation, even age class, regular spacing.

This definition excludes stands that were established as plantations but are now considered seminatural because they have been without intensive management for a significant period. It allows standardised and comparable reporting on the world forest resource. The definition was not developed to replace existing national classifications, because national inventories, terms and definitions have specific purposes and suit each country's ecological setting and/or functions and its use of forests (FAO 1998b).

2

Regional profile of plantations

The statistical regions defined by the Food and Agriculture Organisation — Africa; Asia; Europe and the former Soviet Union; North and Central America; Oceania; and South America — are adopted in this report. A list of countries in each statistical region is presented in appendix A.

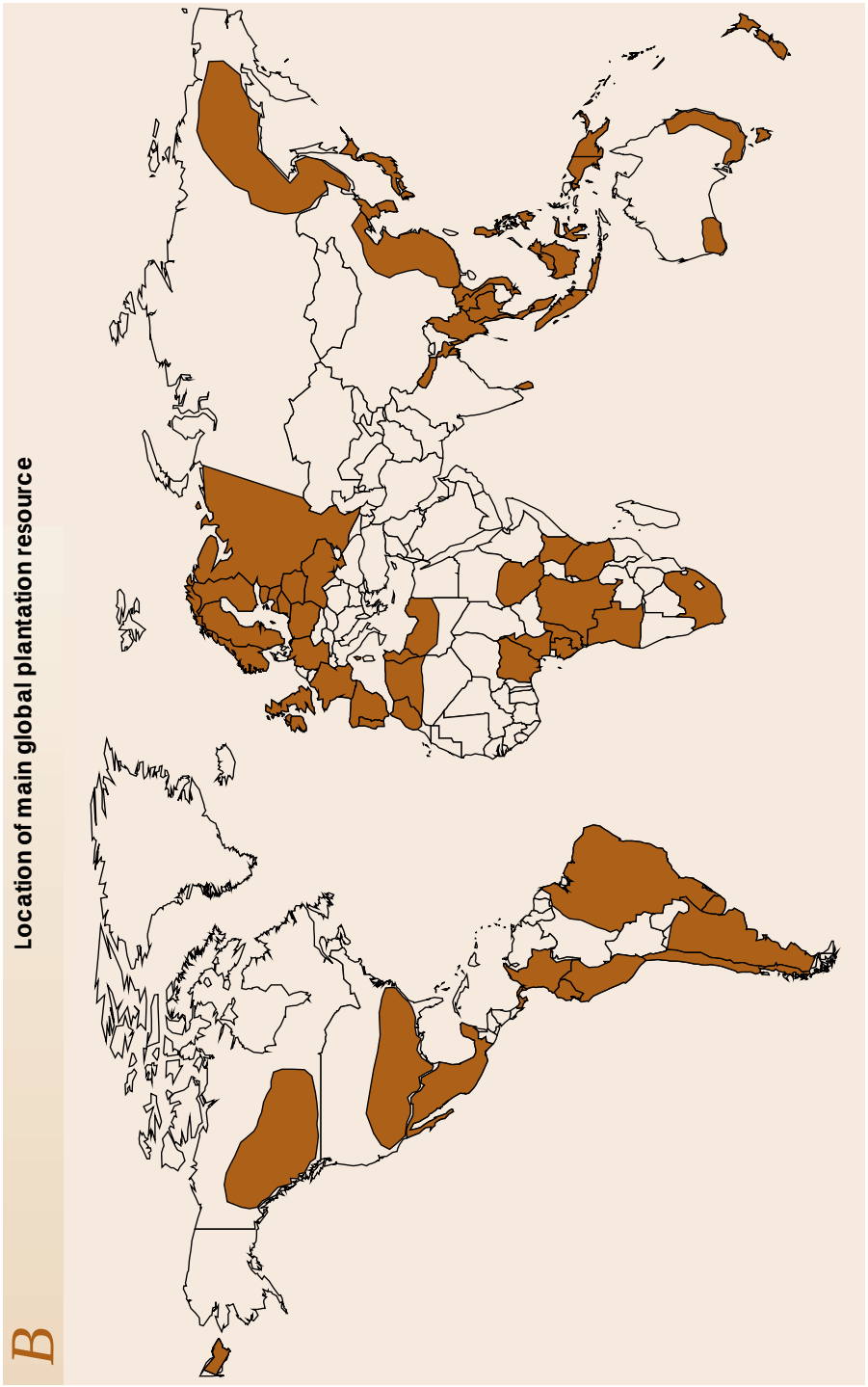
Plantation areas

Plantation forestry in the temperate and subtropical regions of the world, particularly in the southern hemisphere, has expanded rapidly since the early 1950s and is making a significant contribution to wood production in these regions. The expansion of tropical plantations has increased dramatically over the past two decades and is poised for further expansion (Kile 1997). Significant expansion of temperate plantation resources (predominantly located in the northern hemisphere) is prevented by land availability constraints.

Industrial plantations are defined as 'plantation resources with the primary purpose of supplying roundwood for sawntimber, veneer and pulp' (Pandey 1997). Location of the main plantation areas are shown in figure B: the largest area of industrial plantations is located in the traditional wood producing regions of Europe and the former Soviet Union, and North and Central America, with a large area also in Asia (table 3).

Plantations are not always successful or suitable for wood production for a number of reasons, including ineffective planning and management, marketing factors, fire and disease. Additionally, plantations are often established for reasons other than commercial wood production, such as land protection, environmental rehabilitation, visual amenity and fuelwood. Effective plantations are defined as 'plantations that are capable of supplying roundwood products to a market at a commercially economic level'.

An estimated 19 per cent of the total industrial plantation area is not suitable for commercial wood production (table 3). Approximately 60 per cent of the plantations in Asia and Africa, for example, are managed as noncommercial plantations. The proportional differences between total area and effective area (by region) are illustrated in figure C. These estimates have


B
Location of main global plantation resource

3 Industrial plantation area, by region

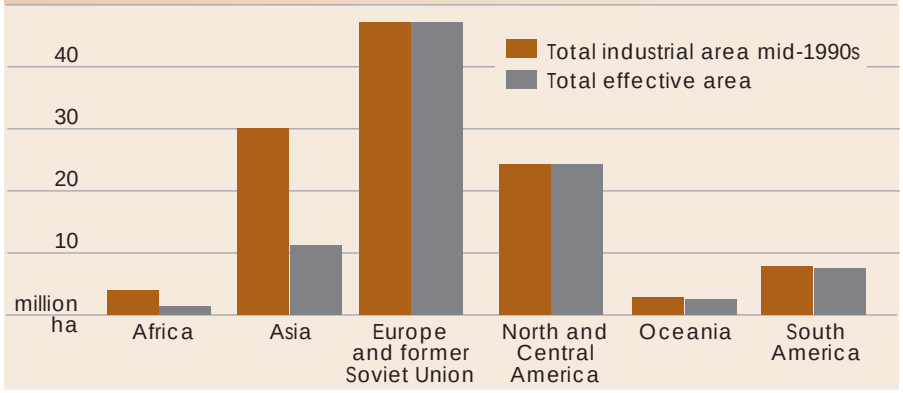
	Area mid-1990s	Total effective area	Current establishment rate
	million ha	million ha	'000 ha/yr
Africa	3.9	1.4	10
Asia	30.1	11.2	1 718
Europe and former Soviet Union	47.1	47.1	na
North and Central America	24.2	24.2	na
Oceania	2.8	2.5	120
South America	7.8	7.5	230
Total	115.9	93.9	na

na Not available.
Source: Global Outlook for Plantations Database.

been developed from country sources, internal Jaakko Pöyry database information and a detailed review of the existing literature. They are lower than those in previous studies by Pandey (1992) and Nilsson (1996), who calculate commercial success rates of 61 per cent for Asia and 60–77 per cent for Africa (although it is unclear whether these estimates also exclude fuelwood).

The definition of plantation forests is often a difficult concept to apply to timber resources, as noted by other researchers (for example, Mather 1993; Kanowski 1997). The conceptual difference between managed natural forest and natural forest plantations is difficult to interpret, particularly in North America and Europe and the former Soviet Union. The assumptions that

C **Plantation area, by region**



underpin the estimates in table 3 are summarised below, by statistical region.

Africa

Africa has a relatively small area of industrial plantations when compared with the other major growing regions, and the majority of the plantation resource is located in South Africa or in the Mediterranean regions. With the exception of a few equatorial countries, Africa is considered an arid continent which has somewhat limited potential for industrial plantation expansion.

The total standing area of industrial plantations in the African region is approximately 3.9 million hectares (table 3). This figure differs from other assessments (Davidson 1995; Neilson 1998; Brown 1998), largely as a result of the inclusion or exclusion of nonindustrial plantation resources, and the difficulties of obtaining accurate figures.

South Africa supports the largest industrial plantation base in Africa, with approximately 1.4 million hectares of *Pinus*, *Eucalyptus* and *Acacia* species. Countries such as Ethiopia, Kenya and Rwanda have large fuelwood plantation resources. Plantations throughout the continent have been established for a variety of reasons, including the stabilisation of sand dunes, environmental rehabilitation and fuelwood production. Plantation areas for individual countries in the region are contained in appendix B.

Asia

Asia has the second largest plantation resource after Europe and the former Soviet Union. However, a large proportion of the area is classified as nonindustrial in terms of wood production, including fuelwood, noncommercial rubber and oil palm. Rubber plantations are considered to be an agricultural crop, so are not included in the plantation areas estimated in this report. However, rubber is increasingly important to the timber industry in the Asian region, particularly in Malaysia where it illustrates the potential of plantations to provide multiple benefits.

The expansion of Asia's plantation resources has occurred predominantly over the past decade, driven by the increasing population, strong economic growth and restrictions on the harvesting of natural forest. The standing area of industrial plantations in Asia is estimated at 30.1 million hectares (table 3),

which is higher than Kanowski's (1997) estimate and lower than Brown's (1998) — a result of different interpretations of the Food and Agriculture Organisation's definition. Brown (1998), for example, includes all of China's plantation resource (17.5 million hectares), whereas the figure is only 5 million hectares (Neilson 1998) in this report because the majority of these plantations are not deemed to be commercially viable.

Further, a number of Asian countries, such as Indonesia, Thailand and India, have unreliable data on their plantation areas and their estimates vary significantly (Wood Resources Quarterly 1993; Jaakko Pöyry 1997; Brown 1998; Neilson 1998). In this report an estimate for each country, based on previous estimations and recent literature, is adopted (appendix B).

Rubber plantations in Asia

Rubber plantations are not classified (according to the Food and Agriculture Organisation's definition) as industrial plantations, but rather as agricultural crops. However, rubber plantations occupied just under 9 million hectares worldwide in 1991 (ITTO 1995) — with 84 per cent in Asia and Oceania — and the total area has the potential to produce an annual sustainable harvest of over 43 million cubic metres of wood. Given this significant area, rubber plantations are identified in this section but not included as industrial plantations for the purposes of this report.

Rubber trees have traditionally been grown in both small and large estates for the production of latex. However, as the latex flow decreases, rubberwood is being increasingly harvested and plantations are being re-established. Rubberwood is used to manufacture furniture, plywood, glulam and building components, reconstituted board products and pulp. Table 4 contains details of rubber plantations for major supply countries.

Europe and the former Soviet Union

Europe and the former Soviet Union support the largest area of industrial plantations. The plantations consist of natural forest species that are not intensively managed, so it is difficult to apply the industrial plantation definition to this region. However, these plantations fall within the scope of the definition in this report through the method of their establishment and the market they supply.

Based on a Jaakko Pöyry assessment, the standing area of industrial plantations in Europe and the former Soviet Union is estimated at 25.2 million

4 Supply of rubberwood in Asia

	Total estate area	Recovery of saw and veneer logs from total available	Saw and veneer log production, 1991
	'000 ha	%	'000 m^3
Indonesia	3 043	45	270
Malaysia	1 835	84	1 350
Thailand	1 779	80	1 638
China	467	85	308
Vietnam	197	95	150

Source: FAO (1997a).

hectares and 21.9 million hectares respectively (table 3). These estimates differ from Brown's (1998) but are similar to those of Kanowski (1993) and the World Bank (1991).

The former Soviet Union has particularly unreliable data on both its plantation and natural forest areas. This can also be said for the remainder of Europe where there are local and regional definitional problems with delineating industrial plantation areas (Kanowski 1997; Brown 1998; Neilson 1998).

North and Central America

North and Central America support the second largest industrial plantation resource, which is concentrated around the northern United States and Canada. The estimated area of industrial plantations in North and Central America is approximately 24.2 million hectares (table 3). The United States dominates this area, with approximately 18.9 million hectares consisting of mostly *Pinus* and *Pseudotsuga* species. Five million hectares of intensively managed forests in Canada, although not considered plantations by other authors (for example, Brown 1998), are included in this estimate because they are deemed (under the definition used here) to be managed industrial plantations. Plantation areas for major countries in the region are contained in appendix B.

Oceania

The area of industrial plantations in Oceania is small compared with areas in the other statistical regions. However, Oceania has proved to be one of

the most dynamic expansion regions for planting over the past decade. This expansion has been driven by the privatisation of public resources and a strong link to Japan's pulp and paper markets.

Traditionally, plantations in Oceania — usually softwood species (such as *Pinus* species) — have targeted a combination of the solid wood and pulp and paper markets. However, more recent plantings are devoted to the production of pulp. The economic and political climate is highly suitable for the export of industrial plantation products, and the expansion of plantations is expected to continue.

The standing area of industrial plantations in Oceania is an estimated 2.8 million hectares (table 3), which is consistent with other estimates (Kanowski 1997; Brown 1998; Neilson 1998). The national inventory programs in both Australia and New Zealand are considered to be relatively accurate estimates of total plantation area.

South America

South America has exhibited a rapid expansion in plantation development since the 1970s. The majority of timber produced from this resource is used to supply raw material to the region's pulp and paper industries and charcoal for the region's steel industry.

The region has approximately 7.5 million hectares of economically viable plantations (table 3). Estimates of South America's industrial plantation area vary depending on the data source: Brown (1998) estimates a resource of 5.4 million hectares, while Kanowski (1997) estimates that the area was 6.1 million hectares in the mid-1980s. Other sources (Wood Resources Quarterly 1995; Jaakko Pöyry 1997; Neilson 1997) estimate a significantly greater area.

Several South American governments have introduced tax incentives to facilitate plantation establishment in the past thirty years (Wood Resources Quarterly 1995). However, few of these plantings were managed after establishment and subsequently failed. Other plantations were established too far from existing processing facilities and markets (in the belief that infrastructure would develop), and they are not considered to be economically viable.

The estimated plantation areas for South American countries are summarised in appendix B.

Plantation species

The selection of suitable species for specific growing conditions is important in maximising the productivity and quality of a plantation. Softwoods dominate the northern hemisphere temperate regions: plantations in North and Central America are almost entirely softwood, and plantations in Europe and the former Soviet Union are approximately 88 per cent softwood (tables 5 and 6). The species planted within these regions are mainly white and black spruce (*Picea* species), Douglas fir (*Pseudotsuga* species) and *Pinus* species, which are native to the region and grow in their natural habitat (appendix B). Productivity is generally low (with a mean annual increment of 1–9 cubic metres per hectare a year), and rotation lengths are long (forty to one hundred years or more).

In comparison, hardwoods (mainly *Acacia* and *Eucalyptus* species) dominate the tropical industrial plantations in Asia and the north of South America (mainly Brazil). These plantations are managed on short rotations (seven to thirty years) and consist of mainly introduced species. They are generally fast growing, achieving mean annual increments of 15–35 cubic metres per hectare.

Softwoods dominate the temperate plantations in the southern hemisphere — in Oceania, the south of Africa (mainly South Africa) and the south of South America (mainly Chile, Venezuela and Uruguay) — and consist of mostly *Pinus* species (mainly *Pinus radiata*). These plantations predominantly

5 Softwood and hardwood plantations, by region

	Softwood		Hardwood	
	Area	Proportion of total	Area	Proportion of total
	million ha	%	million ha	%
Africa	2.0	50	2.0	50
Asia	9.3	31	20.8	69
Europe and former Soviet Union	41.4	88	5.7	12
North and Central America	23.7	98	0.5	2
Oceania	2.5	90	0.3	10
South America	4.1	53	3.7	47
Total	83.0	72	32.9	28

Source: Global Outlook for Plantations Database.

comprise introduced species grown on short rotations (ten to thirty years). Growth rates are high, with mean annual increments of 15–30 cubic metres per hectare, and improved silviculture and breeding have significantly improved the quality of the product. Hardwood species, mainly eucalypt species, are growing in importance in these regions, although they still represent only a small proportion of the total plantation area. Tree breeding techniques and species selection are producing relatively high productivity from eucalypts in these regions, with mean annual increments of 14–38 cubic metres per hectare.

Species selection for industrial plantations is driven by market demands, site suitability and land availability. Recent trends indicate that introduced, fast growing species are favored over the more traditional long rotation species. This trend has largely developed to accommodate the rapidly expanding pulp and paper industry. Tree breeding and an improved understanding of localised growing conditions will play a major role in the future development of plantations.

6 Softwood and hardwood plantation areas in selected countries

	Softwood (coniferous)		Hardwood (nonconiferous)	
	Area	Proportion of total	Area	Proportion of total
	’000 ha	%	’000 ha	%
Algeria	336	80	84	20
Argentina	392	49	408	51
Australia	887	85	156	15
Brazil	1 260	30	2 940	70
Chile	1 377	81	323	19
China	1 500	30	3 500	70
Fiji	50	54	43	46
India	397	7	5 273	93
Indonesia	216	12	1 584	88
Japan	10 094	98	206	2
New Zealand	1 581	97	49	3
South Africa	749	53	664	47
Thailand	100	25	300	75
United Kingdom	1 120	80	280	20
United States	18 502	98	378	2
Vietnam	108	18	492	82

Source: Global Outlook for Plantations Database.

7 Mean annual increments of selected plantation species, by region

	Species	Mean annual increments
		m^3/ha/yr
Africa	*Acacia* spp.	9–26
	Eucalyptus grandis	16–24
	Pinus elliottii	12–15
	Pinus patula	12–15
Asia	*Acacia* spp.	8–30
	Eucalyptus spp.	11–25
Europe and former Soviet Union	*Picea* spp.	1–6
	Pinus sylvestris	3–8
North and Central America	*Picea* spp.	2–6
	Pinus spp.	7
	Pseudotsuga spp.	2–12
Oceania	*Eucalyptus nitens*	14–32
	Pinus radiata	12–26
	Pinus caribaea	13–26
	Eucalyptus globulus	15–38
	Acacia mangium	20–60
	Swietenia macrophylla	7–10
South America	*Pinus* spp.	10–25
	Eucalyptus spp.	15–30

Source: Global Outlook for Plantations Database.

8 Public and private ownership of plantation forest, by region

	Public		Private	
	Area	Proportion of total	Area	Proportion of total
	’000 ha	%	’000 ha	%
Africa	na	na	na	na
Asia	na	na	na	na
Europe and former Soviet Union	23 530	50	23 530	50
North and Central America	14 530	60	9 686	40
Oceania	933	33	1 893	67
South America	0	0	7 799	100

na Not available.
Source: Global Outlook for Plantations Database.

Growth rates

The growth rate, or mean annual increment, of a specific tree species on a specific site is critical in determining its suitability as a plantation species. Some of the world's most used, fast growing species — such as *Pinus radiata* and a number of eucalyptus and acacia species — are planted and managed outside their natural environment where there are fewer pests and diseases and more suitable environmental conditions. High growth rates are also achieved with provenances of indigenous species introduced to new locations and slightly different environments. These species and provenances make up the majority of new intensively managed plantation programs, particularly in South America, Oceania and Asia.

The more common plantation species are summarised in table 7. Also illustrated in the table is how their growth rates vary depending on the region in which they are planted. Growth rates of many plantation species are expected to improve with more advanced silvicultural techniques, genetic improvement through intensive breeding programs, and a better understanding of specific climatic and environmental growing conditions.

Plantation ownership

Plantations in South America have a high proportion of private ownership, and some countries in Africa also maintain a significant proportion of private ownership (tables 8 and 9). Oceania and some parts of Asia (particularly Vietnam and Thailand) have historically had a high degree of government ownership, although some of these public assets have recently been sold to the private sector, increasing the level of private ownership of plantations.

In contrast, significant areas of North and Central America, Europe and former Soviet Union, and other parts of Asia (for example, China) maintain a significant level of public plantation ownership. Given the different political objectives for plantations in these regions, they are unlikely to experience the shift to private ownership observed in the southern hemisphere in the near future.

Additionally, the increase in the private ownership of plantations indicates that plantation crops are becoming commercially more attractive, with forestry companies prepared to invest in offshore plantation ventures. Japan's pulp and paper industry is an example of a local industry establishing and managing plantations offshore: Japanese companies have purchased and

9 Public and private ownership of plantation forest in selected countries

	Public		Private	
	Area	Proportion of total	Area	Proportion of total
	’000 ha	%	’000 ha	%
Angola	172	100	0	0
Argentina	0	0	800	100
Australia	709	68	334	32
Brazil	0	0	4 200	100
Canada	3 750	75	1 250	25
Chile	0	0	1 700	100
Congo	0	0	53	100
Fiji	93	100	0	0
India	4 820	85	850	15
Indonesia	1 566	87	234	13
Japan	3 605	35	6 695	65
Kenya	119	100	0	0
Mozambique	40	100	0	0
New Zealand	163	10	1 467	90
Portugal	125	15	710	85
Russia	700	100	0	0
South Africa	424	30	990	70
South Korea	1 470	100	0	0
Spain	570	30	1330	70
Sweden	1 250	25	3 750	75
Thailand	192	48	208	52
United Kingdom	420	30	980	70
United States	9 440	50	9 440	50
Zimbabwe	46	50	46	50

Source: Global Outlook for Plantations Database.

developed plantations in Chile, Vietnam, South Africa, Papua New Guinea, New Zealand, and Australia (see table 13 for details). Meanwhile, US companies have purchased plantations in Australia, and international companies are establishing plantations in South America, Oceania and Asia.

3

Costs and benefits of plantation development

Plantations can provide significant economic, environmental and social benefits, and it is important to take full account of these benefits during the planning and design phase. Otherwise, plantations may have significant disadvantages, leading to economic costs and environmental and social costs (which are sometimes overlooked in the planning process because they can be difficult to value).

The benefits and costs of plantations — in economic, environmental and social terms — are identified in this chapter. Case studies to illustrate these costs and benefits more clearly are contained in chapter 4.

The nature of costs and benefits

In contrast to many other activities, plantation development is a long term venture, with rotation lengths ranging from five to fifty years or more. The activities of plantation development are uneven in nature, with the establishment and harvesting phases being the main activities, yet occurring years apart. This can make it difficult to identify costs and benefits of plantation development, with those identified at one stage of plantation development being offset by those at a later stage. The cost to regional employment (when plantations displace agricultural activities), for example, may be offset through employment generated for plantation harvesting and wood processing. Further, many costs and benefits may not be readily identifiable with the plantation development: for example, many environmental impacts on soil and water balances may take years or even decades to emerge.

Economic benefits

Industrial plantations are largely concentrated in regions that exhibit particular characteristics, such as the availability of land and the proximity to markets and existing infrastructure. The forest products industry has mostly developed in conjunction with the plantation resource, often including export facilities. This has allowed greater specialisation in the growing and processing of wood, and has improved the economic efficiency of growing, transporting and processing plantation grown wood (Hyde, Newman and Sedjo 1991).

Intensively managed plantations offer many advantages (when compared with natural forests) that can greatly enhance productivity and operational efficiency. However, there is a tradeoff between wood yield and wood quality, and most wood derived from plantations is directed to low quality uses such as pulp and reconstituted panel products. Slower growing trees have characteristics better suited to solid wood products.

The following practices indicate some gains that can be achieved:

- matching species with site conditions to maximise growth;
- limiting stands to one or two species that suit the needs of the intended user, and maintaining an even age class, so as to provide a relatively homogeneous end product that is well suited to highly mechanised harvesting and processing operations;
- fully stocking a site to ensure maximum use of its potential, thus leading to efficient land use, high output volumes per hectare and cheaper harvesting costs per cubic metre; and
- controlling the initial spacing and thinning of trees to provide the desired mix of log types (for example, poles, sawlogs and pulpwood) (Evans 1992).

These are significant advantages given the large wood intake requirements of world scale mills (particularly pulpmills and paper mills), the high level of mechanisation within these facilities and the increasing costs of accessing the natural forest resource (Pandey 1992).

A New Zealand assessment of the long term returns from that country's plantation forestry over two rotations from 1935 to 1996 showed a real rate of return of over 7 per cent (based on a return of 6.3 per cent in the first rotation and 7.9 per cent in the second), given improved management and improved research information. The return was found to be substantially better than the returns from government bonds over the same period (Horgan 1996).

Intensive management of plantations also allows the use of additional technologies to increase forest production. Higher growth rates can be achieved, without introducing different species or genetic improvements, through the use of fertilisers and herbicides. These can overcome nutrient deficiencies in the soil and reduce competition from weeds and naturally growing plants for water and nutrients. In Brazil, the addition of 100 kilograms of potassium per hectare to *Eucalyptus grandis* plantations grown in eight to twelve year rotations increased stemwood production from 55 tonnes per hectare

to 125 tonnes per hectare (Nambiar 1996). Such additional technologies may enable the forest manager to improve economic returns by making better use of growing conditions on the site. In areas with low rainfall, such as in Egypt, improved technology has enabled irrigation of plantations using treated sewage water (Undersecretariat for Afforestation 1999).

Pest, disease and fire control procedures can also be included to reduce the risk of damage to a plantation and to maintain its productive potential. Clonal forestry narrows the genetic base, but the continued use of unrelated improved material, and careful management of the number of clones and their pattern of deployment, can reduce the risk of pest and disease problems. Recent developments suggest the use of six to ten unrelated clones will secure the plantation against catastrophic failure in most circumstances (Roberds and Bishir 1997). Further, rigorous screening of new clones for disease and pest resistance limits the potential for large scale infestation. By managing the genetic make-up of the plantation, plantation managers can reduce the risk of pests and disease and therefore potential loss of income.

Further improvements in productivity, generating higher economic returns, can be achieved with the introduction of fast growing exotic species and genetically improved planting stock. Many species of eucalypt and pine have shown high productivity when planted outside their natural environment, evidenced by the widespread use of eucalypts in South America, China and South Africa, and pines in Chile, New Zealand, South Africa and Australia. Clonal forestry, using genetically improved planting stock, also offers economic benefit through its large scale use of a limited number of superior clones.

Through improved management techniques and the selection of appropriate fast growing species matched to the site, there is scope to further increase the productivity of plantations. The role of plantations in the international trade in industrial wood and wood products has increased over recent years, and is likely to grow further in the future. Plantations are particularly important in the development of new timber markets, with most of the increase in timber harvests over the next century expected to come from plantations (chapter 7).

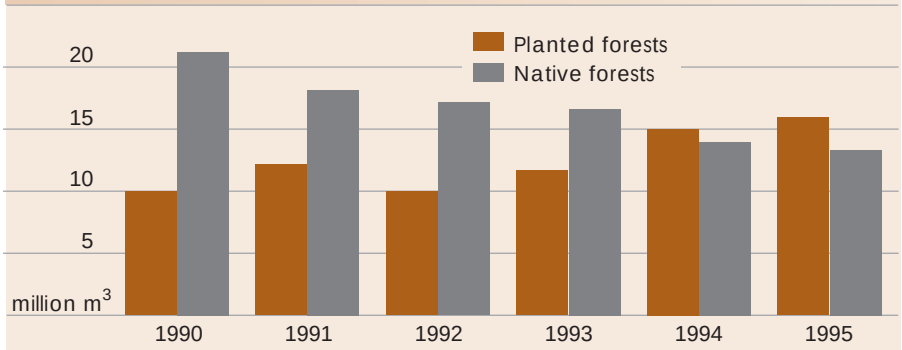
Wood is an important source of fuel in many developing countries, with wood or other biomass providing up to 70–80 per cent of total energy supply in some of these countries and averaging 15 per cent of total energy supply in the developing world (Solberg 1996). Wood is expected to remain the main source of fuel in rural and urban communities in the developing world,

reflecting a lack of options that results from their low income. Plantation establishment for fuelwood purposes began on a large scale in the late 1970s, and was largely concentrated in the African and Asian regions (Pandey 1995).

China's government has developed fast growing fuelwood species and increased the area of fuelwood forests to address fuelwood shortages. China's Ministry of Forestry plans to plant an additional 12 million hectares of plantations, largely in areas experiencing fuelwood shortages (Zhang, Chen and Li 1999).

Many countries also use plantation grown wood as energy for industrial uses, through conversion to ethanol, gasification, charcoal production and the direct use of solid wood as a fuel. An example of the increasing importance of plantation wood for industrial energy generation in Brazil is shown in figure D (Brazilian Society for Silviculture 1998).

D **Consumption of wood and industrial energy generation in Brazil**



Growing wood in plantations also offers the benefit of sequestering carbon dioxide. Using plantation grown wood for energy, with continuing replacement, is neutral in the release of carbon dioxide, and thus is less polluting than many alternative energy sources.

Economic costs

Brown (1998) and Neilson (1998) detail many of the cost factors in plantation establishment, including capital costs, pre-planting, operational costs, project overheads and the varying costs of land. It is clear that the cost of establishing and managing industrial plantations depends on the cost of labor,

the availability of land, the availability of infrastructure and specialised equipment, the physical and climatic conditions of the site, and the political and economic climate of the country.

Plantation establishment costs (capital and silvicultural costs, and overheads) have been estimated for a range of countries. Excluding land purchase costs, these vary between US$1500 and US$2500 per hectare for softwoods, and between US$1200 and US$4200 per hectare for hardwoods. Establishment costs in developing countries are likely to be significantly lower than in developed countries, reflecting the lower cost of labor. Economies of scale also have an impact on the cost of establishment and management; large, unfragmented blocks are cheaper to establish and manage than smaller parcels of land (Brown 1998).

Plantations are a unique investment, with the bulk of costs incurred at the beginning of the rotation and the bulk of revenue received at the end of the rotation (which may be up to and over fifty years later). Given the long period of a rotation, small changes in the establishment and maintenance costs can have a significant impact on the potential profitability of a plantation. The long period of rotation will also have an impact on the risk of plantation development, requiring a higher rate of return to compensate for the risk undertaken. Thus, the effects of discounting and risk are important costs of plantations.

Environmental benefits

Plantations offer environmental benefits when established on degraded land, by contributing to site rehabilitation. Trees improve soil structure, increase soil organic matter and improve fertility on such land, benefiting the microclimate and local habitat (Evans 1992). Plantations are established in some areas solely for protective purposes, such as soil stabilisation and the prevention of erosion, the control of water runoff in catchment areas, and the provision of shelter from wind, heat and sand storms (IIED 1996). Most plantations grown for protection do not necessarily exclude wood production. In Australia, for example, clones of eucalypt species suited to highly saline soils help to improve degraded land but also produce a good economic return (Nilsson 1996).

There can also be an economic benefit from planting trees on cleared degraded land, because such land offers easier access and lower preparation costs, making it more favorable than forested areas for plantation establish-

ment. Recent plantation developments in temperate, subtropical and Mediterranean regions (Brazil, New Zealand, South Africa, Spain, Portugal and the southern United States) have occurred on abandoned or low yielding farmland (Evans 1992).

Plantations have a significant role in providing nonindustrial benefits and services, mainly relating to environmental protection and/or rehabilitation. Egypt, for example, has planted 25 million trees for windbreaks (Undersecretariat for Afforestation 1999), and nonindustrial plantations for soil and slope stabilisation are common in areas such as China, Japan, Nepal and Switzerland. Tree establishment is also encouraged within smallholder farming systems in Africa and South East Asia, to maintain or enhance agricultural productivity by reducing erosion and accelerating nutrient cycling (Kanowski 1993).

There has been recent interest in the role of plantations as potential carbon sinks (Pandey 1992; Nilsson 1996). Growing plantations sequester carbon from the atmosphere and thus may help to offset carbon dioxide emissions from industry and other sources, until a steady state is reached (chapter 5).

Environmental costs

Many costs that can act as a disincentive to plantation establishment can be controlled, because they are usually linked with poor planning and management and poor choice of site.

The transformation of natural forests to plantations can result in simplified ecosystems, given that most plantations are of a single species. The reverse is likely when plantations are developed on highly degraded and cleared land and an understory of native species develops. However, simplification of the ecosystem is likely to be more pronounced if the tree age range is narrow. Further, any exotic plantation species may not support the understory of native vegetation, fauna and soil micro-organisms that is common in natural forests.

Choice of plantation site and plantation design and management are important, and poor decisions can result in significant environmental damage. Plantations established on fragile soils and steep slopes can create an erosion risk while the soil is exposed before the plantation is fully established. During harvesting, the use of heavy machinery, clearfelling and cultivation can exacerbate erosion, especially on steep slopes (IIED 1996). Most tropical soils,

as well as being highly erodible, are intrinsically poor in nutrients and rely on a rapidly decomposing humus layer to supply nutrients and to protect the soil from erosion. When tropical forests and their humus layer are removed for agriculture or tree plantations, the upset balance can result in a nutrient depleted, highly eroded soil in which it is difficult to re-establish tree plantations.

In seasonally dry environments, trees and other land uses compete for water. Some eucalypt plantations which have been established on natural grasslands in Uruguay and South Africa have been found to affect the availability of local water by lowering watertables. Creeks and wells have dried up, requiring local people to travel further to obtain water. Further, insecticide and fertilisers used in plantation management can affect the quality of local water supplies and aquatic fauna.

Plantations can also increase the risk of disease and pest infestation. Given the large unbroken areas of single species common to plantations, such problems easily spread to neighboring native forest. Exotic plantation species have also been known to spread into surrounding areas of natural forest, where they may compete with local vegetation or hybridise it. Such hybridisation may result in the loss of valuable and unique adaptive features among native local species. For example, the spread of *Prosopsis* wildlings into neighboring native forests in Brazil is affecting the species composition of the native forest, with the *Prosopsis* species outcompeting the native vegetation.

Social benefits

Many plantations have been established to provide employment and infrastructure, benefiting the community (IIED 1996). Plantations can be labor intensive, providing a high level of employment per unit of investment. They provide a reason for developing infrastructure — such as roads, communications, services, houses, shops, schools and so on — to often remote areas. Plantations can also provide local communities with recreation and other social facilities. Langer (1995, in Maclaren 1996) compared beef and sheep production to forestry activity in the McKenzie–Waitaki basin of New Zealand. Using a detailed model, Langer calculates that forestry employment would increase by 200–600 per cent depending on the extent of afforestation and whether the wood was processed locally. He also concludes that afforestation would increase the rural population, school enrolment, medical services and housing demand in the area.

Tree planting has an important role in rural development in many countries. Growing trees that satisfy essential village needs for firewood, nuts and fruits, building materials, fodder, shelter and shade is as important as industrial plantation development in many developing countries.

Plantations in isolated areas, especially in developing countries, provide rural employment in circumstances where labor is readily available and its cost is relatively low. South Africa's forestry plantation sector, for example, employs more than 60 000 people directly, while associated secondary industry provides a further 50 000 jobs (table 10). Seventy per cent of all these jobs are located in rural areas and contribute to regional economic activity and employment, while 50 per cent of these jobs are undertaken by unskilled or semiskilled workers (Department of Water Affairs and Forestry 1997).

In developed countries, mechanisation has substantially reduced the historically high levels of employment required for plantation establishment and management (Stewart 1987). However, in economies where labor costs are relatively low, plantation programs continue to have considerable potential to generate employment (Davidson 1987; Kanowski 1993).

10 Contribution to employment by plantations in South Africa

	Own employees	Contractor employees	Total employees
	no.	no.	no.
Forestry plantation segment (primary sector)			
Corporate	17 930	15 620	33 550
Private	4 200	5 480	9 680
State	9 860	1 000	10 860
Local authorities	450	1 980	2 430
Small growers	3 860	1 170	5 030
Total forestry	36 300	25 250	61 550
Forest products segment (secondary sector)			
Sawmilling	–	–	23 000
Pulp and paper	–	–	13 000
Mining timber and poles	–	–	7 000
Board products	–	–	7 000
Total forest products industry	–	–	50 000
Total forest products and forest industry	–	–	111 550

Source: Department of Water Affairs and Forestry (1997).

Social costs

The negative social impacts of plantations usually concern reduced access to forests for local people and limited rights to use land for traditional activities. Social costs can also include reduced local control of land and forest production, displacement of rural communities, loss of income and subsistence, and aesthetic degradation (Sedjo 1983).

Some developing countries, such as Brazil, Indonesia and Thailand, have had only limited regulation of plantation development and do not have a system of clearly defined land tenure. Broadacre plantation establishment in these countries has occurred on land historically used for shifting agricultural activities and other traditional land uses. This has led to some dislocation of indigenous people and subsistence farmers (Carrere and Lohmann 1996).

Minimising the costs of plantation development

A review of relevant literature and case studies indicates that the costs of plantation failure can be significant. Nilsson (1996), reviewing plantation performance, identifies issues with the planning and management process that have contributed to the economic, social and environmental costs of plantation development. These include the following problems:

- the onward monitoring of plantations is often poor;
- knowledge of growth and yield is often poor;
- large scale plantations are often based on part results from small scale experiments;
- tree species and provenances chosen for industrial plantations are often not suited to the site or region;
- there is often inconsistent management of the plantation;
- poor location planning leads to minimal or no market opportunities;
- the productivity effects of biotechnology are often overestimated; and
- production costs are often underestimated.

Careful design and management processes, that consider the full range of economic, social and environmental costs and benefits of plantation development, can overcome many of these issues.

4

Case studies

The economic, environmental and social costs and benefits from plantation development vary with plantation location, species choice and reasons for establishment. The following case studies more clearly illustrate the different costs and benefits.

Case study 1: National Afforestation Project (CR. 2145–CHA), China

The World Bank Forestry Development Project began in 1985, aiming to reduce the shortfall in wood availability that resulted from insufficient state investment, and to establish and transform commercial timber plantations, construct forest roads and procure accessory equipment. In June 1988, the Chinese government requested that the World Bank provide funds and support to introduce advanced techniques for the establishment of fast growing and high yield timber plantations in sixteen provinces/autonomous regions. The scale of afforestation in the first phase of this project was 985 000 hectares with a total investment of 2.36 billion yuan, of which the World Bank loan was US$300 million (1.1 billion yuan).

In 1989, the State Planning Commission approved a proposal to establish 6.7 million hectares of fast growing and high yield plantations by using the World Bank loan and domestic funds. The World Bank approved the ongoing China National Afforestation Project (CR. 2145–CHA, 1990–95) in May 1995.

A total 1.4 million hectares were planted under the National Afforestation Project between 1990 and 1995, and this area is expected to produce 234 million cubic metres of wood. This output is valued (in constant prices) at 71.63 billion yuan. The species planted include larch, poplar, paulownia, Siberian elm, Chinese fir, masson pine, exotic pines, eucalypts and Caribbean pine.

Institutional benefits

This project facilitated the establishment of a more efficient administrative system within the provincial and county forestry bureaus. Overseas training

and study tours financed by the project accelerated the process of technology transfer. Several thousand county and township extension workers received field training in silvicultural methods. The project also stimulated new institutional links among forestry researchers, extension staff and farmers, and helped create new nonstate commercial forestry enterprises: of the 10 000 afforestation entities that participated in the project, around 40 per cent were structured as new shareholding entities.

Environmental benefits

Land used for plantations is estimated to be losing 60–70 per cent less soil from erosion than it would have if left barren. The environmental guidelines for forest plantations developed under the project have extended new soil and water conservation and biodiversity protection benefits to other government and nongovernment investments.

Social benefits

This project has also had important socioeconomic impacts in poor, remote areas. More than a third of the counties involved with the project are classified below the poverty line. In these areas the project investments have generated employment and production income that will double household income over the medium term. The project infrastructure has also facilitated economic development.

Source: Zhang et al. (1999).

Case study 2: Ston Forestal Genetic Improvement Program for melina in Costa Rica

Ston Forestal established 14 000 hectares of plantation forest in southern Costa Rica, conducting research into site classifications, plant nutrition, weed control and intensive silvicultural management for *Gmelina arborea* (melina). It has also developed the genetic improvement program to improve melina for paper pulp production.

In 1989, the company began selecting trees from the Costa Rican melina population (3000 hectares planted with trees aged 6 years or older, located in the northern and dry Pacific regions of the country). In 1992, the company had 34 000 selected clones located in a 15 hectare farm and it began progeny tests. Seed production with some degree of improvement was started in

the Farm Seed Orchard in 1993. In 1994, the Farm Seed Orchard produced 3000 kilograms of seed. The first 200 hectares of plantations were established using this seed, which resulted in a volume increment that was 22 per cent greater than that obtained using seed from the country's dry Pacific region.

Since 1995, the company has used only seed from the Farm Seed Orchard to establish new plantations. The annual establishment rate is 1000 hectares and the level of improvement has increased, as there is now more information available on the best sites for developing the species, as well as on intensive silvicultural management technology.

Costs of the program

The annual investment necessary for the Genetic Improvement Program is approximately US$100 000. An estimated US$1.2–1.5 million has already been invested. The cost of one full production cycle in Costa Rica is estimated at US$1287 a hectare. This figure does not include the price of land, which fluctuates between US$1000 and US$1500 a hectare.

Results and benefits from the program

The seed produced by Ston Forestal showed the best growth results in melina trials, both within Costa Rica and in Colombia, Venezuela and Indonesia. Three test seed samples from Thailand and one from the Ston Forestal company plantations in Costa Rica were used in these trials. Results included the following findings.

- All provenances using Ston Forestal seed in Costa Rica showed height increments that were 50–60 per cent greater than those of other seed sources at one year of age.
- The company seed exhibited 2–6 per cent greater height increments in Colombia, Venezuela and Thailand.
- The height increment of the one year old seed plantation was 10.8 metres in Ston Forestal plantations in Costa Rica, noticeably higher than other seed in any other provenance inside or outside Costa Rica.

The Ston Forestal melina plantation gave an internal rate of return of 12–18 per cent, depending on the quality of the site and the price of the wood. For a plantation located in Costa Rica on an average productivity site (16.2 cubic

metres per hectare a year of commercial volume taken from logs down to 10 centimetres small end diameter), the internal rate of return is 16.9 per cent and the net present value (12 per cent) is US$352.6 a hectare. This does not consider the financial income provided by the reforestation incentives, which would make the internal rate of return much higher.

The improved seed will allow short rotations (ten to twelve years) to ensure a shorter period of time to recover the initial investment.

Source: Zeaser in Alfaro and de Camino (1998).

Case study 3: Sustainable forest management in Indonesia – minimising the risk of plantation failure

The size of plantation forests in Indonesia has increased dramatically since the mid-1980s, particularly for short rotation plantations for pulp production. The Indonesian government launched an ambitious program for rehabilitating unproductive grassland and secondary scrubland into industrial plantation forests. The target is to establish 2.3 million hectares of plantation forests by 2000 and 10.5 million hectares by 2030, mainly to produce wood for paper or medium density fibreboard.

There has been encouraging evidence of efforts to maintain and enhance the long term sustainability of recent plantations in Indonesia. This sustainability can be attained through the adoption of improved silvicultural practices, including organic matter retention, attention to weed control, amelioration of soil nutrition, genetically improved planting stock and improved harvesting practices that minimise physical damage to site and conserve organic matter. This case study examines what is being done in these areas to achieve sustainable management of plantations.

To maximise benefits from plantations and avoid failures, the species and provenances used must be the best available in terms of being able to adapt to the site and satisfy the specific objectives of establishment. The bulk of recent plantation forests have been established in mainly lowland, humid locations on soil of inherently poor fertility and high acidity. *Acacia mangium* is the principal species to be planted — given its fast growth, its adaptability to existing site conditions, and the suitability of its wood for pulp and paper — although other exotic species such as *Acacia* spp., *Eucalyptus* spp., *Gmelina arborea* and *Paraserianthes falcataria* have also been planted.

The practice of using good genetic material was still limited at the outset of these projects, and almost all the *A. mangium* plantations were established using a poor Subanjeriji (South Sumatra) seed source. It is now understood that better seed sources could have included far north Queensland, Papua New Guinea or south east Irian Jaya, and there is now a movement toward using better genetic material in new plantations. A number of countries have developed comprehensive breeding programs for *A. mangium* to improve growth and form. Improved seeds have been produced from mostly seed production areas, with smaller quantities from seed orchards.

Based on field trials and pilot plantations at several sites, *A. crassicarpa* seems promising for pulpwood plantations. *A. auriculiformis* has been used for firebreaks in reforestation projects, but its poor stem form and slow growth mean that it has not been used in pulpwood plantations despite excellent wood properties. It is now being planted to produce parent materials for hybridisation with *A. mangium*. A poor species is *Paraserianthes falcataria*, which performs poorly on podzolic soils with low fertility and pH (a feature of almost all sites) and which has a wood density that is too low for the pulp industry. The failure of these plantations can be attributed to inadequate field testing before establishment.

With the expanding plantation area, it is increasingly difficult to find a suitable site for plantation development. Consequently, some plantations have been developed on marginal sites, such as swampy areas. On such sites, *A. mangium* often shows leaf yellowing, thought to be related to the existence of a sand layer and/or hardpan in the subsoil. Again, selecting species adapted to such a site is extremely important — for example, *A. crassicarpa* seems to be better adapted to swampy areas than is *A. mangium*.

Some recently established plantations have been harvested, mostly using manual methods. Thus, experience in the most suitable method for harvesting is limited. Short rotations mean that site disturbances occur more frequently, so more research is needed on harvesting methods that minimise the impacts and costs of future rotations.

Trials such as these reduce the risk of plantation failure, helping prevent losses from failure in the future.

Source: Hardiyanto (1998).

Case study 4: East Coast Forestry Project in New Zealand

The Gisborne district suffers a severe erosion problem: it occupies 7.8 per cent of the North Island yet contains 26 per cent of the land that is at least 'severely eroding'. In 1992, the New Zealand government announced the East Coast Forestry Project, with the objective of 'promoting large-scale commercial forestry as a means of controlling soil erosion, providing employment and regional development and to recognise environmental needs on individual properties'. It aims to plant 200 000 hectares of eroding and erosion prone land over 28 years, with an annual budget of NZ$6.5 million for grants. The project is the only known government program to address hill country erosion (or any sustainable land management issue) and has ongoing commitments for the next twelve years.

After five years, 16 174 hectares have been planted under the scheme. The project's benefits in controlling soil erosion have not been specifically monitored (and would not be distinguishable in such a short time anyway) but research by Landcare Research and monitoring by Gisborne District Council show that afforestation will have a beneficial impact in reducing soil erosion and sedimentation in rivers and streams (table 11). There is also evidence to suggest a positive impact on employment opportunities in the district as a result of increased forestry development from the project. Reduced soil erosion appears to be the major objective, but the choice of instrument — commercial forestry — clearly indicates that employment and regional development were important to the project.

Economic impacts of the project

Forestry has been Gisborne's fastest growing industry in recent years. Employment rose from 251 full time equivalents to 460 in 1994 and 540 in 1996, while gross output of forestry increased by 84 per cent (in real terms) over the same period.

One study examined the impact of forestry development in the Gisborne district, using 112 000 hectares converted from farming to forestry as the base scenario. This was estimated to reduce on-farm employment by 130 full time equivalents plus 96 off-farm jobs over 28 years. The increase in forestry activity was projected to result in 320 jobs and another 110 associated jobs before harvesting begins. Harvesting was estimated to create a further 1160 jobs and 870 associated jobs (table 12). However, for the region

11 Benefits and costs of the East Coast Forestry Project, New Zealand

Benefits	Costs
Onsite benefits	***Onsite costs***
• Erosion control	• Costs of afforestation, tending and harvesting
• Income from wood production	• Loss of agricultural output
Offsite benefits	***Offsite costs***
• Saved damages/costs from reduced flooding	• Administration costs of the project
• Saved maintenance costs of river and marine environments	• Increased road maintenance costs
• Increased quality of river water and marine environments	• Multiplier effect of reduced output and processing
• Multiplier effect of forestry estate development activities and value adding processing (regional development)	• Loss of employment in agriculture and associated industries
• Employment creation in forestry and associated industries	
• Social benefits	
• Greenhouse gas absorption	
• Clean and green image: the achievement of sustainable land management on eroding country	
Benefits to government	***Costs to government***
• Tax from timber earnings	• Cost of grants
• Reduced costs in the case of a storm event	• Administration costs

12 Predicted economic impacts of the East Coast Forestry Project, New Zealand

	Gross household income	Employment	Value added
	NZ$m	Full time equivalents	NZ$m
Farming	–8	–230	–11
Forestry	97	2 460	129
Forestry and processing	135	3 980	215
Total impact at year 30			
– without processing	90	2 200	120
– with processing	130	3 800	200

to capture all possible employment benefits, more staff training and more reliable work habits would be needed; otherwise, many jobs would be likely to go to workers from outside the region.

It is unclear whether the national benefits of the project outweigh the costs of government intervention. But it can be concluded that the project is delivering desired benefits. It has always been understood that soil erosion control benefits take a long time to eventuate and are hard to quantify.

Source: Bayfield and Meister (1998).

Case study 5: Forest replanting in east England

The Forestry Commission estate covers approximately 98 000 hectares of forest and wooded land in east England. The total forest cover in this area is 7.8 per cent of the land, and the forests are predominantly lowland. The area is densely populated, which creates a high demand for countryside recreational services. The lowland forests of east England were chosen as a case study to compare the financial and nonmarket costs and benefits of forestry.

The proposal was to replant 3500 hectares of this area over three years. Financial costs for this project are high and the benefits are low, while the opposite is true of its nonmarket costs and benefits. Many forestry developments in east England could not be justified on financial grounds alone, but the nonfinancial aspects of replanting forests increase the economic rate of return on the investment to a level that justifies replanting. The Forestry Commission has to carry out investment appraisals to justify spending public money on replanting its forests. Forestry investments that earn a real rate of return of 3 per cent in financial terms are acceptable, although the government generally sets a required rate of return of 6 per cent.

Assuming full land costs, standard overheads for the areas, and constant future timber prices and establishment costs (in real terms), the replanting program has only a 2.4 per cent rate of return on investment. This is partly because it uses slow growing nonconiferous species, which have low financial rates of return but large nonfinancial benefits. When the benefits of recreation and carbon storage are included, the rate of return is above the required target of 6 per cent (table 13).

Using the travel cost method, the recreation value for the public forests is averaged at about £2 per visit. Specialised recreation activities such as

13 Rate of return on investment, east England average

Rate of return including recreation and carbon storage benefits		Rate of return including all non-financial costs and benefits	
Low	High	Low	High
12.6%	14.1%	21.1%	36.0%

orienteering could generate consumer surplus, estimated at £1–10 per hectare a year in the forest districts of east England. The benefits of nature conservation are potentially much higher: they could be 1.3–2.4 times the use value. Carbon storage is valued at £3–6 per tonne of carbon dioxide stored.

There is evidence that forests increase water supply costs. Demand for water is high in east England, and much of the water comes from expensive underground sources. Assuming that stream flow would increase without forests, and that water demand would decrease, the increase in water supply costs as a result of forestry is an estimated £4 per hectare a year. Other environmental costs that could be valued include the cost of air pollution from the machinery used in forest operations. These are small, totaling less than £1 per hectare a year. Land cost is reduced to only 60 per cent of its market value in the appraisal because this is believed to be close to the true opportunity costs of land used for forestry.

Other externalities from replanting are also thought to be noteworthy, but could not be valued. The effect of forestry in the landscape is felt to be quite beneficial, but there may be other environmental costs in terms of water and soil quality (resulting from disturbance by forest operations, and the use of chemicals). Overall, the factors that could not be valued are expected to increase the rate of return on replanting, but only minimally (table 14).

14 Financial returns to replanting in the forest districts of east England
Average, 1990–93

Discounted cost a	Discounted revenue a	Net present value	Internal rate return
£3500/ha	£700/ha	£2800/ha	2.1%

a 1990-91 prices.

Research indicates that the nonfinancial costs and benefits of forestry in this case are probably larger and more important than the financial costs and benefits. The presence of hardwood in the replanting program has probably cost the Forestry Commission up to a 1 percentage point loss in the financial rate of return. However, by making the forests more attractive to both visitors and wildlife, this sacrifice is probably more than adequately covered by the increases in nonmarket benefits.

Source: Whiteman (1991).

5

Factors influencing plantation development

Government involvement

Governments can become involved in plantation development to overcome perceived impediments to plantation investments, such as:

- the high risk of investment loss, as a result of fire and disease;
- the high cost of financing the investment;
- the need for a critical mass of wood availability before processing facilities can be developed;
- the long period of investment, whereby high initial costs are needed for establishment but revenue is only received on harvest;
- the lack of information on appropriate species, establishment and management techniques;
- the lack of regional infrastructure to support plantation development;
- the high risk of marketing products especially for small wood from thinnings;
- the lack of secondary plantation markets to allow the sale of plantations before harvesting; and
- the limited rights to harvest or other government restrictions that may be perceived as sovereign risk.

Governments can also use plantation developments to meet specific economic, social or environmental policy objectives, including assisting forest industry development, increasing regional infrastructure and boosting employment.

Government policy has been a significant factor in the growth in planted areas over the past thirty years. Large scale plantation development began largely as a government activity in most parts of the world, including the United Kingdom, Australia, Chile and New Zealand. Plantations were developed through direct government involvement or through government incentive schemes, including taxation incentives, loans on subsidised rates and

conditions, and grants. Some key policy issues that have influenced plantation expansion in each region are identified in table 15.

The extent to which economic, environmental and other values of plantation forests can be captured varies with the government's policy objective and the extent and stage of plantation development. New Zealand is an

15 Issues influencing plantation policy, by region

Region	Issues
Africa	• Fuelwood shortages (except in South Africa) • Desertification control • South Africa's lack of natural forests for industrial wood
Asia	• Wood deficits (except in Indonesia and Malaysia) • Unsustainability of current harvesting rates in Malaysia and Indonesia unless plantations substitute for the native forests • The need for economic development of the region
Europe and the former Soviet Union	• Provision of a wood resource • The removal of surplus agricultural production capacity and reclamation of unproductive moorland • Multipurpose use of forests, such as increasing recreation use of government planted forests (exclusive recreational use in some cases) • The development of many new forest products over the past fifty years — for example, particleboard, medium density fibreboard and oriented strandboard, all of which can be produced from relatively small, plantation grown wood • Increasing demand for paper that can also be made using small, plantation grown wood
North and Central America	• Environmental pressures which have reduced the availability of the native resource on federal land, especially in the Pacific north west and eastern Canada • The importance of recreation in the United States, leading to the establishment of plantations by private landowners for hunting as well as wood production
Oceania	• The lack of a significant natural softwood resource • Environmental pressure which reduces the availability of the natural hardwood resource • The need for regional development and measures to address forest product trade imbalances
South America	• The promotion of economic development and provision of employment in regional areas

example of how governments can use plantation forests to meet certain policy objectives. By 1987 that country had one million hectares of plantation forest capable of supplying its wood needs, yet considerable areas of natural forests were also felled for wood. Public expenditure on forests remained high compared with the revenue generated by both the planted and natural forests. Further, the felling of native forest, often to be replanted with plantations, led to some cases of environmental degradation.

To overcome these problems the New Zealand government decided to bring almost all of the 6 million hectares of the country's state owned native forests under conservation, allowing logging on only a temporary basis. Responsibility for managing the half million hectares of state owned plantation forests was given to a new, commercially oriented government corporation and later sold to the private sector. Further, all subsidies for plantation forestry were removed. These measures have enabled the country to:

- enhance the conservation values of the native forest estate;
- improve the profitability of planted forests;
- reduce the public outlay in running the government forest agency; and
- provide economic returns from planted forest as well as native forest in the areas where logging is allowed.

Not all plantation development programs have been successful (chapter 2), leaving a significant proportion (around 20 per cent) of the world's plantations unsuitable for commercial wood production. The lessons learned from past plantation developments and the increasing effects of international market forces have influenced the nature of recent plantation developments and government plantation policies. Australia's *Plantations: The 2020 Vision* initiative is an example: the joint government–industry initiative aims to remove any institutional or market based factors that inhibit plantation development in Australia. The initiative envisages a trebling of the Australian plantation area (to 3 million hectares) by 2020 (Ministerial Council on Forestry, Fisheries and Aquaculture 1997).

Initiatives such as *Plantations: The 2020 Vision* have assisted the trend in forest resources away from public ownership to private sector ownership by addressing some factors that may inhibit private investment. These policies also acknowledge the increasing globalisation of the forest sector. Large, often multinational, companies can effectively diversify the investment risk of plantations through portfolio diversification or horizontal integration.

They also can access financial markets or other funding sources to fund plantation investments.

The trend toward privatisation of publicly owned plantations can also be observed in other countries, including Vietnam and Indonesia, although plantations in the United Kingdom, Denmark and other European countries are likely to continue to be controlled by government agencies. These countries have exhibited a trend of setting aside public sector plantations, originally established for commercial wood production, for recreational use.

The appropriate role of government in plantation forestry remains an issue of debate, given the need for forests to supply nonindustrial wood products and nonwood products (Kanowski 1997). Each country must resolve the issue based on its needs and policy objectives.

Changing and emerging markets

Markets change, with new products emerging and other products becoming less cost competitive, as a result of changing technology and policies. In the wood products markets, reconstituted wood products are increasingly being substituted for solid wood while steel, concrete, aluminium and plastics are also being substituted for wood products (including timber flooring and framing, structural timber, and timber joists, bearers and studs). New products such as wood based carbon credits are emerging and have the potential to significantly change the nature of forest product markets.

Technological advancements

Advances in technology, including tree improvement, the introduction of best practice management and improved wood processing technologies, have led to significant improvements in growing and processing plantation wood. Plantation products have therefore increased in competitiveness compared with natural forest products, given their uniformity, cost competitiveness and increasing availability.

Tree improvement

Tree improvement programs involving genetic selection can be used to improve growth, resistance to pests and disease, wood and fibre quality, and tree form. Improved wood and fibre characteristics may enable easier processing of wood products.

Recent work has delivered promising results, with increases in yield, wood quality, resistance to disease and other environmental factors. This has improved the environmental suitability of plantation species to a wider range of sites, and has increased economic returns. Average growth rates of over 50 cubic metres a year have been reported for some species. The use of hybrid eucalypts in Brazil and Indonesia has resulted in a doubling in yield in some cases. Further, developments in cloning and tissue culture have allowed the production of large numbers of improved seedlings at lower cost.

These improvements have probably had little effect on the global production of plantation wood because most plantations incorporating genetic and silvicultural improvement over the past thirty years are yet to be harvested. In the United States, for example, genetically improved trees planted from the mid-1980s will be harvested over the first half of the next century. However, the recent improvements may have a much faster impact on production, with rotations as short as six years predicted for some pulpwood plantations in semitropical regions (Sedjo 1997).

Fast growing, high yielding, specially adapted plantation trees will have a significant role in providing timber in the future.

Best practice management

Intensive research programs and increasing field experience with various plantation species have produced an increased understanding of the relationship between species and growing environments. This evolving knowledge base has allowed forest managers of certain species (including *Pinus radiata* in Oceania and *Eucalyptus globulus* in Australia) to maximise productivity through careful establishment and silvicultural operations.

Climatic and environmental variables such as rainfall, humidity, solar radiation, soil depth and structure, soil nutrition, insect pests and diseases can have a major impact on the quality and growth of a plantation crop. If the interrelationships between these variables are well understood, a management regime can be applied to the crop to manage these variables to maximise the plantation's economic return.

Wood processing

Given advances in processing technology, wood based panels (particleboard and medium density fibreboard) and glue laminated products are being substituted for solid wood products in many applications. World production of solid wood products (sawntimber and veneer) has declined slightly over the

past decade, falling back to 1970 levels, but world production of wood based panels has risen by 80 per cent (FAO 1997a). Wood based panels now represent almost 30 per cent of the market for wood products in Europe, 15 per cent in North America and 10 per cent in Asia.

The growth in market share of reconstituted board products favors plantation grown timber. Wood based panels can use low grade timber and small diameter logs from fast grown short rotation plantations. Glue laminated products can also use small diameter logs from plantations to provide large sections and long spans of high strength products that previously could only be supplied by high quality large diameter logs from natural forests.

The trend away from solid wood products is expected to continue and, although reconstituted board products may never replace some solid wood products (particularly those used in decorative and high quality furniture applications), there is still significant market share to be gained.

Pulpwood growers have developed plantation species with improved pulping and fibre characteristics, such as longer fibre lengths, thinner cell walls, lower extractive content and more uniform basic density. These developments have allowed pulp producers to target specific product markets (such as those for fine writing papers) more effectively.

Changes in technology have also led to increased substitution of wood products with nonwood products, such as steel, plastics, aluminium and concrete. In the Australian housing market, aluminium, steel, concrete and brick are increasingly replacing timber. Aluminium now dominates the market for window frames, and steel is beginning to make inroads into the wall and roof framing markets (although penetration has been much slower than the steel producers anticipated). Concrete is increasingly used for floors, and a single course of brick (brick veneer) dominates the external cladding market (Love, Yainshet and Grist 1999). These products will continue to compete with wood, with their competitiveness depending on world commodity markets, changing technology, convenience, reliability of supply and ability to meet specifications.

Carbon markets

The international community's adoption of the Kyoto Protocol on 11 December 1997 marks the beginning of a process to address the global problem of climate change. It also marks the beginning of a process that could

effect far reaching and fundamental change to many industries and economies worldwide. The forestry sector is a key sector that is likely to be influenced by any action resulting from the Kyoto Protocol: two key issues in the protocol that are of significant interest to the forestry sector are the provisions for sequestered carbon and emissions trading to be used to help meet a country's greenhouse commitments.

Based on present interpretation of the protocol, plantations established since 1 January 1990 on previously cleared agricultural land could be classified as a 'Kyoto forest' (where they meet certain conditions and where they can be accurately measured and verified). Carbon sequestered in these plantations could count toward meeting a country's emissions commitments or be used in emissions trading. International regulations and guidelines on emissions trading, and the definitions of forests that could be counted, are still in the early stages of negotiation. However, a small number of trades in the right to carbon sequestered from plantations have occurred in anticipation of the development of carbon sequestration markets.

Carbon markets could influence plantation development and associated wood processing if a trading system is implemented. However, the likely implications for the expansion of plantations are unknown.

Land availability

Land availability will be a key factor in determining the expansion of plantations in the future. Environmental concerns mean that the clearing of native forests for plantations is unlikely to occur on a large scale in any part of the world, despite the large increases in wood production per hectare that could be achieved.

The International Tropical Timber Council's Target 2000 Initiative guidelines, for example, identified the need to prevent deforestation as a key requirement for sustainable forest management. Therefore, any increase in plantation area is likely to come from cleared agricultural or degraded land, so the availability of large areas of surplus agricultural land that is suitable for plantation establishment will help determine whether a region expands its plantation resource.

A recent development in the supply of forest products is a shift from the use of traditional tree growing areas in the northern hemisphere to the use of regions in the southern hemisphere. This regional shift appears to be the

result of a comparative advantage based on land availability — that is, parts of Asia, South America and Oceania are better placed to use large areas of surplus agricultural land that are suitable for plantation development.

Nilsson and Schopfhauser (1995) estimate that around 345 million hectares of land are suitable for plantations and agroforestry worldwide. An earlier study by Grainger (1988) assessed degraded land in the tropics, estimating that about 758 million hectares of degraded tropical land are potentially suitable for plantations. However, economic and social factors will limit the areas that could be used for plantation establishment in these regions. Converting all forest fallows in the humid tropics to timber production may result in high social costs, for example, because these areas are also used for shifting cultivation.

Temperate areas of the southern hemisphere such as South Africa, Australia, New Zealand, and countries of South America such as Chile, Venezuela and Uruguay, all have areas of land suitable for plantation expansion. It has been estimated by the Bureau of Rural Sciences that up to 19.4 million hectares of land in Australia have biological and climatic characteristics suitable for plantation establishment (Burns, Walker and Hansard 1999). Again, the area used for plantation establishment will also depend on economic, social and environmental considerations and, for these reasons, the actual area is likely to be significantly less than this estimate.

In the northern hemisphere, the former Soviet Union is also likely to have significant areas of agricultural land potentially suitable for plantation establishment. However, this area is yet to be quantified, and considerations such as the availability of infrastructure to access these lands are important unresolved issues.

Access to natural forests

Demand for forest products is likely to increase significantly and there is some potential to use more efficient operations to increase production from areas currently being harvested. However, the area of natural forests available for harvesting is not expected to increase, and may even decrease. Many of the world's accessible natural forests have been cleared or are currently being cut, so any future expansion is likely to occur in less accessible areas. Further, increasing environmental awareness is leading to the exclusion of some commercially valuable areas from harvesting, which places greater demands on the remaining areas.

As less accessible natural forests are harvested, the cost of harvesting and transport will increase relative to these costs for plantations. Thus, although plantations require a high initial investment cost, increasing harvesting and transport costs in natural forests are making plantations more competitive in the supply of forest products.

Plantations have the advantage of flexibility in site location, produce more wood per hectare, and are more suited to mechanised harvesting. This gives them greater efficiencies in harvesting and transport relative to those for natural forests, and enables them to become more competitive as product prices increase. Given these factors, any increase in world demand for forest products is likely to largely be sourced from plantations.

Environmental issues

Just as the world's forests are in transition, society's perceptions of forests have also changed. There has been an increasing focus in the past thirty years on the way in which forests are managed and used. As a result, an increasing area of natural forests has been set aside as parks and reserves, and harvesting activities have been limited in these natural forests. Management policies and practices have also changed to reduce the amount of timber that can be removed from a site and to change the way in which harvesting occurs.

The United Nations Conference on Environment and Development (UNCED) meeting in Rio de Janeiro in 1992 resulted in a number of forestry initiatives aimed at limiting deforestation and improving forest management and logging practices. At the international level, countries have been examining ways for developed countries to move toward mutually acceptable methods and standards for managing their forests (for example, the Helsinki Process, involving European countries and the Montreal Process and Santiago Declaration, involving largely non-European industrial countries). At the national level, most countries are assessing and adjusting their forest policies and practices to accord with these evolving international initiatives. There is now a range of international organisations and agreements that address the issue of sustainable management (table 16).

Certification of forest products

Many international forums are examining the certification of environmental characteristics of forest products. It is seen as a tool for improving forest management and resolving environmental problems. Certificates for most

16 International organisations to address sustainable management of forests

Organisation	Objectives
World Bank	• To prevent excessive deforestation • To act to meet increasing demand for forest products and services in developing countries through tree plantations and management of existing resources • To strengthen forest institutions and the involvement of the international community
United Nations Food and Agriculture Organisation	• To cooperate with member countries in rural development, policy analysis, institutional strengthening, plantation forestry, community forestry, participatory forestry, sustainable forest management, education, training and the production of scientific information and global statistics on forestry • To provide a neutral forum for discussion on global and regional matters
International Union of Forest Research Organisations	• To link forest research institutes into a global network of research units • To run a special program for developing countries that supports training and self-teaching programs, information services and the promotion of interagency contacts
Centre for International Forestry Research (CIFOR) (member of the Consultative Group of International Agricultural Research, or CGIAR)	• To operate in a decentralised fashion through continental coordinators, networks and collaborative research • To focus on conservation and the improved productivity of forest ecosystems, with programs in natural forests, open woodlands, plantations and woodlots, and degraded lands • To strengthen natural forest research institutions
International Council for Research in Agroforestry (member of CGIAR, cooperating with CIFOR)	• To undertake global agroforestry research
International Board for Plant Genetic Resources (established by the Food and Agriculture Organisation, but soon to be autonomous and a member of CGIAR)	• To prepare proposals for involvement in the conservation of biodiversity and the germplasm of forestry species
International Tropical Timber Organisation	• To support various programs concerned with timber harvesting, forest management, reforestation, wood use and marketing, as well as providing a forum for the international timber trade • To seek to encourage member countries to move toward sustainable management of tropical forests

Source: FAO (1993).

forest products are aimed at assessing forest management practices and are a form of single issue certification. Forestry certification emphasises determining whether forests are well or sustainably managed, rather than tracing the raw material through its processing and distribution phases (Bourke 1996). The aim is to inform buyers and encourage them to purchase only material or products made from timber from sustainably managed forests.

In plantation grown forests, certification is likely to target poor management, which is the underlying cause of many of the environmental and social costs of plantations.

Environmental policies such as sustainable forest management and the certification of forest products are also likely to have an impact on the pattern of world trade. Any impact of certification on current trade is negligible (Bourke 1996), although over time these policies could lead to reduced output from some traditional exporting nations and/or increased prices of wood products from sustainably managed forests (IIED 1996).

Sustainability of plantations

There is little information on the sustainability of plantations, because this would require data from several rotations. However, sustainability is becoming increasingly important, given that future supplies of forest products will increasingly depend on plantation grown timber. Evans (1997) addresses this issue using research findings from *Pinus patula* in the Usutu forest in Swaziland, *Pinus radiata* forests in South Australia and *Cunninghamia lanceolata* forests in subtropical China. He concludes that there is no significant or widespread evidence that plantation forestry is unsustainable in terms of wood yield; where yield decline has been reported, poor silvicultural practices and operations appear to be largely responsible. Plantation managers could overcome problems with a potential loss of productivity between successive rotations via a careful approach to harvesting operations, conservation of organic matter and management of weeds. Evans (1997) also notes that genetic improvement of the growing stock offers the prospect of substantial and long term gains over several rotations.

A number of programs have been established to understand plantation sustainability more fully — for example, programs under the US Forest Service (Powers 1991), the EU Level II network under Europe's Air Pollution regulations and the Centre for International Forestry Research (CIRFOR). These programs will use a network of sites to gather data on changes to nutrient

supply budgets and physical soil characteristics (Evans 1997). (This treatment of sustainability relates to plantation productivity only; whether plantations are sustainable in a broader environmental, social and economic context involves a full assessment of their costs and benefits, as discussed in chapter 3.)

Sustainable forest management is not limited to environmental factors. It requires the correct balance between environmental protection, finance, production and social values. If any of these factors is overemphasised or overlooked, then a plantation will not be sustainable.

Globalisation of forest industries

Forest product markets are part of world markets, in the same sense that world markets exist for many agricultural commodities and manufactured goods. The wood fibre economy is now global, with wood processing companies everywhere in competition with firms in distant countries. International trade in wood fibre has quadrupled since the 1960s, while the world market for pulp has grown fivefold over the same period. Russian logs are sent to Finland, woodchip and pulp from Canadian mills are shipped across the Pacific to feed Japan's paper mills, and Indonesian pulp and paper go to the Middle East. This is the result of improved transport systems and worldwide integration of markets for forest products, which have led to an increased regional specialisation in products based on comparative advantage in tree growing (Sedjo 1983).

Global trade in forest products is expected to increase further following the completion of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) in 1993. This round of negotiations added momentum to efforts to reduce trade restrictions across a wide range of products and services, including forest products. The GATT secretariat estimates that trade in forestry products in 2005 (when the results of the Uruguay Round are fully implemented) will be 3.7–5.6 per cent higher than would have occurred in the absence of the Uruguay Round (Solberg 1996).

Investment in the forestry sector is also becoming global. Producers are expanding, purchasing and developing plantation resources in the international market — for example, a US company, International Paper, part owns the New Zealand based Carter Holt Harvey, which owns plantations in Chile. Large international companies are also investing in processing facilities in many countries. Japanese companies have established pulp and paper making

17 Japan's private investment in industrial plantations overseas

Company	Start	Country	Site	Area at March 1998	Target area	Species
				'000 ha	'000 ha	
Oji	1975	Papua New Guinea	harvested area	8.4	10.0	*Eucalyptus, Acacia*
Daishowa, Itochu	1989	Australia	pasture	0.7	1.0	*Eucalyptus*
Daio, Nagoya P., Itochu	1989	Chile	grassland	23.0	40.0	*Eucalyptus, Pinus radiata*
Mitsubishi, Mitsubishi Corp.	1990	Chile	grassland	8.7	10.0	*Eucalyptus*
Nippon, Sumitomo Corp.	1991	Chile	grassland	7.7	13.5	*Eucalyptus*
Oji, Nippon	1991	New Zealand	harvested area	28.9	30.0	*Pinus radiata*
Oji, Itochu, Fuji Xerox Group	1992	New Zealand	pasture	5.0	14.4	*Eucalyptus*
Oji, Itochu	1993	Australia	pasture	10.8	26.0	*Eucalyptus*
Oji, Nissho Iwai, Dai Nippon Pr.	1995	Vietnam	grassland	4.6	10.5	*Eucalyptus, Acacia*
Mitsubishi, Mitsubishi Corp	1995	Australia	grassland	2.3	22.5	*Eucalyptus*
Nippon, Mitsui & Co.	1996	Australia	pasture	2.7	20.0	*Eucalyptus*
Nippon, Mitsui & Co.	1996	Australia	pasture	0.7	9.0	*Eucalyptus*
Nippon, Sumitomo Corp.	1996	South Africa	harvested area	4.4	10.0	*Eucalyptus, Acacia*
Nippon, Mitsui & Co.	1997	Australia	pasture	0.4	10.0	*Eucalyptus*
Oji, Nissho Iwai, Toppan Pr.	1997	Australia	pasture	0.4	20.0	*Eucalyptus*
Chuetsu, Hoketsu, Marubeni	1997	New Zealand	pasture	0.1	10.0	*Acacia*
Nippon, Itochu	1998	China	harvested area	na	10.0	*Eucalyptus*
Toyota, Mitsui & Co.	1998	Australia	pasture	na	5.0	*Eucalyptus*
Oji, Itochu, EPDC	1998	Australia	pasture	na	10.0	*Eucalyptus*
Total				108.8	281.9	

na Not available.
Source: Japan Overseas Plantation Center for Pulpwood (1998).

facilities in Canada, and North American companies own processing operations in New Zealand and Australia. An example of Japan's overseas investment in plantations is provided in table 17.

The main factors driving this worldwide expansion of wood processing industries are the scale of cost efficient processing plants and the cost of transporting logs, which together require mills and large quantities of wood to be closer. Further, efficient pulp production requires homogeneous fibre inputs, so industrial managers generally favor single species plantations (Hyde, Newman and Sedjo 1991). The need for low cost inputs favors the development of plantations in the developing world, but the cost of capital and the need for skilled labor to build and operate plants favors locating processing facilities in developed countries. Countries such as Chile, Brazil, Australia and New Zealand have the advantage of large available land resources and a highly skilled workforce. This gives them a competitive advantage in the development of plantations and processing facilities, but these countries are far from the main markets, which are located in the northern hemisphere. Wherever plantations and processing facilities are finally located, the global nature of the forest products market and investment will drive the sector's expansion.

Changes in world economies

Recent economic downturns in Asia, Russia and Latin America has highlighted the fact that economies are not static and markets can be unpredictable. After strong growth over the previous decade, both Asia and Latin America experienced a significant slowdown in 1998. South East Asian economies as a whole contracted by 7.9 per cent in 1998 and are assumed to contract by a further 2.0 per cent in 1999. Russia has experienced a similar economic decline, with its rate of economic growth contracting by 4.6 per cent in 1998 and an assumed 8.5 per cent in 1999. Economic growth in Latin America grew by only 2.5 per cent in 1998 but is assumed to also fall in 1999 (by 1.5 per cent) (Penm and Hoctor 1999).

The increasing interdependence of world markets on these regions in the past decade (particularly Asia, whose share of world income grew from 7 per cent in 1988 to 27 per cent in 1997) caused a spillover effect into other regions, slowing world economic growth. Economic activity contracted in Japan particularly, and growth in the United States was moderated as a result of a reduction in trade with Asia and, to a lesser extent, Latin America (Penm and Hoctor 1999).

The economic slowdown in major regions has had a significant impact on forest product markets, with trade declining and prices falling. Japan's imports of logs and sawn lumber declined by 28 per cent in 1998 from the previous year's imports (Japan Lumber Importers Association 1998). The export price of paper products from Asia dropped by 23 per cent from US$1000 a tonne to US$767 a tonne between September 1996 and March 1998 (AUSNEWZ 1998).

Most Asian economies, although experiencing low growth in 1997 and 1998, are showing signs of recovery. Now that various structural reforms are in place, the economic outlook of the region is cautiously positive, with investor confidence and economic stability returning to many countries (Jaakko Pöyry 1998). Economic shocks, while causing serious disruption in the short to medium term, are unlikely to have a large effect on the demand for forest products in the long term.

6

Outlook for world timber

The global demand and supply of industrial roundwood is reviewed in this chapter, along with the future role of plantations in supplying wood to global markets (focusing on implications for the major forest regions). Fuelwood is a significant proportion of world demand, but accurate data on fuelwood are not readily available and fuelwood is largely not traded, so it is only briefly covered in this analysis. A more comprehensive review of global fuelwood demand can be found in Solberg (1996).

Outlook for demand and supply

A number of recent studies have addressed global demand and supply of wood. Some studies were conducted before the recent economic downturn in Asia (before September 1997). The downturn is having a significant effect on economic growth in the region in the short term, but many analysts agree that it will have only moderate impacts on economic growth in the longer term. These studies are therefore not redundant because many are based on long term trends in economic variables and are not necessarily affected by short term fluctuations in these variables.

Solberg (1996) reviewed recent studies, including FAO (1995a), Apsey and Reed (1995), Sedjo and Lyon (1995, 1990), Sharma et al. (1992) and Nilsson (1996). A number of other studies since this review include Sedjo and Lyon (1996), Sohngen et al. (1997) and FAO (1998a).

Sedjo and Lyon (1996) explored the nature of supply and demand for pulpwood and solid wood separately. Sohngen et al (1997) analysed the likely regional supply responses to global demand, and examined the relationship between supply from existing forest regions and the potential role of plantations. FAO (1998a) provides the most recent analysis, with a revision of the *Provisional Outlook for Global Forest Products Consumption, Production and Trade to 2010* (FAO 1997b). This revision is based on new estimates of future economic growth and a re-evaluation of the assumptions about timber supply. These projections are summarised in table 18.

All these studies are similar in their recognition of the key factors determining demand and supply of industrial wood. Demand is likely to be

influenced by population growth, economic growth, and prices for forest products and substitutes. Supply is likely to be influenced by the current state of forest resources, the cost of resource access and management practices and policies (Solberg 1996). However, the studies do not describe many of the assumptions underlying these key factors, making comparison difficult (table 19).

There is general agreement that average annual demand for roundwood will increase by around 1 per cent a year over the coming decades, but opinions differ on the likely supply side response and the level of price adjustment required to make global demand equal supply over this period. The market equilibrium approach adopted by Sedjo and Lyon (1996), Sohngen et al. (1997) and FAO (1998a) suggests that the global supply of wood is sensitive to price changes and that only small increases in roundwood prices are required to equate global demand and supply. Solberg (1996) also explores this issue by examining the response of demand to price. A constant price or a low change in price results in demand projections that are broadly consistent with those of Sedjo and Lyon (1996), Sohngen et al. (1997) and FAO (1998a).

The range of projections for global roundwood demand are summarised in figure E. Given that they reflect the possibility of moderate economic growth

18 World demand for industrial roundwood

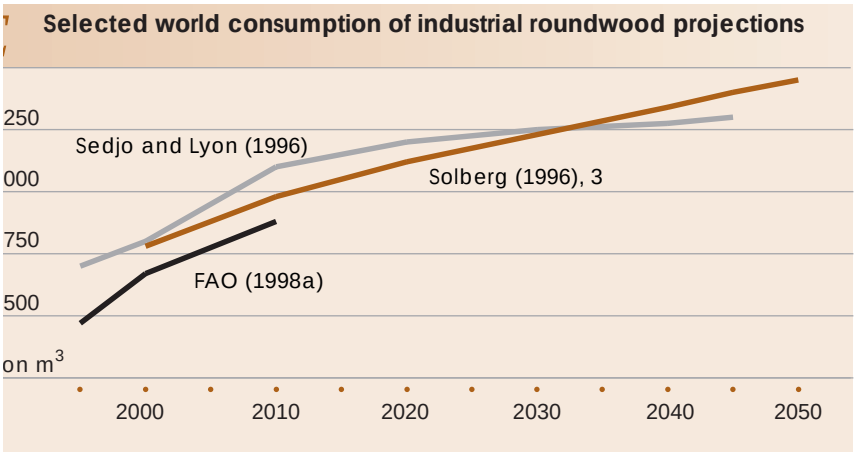
Study	1995	2000	2005	2010	2020	2030	2040	2045	2050	2140
Apsey and Reed(1995)	1.66	1.79	–	1.94	2.25	–	–	–	–	–
FAO (1995a)	1.74	1.9	–	2.28	–	–	–	–	–	–
FAO (1998a)	1.47	1.67	1.77	–	–	–	–	–	–	–
Jaakko Pöyry (1995a)	–	1.5	–	1.7	–	–	–	–	–	–
Nilsson(1996)	–	1.73	–	1.89	2	–	–	–	–	–
Sedjo and Lyon (1996)	1.7	1.8	–	2.1	2.2	2.25	2.275	2.3	–	–
Sedjo and Lyon(1995)	1.74	1.81	–	1.97	2.14	–	–	–	–	–
Simons (1994)	–	–	–	2.15	2.55	–	–	–	–	–
Sohngen et al. (1997)	–	1.8	–	2.1	2.2	2.25	2.275	2.3	–	2.5
Solberg (1996), 1	–	1.73	–	1.84	1.87	1.88	1.88	–	1.88	–
Solberg (1996), 2	–	1.73	–	1.86	1.91	1.93	1.95	–	1.97	–
Solberg (1996), 3	–	1.78	–	1.98	2.12	2.23	2.34	–	2.45	–
Solberg (1996), 4	–	1.78	–	2.00	2.15	2.29	2.43	–	2.57	–
Solberg (1996), 5	–	1.81	–	2.08	2.29	2.49	2.71	–	2.93	–
Solberg (1996), 6	–	1.81	–	2.09	2.33	2.56	2.81	–	3.07	–
Solberg (1996), 7	–	1.89	–	2.03	2.16	2.27	2.38	–	2.49	–

for the Asian region and that they are broadly consistent with Solberg's (1996) projections, this study uses the Sedjo and Lyon (1996) projections to illustrate indicative levels of industrial roundwood demand. These projections show that roundwood demand is likely to increase by 35 per cent from 1.7 billion cubic metres in 1995, to 2.3 billion cubic metres in 2045.

Analysts generally agree that demand for industrial roundwood will rise, but there is less consensus on the nature of supply. To assess the likely supply response to roundwood demand (particularly the role of plantation wood in

19 Assumptions used to forecast demand and supply

Author	Assumptions
Apsey and Reed (1995)	Assumptions not stated
FAO (1995a)	Constant real prices: steady, relatively high growth in gross domestic product
FAO (1998a)	Prices endogenous; varying growth in gross domestic product between countries
Jaakko Pöyry (1995a)	Not explicit, except growth in population and gross domestic product
Nilsson (1996)	Assumptions not stated
Sedjo and Lyon (1995)	Fibre types/species almost perfect substitutes; prices endogenous; no explicit assumptions about gross domestic product
Sedjo and Lyon (1996)	Prices endogenous; rational expectations
Simons (1994)	Assumptions not stated
Sohngen et al. (1997)	Price endogenous; no assumptions for population or gross domestic product
Solberg (1996), 1	Lower gross domestic product growth (less than average across 1970–90); annual price increase of 0.5 per cent; medium population growth
Solberg (1996), 2	Higher gross domestic product growth (greater than average across 1970–90); annual price increase of 0.5 per cent; medium population growth
Solberg (1996), 3	Lower gross domestic product growth (less than average across 1970–90); annual price increase of 0.2 per cent; medium population growth
Solberg (1996), 4	Higher gross domestic product growth (greater than average across 1970–90); annual price increase of 0.2 per cent; medium population growth
Solberg (1996), 5	Lower gross domestic product growth (less than average across 1970–90); constant price; medium population growth
Solberg (1996), 6	Higher gross domestic product growth (greater than average across 1970–90); constant price; medium population growth
Solberg (1996), 7	Constant gross domestic product; constant price; medium population growth



future supply), there are two important factors to be considered: first, the nature of demand for industrial roundwood; and second, how supplies from natural and plantation forests react to changes in market conditions, such as an increase in the price of roundwood.

Nature of industrial roundwood demand

Trends in the types of roundwood demanded and in the regional demand for roundwood provide an insight into the nature of demand for industrial roundwood.

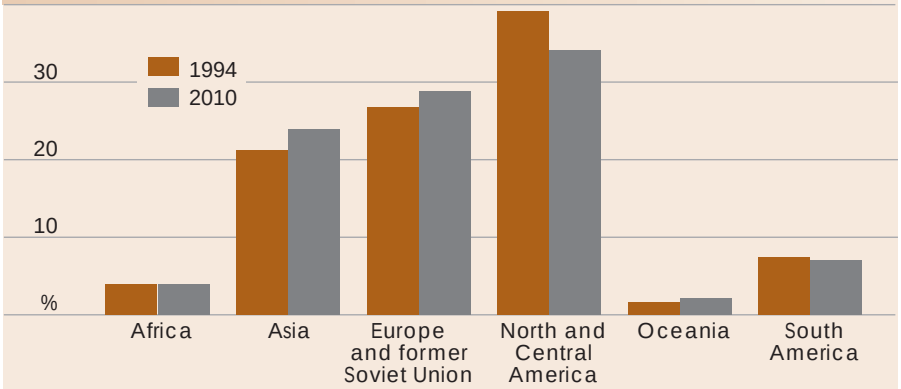
Trends in products consumed

Sedjo and Lyon (1996) divided their roundwood projections into two products: pulpwood and solid wood. Results from their analysis indicate that global pulpwood consumption will increase from about 700 million cubic metres in 1995 (41 per cent of total industrial roundwood consumption) to around 1.33 billion cubic metres by 2045 (58 per cent of total industrial roundwood consumption). These results reflect a growing trend in the composition of industrial wood away from sawlogs to pulpwood.

Likely changes in regional consumption trends

Along with changes in the quantity and type of wood demanded there are also changes in regional demand patterns. These changes are evident in recent estimates of regional demand (FAO 1998a).

F **Share of world consumption of industrial roundwood, by region**



North and Central America consumed 39 per cent of global production in 1994. By 2010, the region's share is projected to fall to 34 per cent (figure F). In contrast, Asia's share of global demand was 21 per cent in 1994, but is projected to increase to 24 per cent by 2010. The Europe and former Soviet Union region is also projected to increase its share of global consumption — from 27 per cent in 1994 to 29 per cent in 2010 — with much of this increase being attributed to expected greater demand in the countries of the former Soviet Union (Sedjo and Lyon 1996). Africa, South America and Oceania are expected to maintain their shares of global consumption to 2010, at 4 per cent, 7 per cent and 2 per cent respectively.

Nature of industrial roundwood supply

Potential supply will depend on factors such as the relative competitiveness of establishing and harvesting plantations versus harvesting existing natural forests. A number of studies have analysed how wood supplies from natural and plantation forests adjust to changing market conditions (Nilsson 1996; Sohngen et al. 1997).

Based on projections for global roundwood consumption, Sohngen et al. (1997) examined how changes in demand will result in changes to prices, areas established to plantations, and harvesting and management intensity from region to region. They found that the supply of wood from temperate forests is likely to remain fairly stable, with some regions increasing while others decrease. Supplies from subtropical plantations are expected to increase, while supplies from tropical natural forests are expected to increase only slightly.

The analysis also suggests an overall increase in management intensity, especially in subtropical plantations. Further increases will come from establishing additional plantations or managing existing natural forests more intensively. Further insights into likely future supply may be revealed by analysing regional trends in roundwood production.

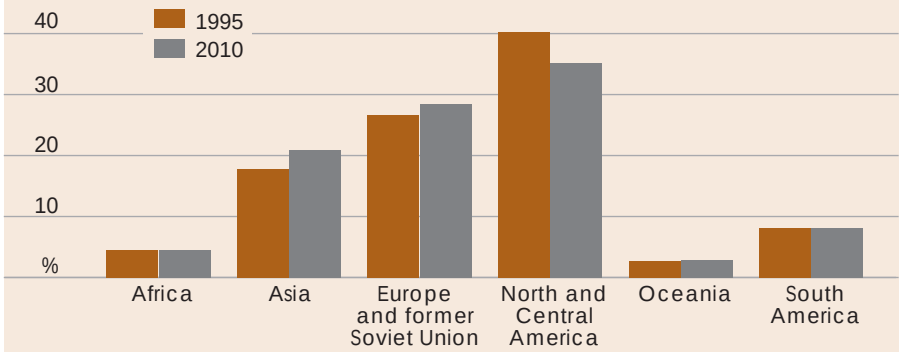
Regional roundwood supply

There are also likely to be changes in the regional patterns of roundwood supply. Many analysts predict that changes in regional supply will be driven by economic and political constraints on the availability of supply from natural forests and/or the availability of suitable land for plantation development (for example, Solberg 1996; Sohngen et al. 1997; Sedjo and Botkin 1997).

Regions relying on supplies from natural forests will be constrained in their ability to increase production by the increasing costs of accessing and harvesting these forests (costs that result from environmental regulations and/or lack of infrastructure) (Sedjo 1996; Sohngen et al. 1997). But regions with plantation forests will be able to increase their roundwood supply through productivity improvements and expanding areas.

Regional analysis (FAO 1998a) indicates that although total supply in 2010 is projected to be about 8 per cent higher than in 1994, North and Central America is projected to decrease its share from 39 per cent to 34 per cent over that period (figure G). This will be largely a result of only moderate increases in industrial roundwood production in both the United States and

G Share of world supply of industrial roundwood, by region



Canada. These increases are likely to be far below the global average, resulting in the reduction in market share. A significant plantation resource in the southern part of the region is not expected to be ready for production before 2020 (Sohngen et al. 1997).

Africa and South America are projected to increase their production levels to 2010 — by around 24 per cent from 1994 levels — to hold their shares of global supply at 4 per cent and 8 per cent respectively. South Africa has the potential to increase supply from plantations, while West Africa has shown signs of increasing supply from natural forests as restrictions on Asia's export of tropical rainforest timbers has turned the focus to tropical areas of West Africa. However, this is likely to be unsustainable in the long term. South America is expected to increase wood supply to 2010, from high productivity plantations in Chile, Brazil, Venezuela, Argentina and Uruguay. Wood supplies from natural forests in the region have declined in recent years, and this trend is expected to continue.

Asia is projected to increase roundwood supply by 44 per cent from 1994 levels by 2010, with its share of global supply to increase from 18 per cent to 21 per cent. China's supply of roundwood is projected to increase by 30 per cent from 100 million cubic metres to 134 million cubic metres over that period. Other parts of Asia are likely to experience reductions in roundwood supply. Malaysia and Indonesia may experience some decline in supply from natural forests over the next decade, although the fall is likely to be offset by increasing production from plantations in these countries.

The Europe and former Soviet Union region is projected to increase its roundwood supply by 32 per cent from 1994 to 2010, and its share of global production from 27 per cent to 29 per cent. Much of this increase will come from maturing plantations established after World War 2 and from natural forests in the former Soviet Union (although the high costs of harvesting the natural forests in the former Soviet Union will constrain production). Through productivity gains, Nordic countries are in a position to expand supply. Western Europe and the Baltic states also show prospects for increasing supply, but the economies of eastern Europe are less likely to show any growth in supply.

Roundwood supply from Oceania is projected to increase by 36 per cent between 1994 and 2010, maintaining a 3 per cent share of global supply. Much of this increase will come from plantations in Australia and New Zealand.

Trade in industrial roundwood

Although only 6–8 per cent of world industrial roundwood production is traded internationally, it is significant in economic terms at an estimated US$114 billion in 1994. This represents a 31 per cent increase in volume and a 75 per cent increase in value (in real terms) of traded products over the past 25 years. The level of world trade is likely to continue to increase as the number of importers and exporters in the world market also increases (FAO 1997).

Developed countries account for most of the international trade, contributing 82 per cent of exports and 77 per cent of imports. A large proportion of forest products is traded within regions through a small number of bilateral exchanges — for example, between Canada and the United States. Five countries account for 55 per cent of exports and nine countries account for 66 per cent of imports (Bourke 1998 and table 20).

However, this pattern of trade is slowly changing with a larger proportion of forest products being traded by and between developing countries, particularly in Asia and South America (Bourke 1998). Increasing production in these two regions, partly as a result of the expansion of their plantation base, is responsible for much of the increase in trade by the developing countries. Exports from Latin America are also increasing, especially products from hardwood plantations in Brazil and softwood plantations in Chile. Imports

20 Top ten exporting and importing countries for industrial forest products

Importers	Value of imports	Exporters	Value of exports
	US$ billion		US$ billion
United States	22.56	Canada	25.33
Japan	18.89	United States	16.94
Germany	11.93	Sweden	11.00
United Kingdom	8.48	Finland	10.30
Italy	6.15	Germany	9.44
France	5.36	Indonesia	5.21
Netherlands	4.49	France	4.19
South Korea	4.43	Malaysia	4.16
Mainland China	3.86	Austria	4.15
Spain	3.55	Brazil	3.23
World	138.65	World	134.66

Source: Bourke (1998).

by China, South Korea and Thailand are increasing as these countries continue to develop their economies. Plantation grown softwood is beginning to substitute for hardwood in many major markets, particularly in Japan, which is a major importer of forest products.

Factors that have influenced these changes include bans on the export of logs by some countries and a general trend toward the manufacturing of value added products. These factors have led to a decline in log exports and an increase in exports of processed wood products. Over the past 25 years, logs' share of global exports has dropped from 15 per cent to 8 per cent, and the sawnwood share has remained constant at 17 per cent. In contrast, significant increases have been observed in the market shares of wood based panels, and paper and paperboard, which represent 11 per cent and 46 per cent of trade respectively (Bourke 1998).

These factors are likely to counter some of the negative influences that have emerged over this period, including the decline in production and export of forest products from Russia and the decline of log exports from Indonesia and the Philippines since the late 1980s. Environmental policies in many countries, particularly the developed countries, will continue to influence the availability and supply of roundwood in many regions.

Fuelwood demand and supply

Fuelwood accounts for over 50 per cent of global wood harvested, and it is a primary wood product used in many developing countries. Global consumption of fuelwood was estimated at 1.7 billion cubic metres in 1995. Solberg (1996) concludes that data for fuelwood consumption and production are based largely on estimates, limiting the ability to assess the fuelwood situation accurately or to reliably project future production or consumption. After reviewing the availability of statistics on fuelwood, Nilsson (1996) concludes that statistics on fuelwood probably underestimate real production; he notes the example of India, which alone probably collects ten times more fuelwood than is officially reported.

Solberg (1996) reviewed recent projections of fuelwood (summarised in table 21), including Sharma et al. (1992), Zuidema et al. (1994), FAO (1995a), Apsey and Reed (1995) and Nilsson (1996). As well as developing three additional projections based on assumptions for gross domestic product, the Food and Agriculture Organisation have also produced a revised set of projections.

21 World consumption of fuelwood

Billion cubic metres

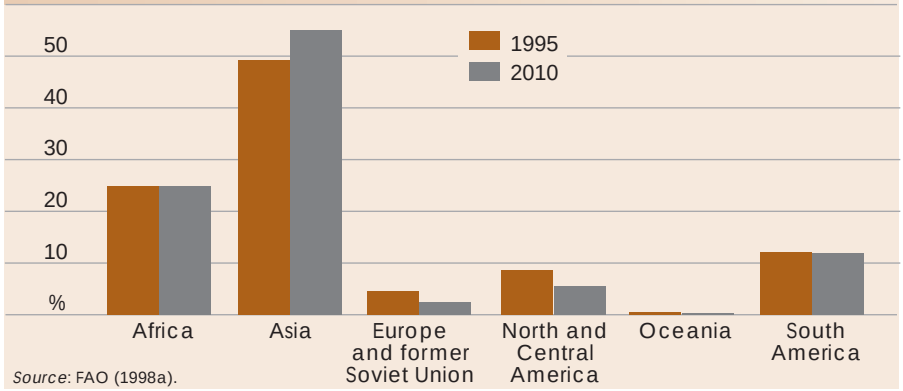
Study	1990	1995	2000	2010	2020	2030	2040	2050
Apsey and Reed (1995)	–	–	–	2.52	–	–	–	–
FAO (1995a)	1.79	1.94	2.09	2.38	–	–	–	–
FAO (1998a)	–	1.74	1.91	2.21	–	–	–	–
Nilsson (1996)	–	–	3.80	4.25	–	–	–	–
Sharma et al. (1992)	–	2.93	3.12	3.45	–	–	–	–
Solberg (1996), 1	–	–	1.9	1.98	2.03	2.03	2.06	2.10
Solberg (1996), 2	–	–	1.9	1.94	1.93	1.88	1.85	1.86
Solberg (1996), 3	–	–	2.12	2.44	2.73	3.02	3.35	3.71
Zuidema (1994)	–	–	–	–	1.50	–	–	–

Source: Revised from Solberg (1996).

Given that fuelwood is not traded to any significant extent, issues about levels of consumption and production are largely local or regional. However, over the long term, local responses to fuelwood shortages will have regional or even global consequences. Increasing incomes and urbanisation in developing countries are likely to result in slower growth in the demand for fuelwood, which may lead to a decrease in fuelwood consumption.

Based on Solberg's projections and assuming a lower gross domestic product growth scenario, consumption of fuelwood is projected to increase from 1.9 billion cubic metres in 2000 to 2.1 billion cubic metres by 2050. FAO (1998a) analysed regional trends in fuelwood consumption. Fuelwood is largely not traded, so regional consumption and production estimates are the same. Asia is by far the largest consumer of fuelwood (figure H): the region

H Share of world demand for fuelwood, by region



Source: FAO (1998a).

is expected to increase its share of global consumption from 49 per cent in 1994 to 55 per cent in 2010. Africa is the second largest region for fuelwood consumption. Africa and South America are projected to maintain their shares of global fuelwood consumption (25 per cent and 12 per cent respectively in 1994) to 2010. Most other regions are expected to decrease their consumption of fuelwood. North and Central America, and Europe and the former Soviet Union, for example, are projected to decrease their shares of global consumption from 9 per cent and 5 per cent respectively in 1994 to 6 per cent and 2 per cent in 2010. Oceania, the region with the smallest consumption of fuelwood, is projected to maintain its share of global consumption at less than 1 per cent over the period.

7

Potential for plantations in future supply of industrial roundwood

The present lack of reliable information on plantations and the economic contribution of plantations to global roundwood supply has been highlighted in this study. Pandey and Ball (1998) and a number of other recent studies support this view. Official statistics on the contribution of plantation wood to global roundwood supply are not available, but a number of analysts have made estimates (table 22). Analysis for this study suggests that around 34 per cent of the world roundwood supply is derived from plantations.

The level of present information on plantations means that any projections of future supply should be considered with caution. However, these projections are an essential part of the debate over the potential role of plantations in global wood supply, and the potential for plantations to increase their

22 Proportion of industrial wood supply from plantations

Country/region	Present share	Future share	Study
	%	%	
World	34		Sedjo and Botkin (1997)
	10	90 in long term	Kanowski (1997)
New Zealand	99		FAO (1999)
South Africa	Almost 100		Pandey and Ball (1998)
Zimbabwe	96		Palmberg-Lerche and Ball (1998)
	50		FAO (1997)
Chile	95		Pandey and Ball (1998)
	84		Palmberg-Lerche and Ball (1998)
Spain	81		Pandey and Ball (1998)
Brazil	60		Pandey and Ball (1998)
	62		FAO (1999)
Argentina	60		Pandey and Ball (1998)
Japan	55		Pandey and Ball (1998)
Australia	55		ABARE internal information
Zambia	50		Palmberg-Lerche and Ball (1998)
Latin America		50 by 2000	Sedjo 1987 (1998)
United States		50 by 2000	de Fégely and Parsons (1997)
Asia		20 by 2010	de Fégely and Parsons (1997)
Asia, Oceania, Latin America		28.5 by 2010	Palmberg-Lerche and Ball (1998)
Africa		13 by 2010	Palmberg-Lerche and Ball (1998)

contribution to future global wood supply was assessed with this in mind. The Sedjo and Lyon (1996) projections from chapter 6 were used to indicate future global demand for industrial roundwood and the benchmark for assessing the global contribution of future plantation supply. The projections of regional contributions to global supply were derived from FAO (1998a). The regional contribution for periods beyond 2010 were assumed to be in the same proportions as estimated (FAO 1998a) for 2010.

To determine the future potential of plantation wood supplies, any increases in the demand for industrial roundwood were assumed to be largely sourced from plantations. This is consistent with the view of many analysts (chapter 6) who believe that political, environmental and economic pressures on natural forests will constrain any increases in the supply of wood from those forests. Given that it is economic to do so, these analysts believe that plantations will largely meet future increases in the global supply of roundwood (Kanowski 1997; Sohngen et al. 1997). Based on this assumption and the projections of global demand, around 600 million cubic metres of additional industrial roundwood will be required by 2040.

Assessing plantation potential

Each region was assessed on its ability to expand roundwood supply from plantations. In assessing regional potential, factors such as existing natural forest and plantations, suitable land, infrastructure, access to plantation technology and political and economic stability were considered. Wood supply from plantations can be increased by using intensified management to achieve greater wood production per hectare and/or by expanding the plantation area. Three hypothetical options were analysed to assess a region's potential to expand supply from plantations:

1. increasing supply through productivity improvement — that is, increasing the mean annual increment (with the plantation area remaining constant);
2. increasing supply through a combination of improving productivity and expanding the plantation area; and
3. increasing supply through expanding the plantation area (with the mean annual increment remaining constant).

ABARE and Jaakko Pöyry's estimates of current and future supply (2000, 2020 and 2040) by region, showing the area and mean annual increment required to achieve a required production level, are shown in table 23. Africa,

23 Scenarios of the potential for plantations to increase future wood production

	Unit	2000	2020			2040		
			Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Africa								
Area	million ha	1.4	1.4	2.1	3.4	1.4	2.5	3.6
Mean annual increment	m^3/ha/yr	11.3	27.1	15.8	11.3	29.3	16.4	11.3
Sustainable production	million m^3/yr	16	38	38	38	41	41	41
Asia								
Area	million ha	11.2	11.2	14.7	21.3	11.2	15.0	22.9
Mean annual increment	m^3/ha/yr	10.0	19.0	14.5	10.0	20.4	15.2	10.0
Sustainable production	million m^3/yr	112	213	213	213	229	229	229
Europe and former Soviet Union								
Area	million ha	47.1	47.1	57.0	66.8	47.1	59.1	71.0
Mean annual increment	m^3/ha/yr	5.0	7.1	5.4	5.0	7.5	6.0	5.0
Sustainable production	million m^3/yr	236	334	334	334	355	355	355
North and Central America								
Area	million ha	24.2	24.2	30.8	37.5	24.2	33.0	41.8
Mean annual increment	m^3/ha/yr	6.0	9.3	7.3	6.0	10.4	7.6	6.0
Sustainable production	million m^3/yr	145	225	225	225	251	251	251
Oceania								
Area	million ha	2.5	2.5	3.0	3.9	2.5	3.1	4.1
Mean annual increment	m^3/ha/yr	10.8	16.8	13.8	10.8	17.6	14.2	10.8
Sustainable production	million m3/yr	27	42	42	42	44	44	44
South America								
Area	million ha	7.5	7.5	8.6	10.0	7.5	8.7	10.5
Mean annual increment	m^3/ha/yr	11.7	15.6	13.7	11.7	16.4	14.1	11.7
Sustainable production	million m^3/yr	88	117	117	117	123	123	123
Total								
Area	million ha	93.9	93.9	119.0	144.3	93.9	124.6	155.3
Mean annual increment	m^3/ha/yr	6.6	10.3	8.1	6.7	11.9	8.4	6.7
Sustainable production	million m^3/yr	624	969	969	969	1 043	1 043	1 043

Note: Totals may not add due to rounding errors.

for example, could achieve a production of 41 million cubic metres in 2040 by increasing the mean annual increment of its existing plantations from 11.3 to 29.3 cubic metres per hectare (option 1) or by increasing its plantation area from 1.4 to 3.6 million hectares (option 3), or by increasing both its mean annual increment from 11.3 to 16.4 cubic metres per hectare a year and its plantation area from 1.4 to 2.1 million hectares (option 2).

Plantation development in each region will be determined by the cost of production factors discussed earlier, but also (and importantly) by the cost of gaining access to natural forests, the availability of land and the level of productivity improvement that can be obtained. Africa, for example, will have difficulty doubling its plantation area over the next forty years. There are many reasons, but particularly the unsuitability of land and problems with water supply in South Africa (which represents most of the current African plantation area) and the lack of infrastructure and suitable land in other African countries. However, increases in plantation wood supply could be obtained from increases in the productivity of Africa's existing and new plantations.

Other regions such as Oceania and South America are expected to meet (and probably exceed) these projections. The Australian government envisages tripling the plantation area to 3 million hectares by 2020. If achieved, this area would provide an increase in the supply from Oceania of significantly more than the 36 per cent projected. This does not include the expectation of further increases in the plantation area in New Zealand, which would expand production in Oceania well beyond the projected 36 per cent increase.

Production in the former Soviet Union is well below previous levels. But there is likely to be a significant increase in production from this region if Russia and other states of the former Soviet Union overcome their political and economic problems. Plantations in Europe and North America, which represent the bulk of the world's effective plantations, have low mean annual increments. Again, with more intense management, improved silviculture and improved genetic selection, there is scope for a significant increase in production from these plantations.

Projections for Asia are more uncertain, given that China (which represents 30 per cent of roundwood supplies from Asia), Indonesia and Malaysia have declining supplies of roundwood. However, given the land available for plantations and high growth rates in the tropics, Asia has the potential to meet its targets.

24 Global roundwood supply

	2000	2020	2040
	million m^3	million m^3	million m^3
Africa	78	98	102
Asia	347	459	474
Europe and former Soviet Union	517	626	648
North and Central America	669	774	800
Oceania	49	64	66
South America	141	179	185
Total	1 800	2 200	2 275

Source: Global estimates based on Sedjo and Lyon (1996). Regional contributions based on FAO (1998a).

Considering these factors, plantations could supply an estimated 1043 million cubic metres of wood by 2040 — a 67 per cent increase over forecast wood supply levels from plantations in 2000.

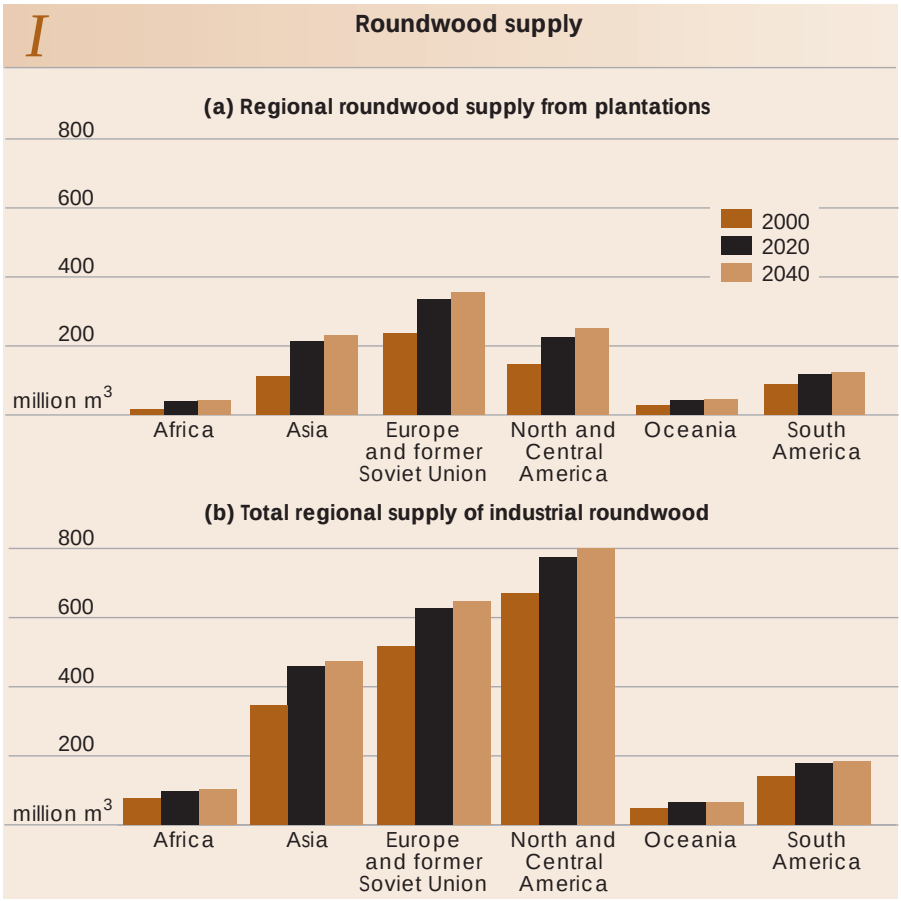
Global and regional significance of plantations

Roundwood production from plantations is projected to increase from 35 per cent of total availability in 2000 to 46 per cent by 2040 (tables 24 and 25). This is just over 88 per cent of the projected total increase in estimated roundwood demand over this period.

Plantations' contributions to global wood supply from all regions will increase, with the major producers of plantation roundwood being the traditional supply regions of Europe and the former Soviet Union, and North and

25 Regional roundwood supply from plantations

	2000	2020	2040
	million m^3	million m^3	million m^3
Africa	16	38	41
Asia	112	213	229
Europe and former Soviet Union	236	334	355
North and Central America	145	225	251
Oceania	27	42	44
South America	88	117	123
Total	624	969	1 043



Central America. Asia will also become a major producer, supplying a projected 10 per cent of global roundwood from plantations by 2040. Other regions such as Africa, South America and Oceania will increase production from plantations, although their market shares are projected to stay constant.

The significance of plantation wood to total regional roundwood supply will increase in all regions to 2040. The increasing importance of plantation wood in all regions is illustrated in figure I. Globally, reliance on plantations for wood supply will rise from about a third of total production to just under a half.

8

Conclusions and recommendations

Plantations are increasingly viewed as a means of meeting a range of economic, social and environmental objectives, yet the information available on plantations reflects more on what is *not* known about plantations.

Institutions such as the Food and Agriculture Organisation and International Tropical Timber Organisation have noted this problem and are continuing to work on practical definitions for plantations and on methods of collecting consistent and compatible information on the plantation resource and the products produced and traded from them. One problem is the variability in the nature and use of plantations in various regions and countries throughout the world. Until the plantation information base is improved, analysis on the future for plantations must rely on information that may not provide a true assessment of their potential.

There is no doubt that plantations are increasing in importance as a source of wood fibre and fuelwood. They are also being effectively used to provide other nonwood products and benefits, from food items through to environmental benefits.

The future potential of plantations as a source of wood fibre, fuelwood and other products and benefits will depend on factors such as improved management and silvicultural techniques (combined with technological advance in tree breeding and wood processing), the continued globalisation and specialisation of forest industries, global and country policies on sustainable forest management, the changing nature of world economies, and the influence of changing and emerging product markets. An analysis of these factors produces the following likely trends in the future role of plantations in the global wood market.

- Increasing access costs to natural forests for wood production will make plantations more viable as an alternative source of wood fibre. However, the competitiveness of plantations against other land uses, including agriculture and urban development, will still constrain expansion of the plantation resource. The ability of plantations to compete for available land will vary between regions and countries. However, given achievable productivity from plantations and the availability of suitable land, new

plantation development is likely to be concentrated in the tropical regions and temperate regions of the southern hemisphere.

- Projections of global roundwood demand indicate an increase of around 35 per cent from current levels by 2040. Many analysts agree that the growing economic, social and environmental constraints on logging natural forests mean that wood sourced from existing or future plantations will meet much of this increased demand.
- With the global demand for pulpwood based products such as paper and panels likely to increase in relation to demand for solid wood products such as sawntimber and plywood, new plantation resources are likely to be dominated by short rotation pulpwood regimes. However, the changing nature of global wood supply will also provide opportunities for sawlog based plantations.
- The current share of the supply of wood originating from plantations is an estimated 34 per cent. It is projected that the contribution of plantation wood to global roundwood supply could be around 46 per cent by 2040. North and Central America, Europe and the former Soviet Union, and Asia are expected to maintain their dominance of world plantation wood supply. In a regional context, plantations are likely to increase their significance in wood production in all regions. South America and Oceania, for example, are projected to source 66 per cent and 67 per cent respectively of their total industrial roundwood supplies from plantations by 2040.
- Patterns in global forest product trade are unlikely to change significantly as a result of increasing production of plantation wood over the period to 2040. This is because traditional large wood supply regions such as Europe and the former Soviet Union, and North and Central America have substantial plantation areas. Any significant trade effect from future plantations in nontraditional wood supply regions are only likely to occur after this period.

In this study a range of economic, social and environmental costs and benefits of plantation development have been identified. A number of costs and benefits were found to vary depending on the size, nature and location of the plantation development, and many were identified as being specific and localised in their nature. Examples of plantation developments resulting in unacceptable economic, social or environmental costs were identified as being largely a result of deficiencies in project design or management. Full consideration of economic, social and environmental factors in the planning

and management of plantation developments can assist in maximising benefits and minimising costs.

Recommendations

An objective in this study was to identify proposals for action that will assist in raising the profile of plantations globally. The following recommendations were developed in consultation with the study's steering committee for consideration by the Intergovernmental Forum on Forests.

Definition of plantations

1. Call on countries to adopt an internationally agreed definition of plantations.

Global and regional plantation expansion

2. Call on countries to work with the Food and Agriculture Organisation to improve the accuracy of data on plantation areas.

3. Call on countries and relevant international organisations such as the International Tropical and Timber Organisation and the Food and Agriculture Organisation to develop and implement forest product statistics databases which clearly segregate wood products derived from natural forests from those derived from plantations

4. Call on countries and international organisations to support a study on the supply of, demand for and value of fuelwood and nonwood forest products, as called for in Proposals for Action by the Intergovernmental Panel on Forests.

Emerging issues

5. Call on countries and international organisations to conduct research studies on the long term (over several rotations) sustainability of plantations from economic, social and environmental perspectives.

6. Call on countries to implement appropriate codes of practice and guidelines for plantation management, and criteria and indicators of sustainability. It is expected that some form of voluntary certification of sustainability will be agreed.

7. Call on countries to contribute to assessing the likely impact of developing carbon markets on plantation development and forest product markets.

8. Call on countries and international organisations to undertake studies to identify and report on the availability of land for plantation expansion from biophysical and economic perspectives, accounting for relevant social and environmental constraints.

Costs and benefits of plantations

9. Support the work of international organisations and countries, with the Food and Agriculture Organisation, to develop a better understanding of, and methods of quantifying, the social and environmental costs and benefits of plantations (including those developed for fuelwood), and the exchange of relevant information.

10. Call on countries to identify and remove obstacles to plantation development and to trade in the context of the emerging importance of plantations in supplying wood and nonwood requirements.

A Appendix

FAO statistical regions

Africa
Algeria
Angola
Benin
Botswana
British Indian Ocean Territory
Burkina Faso
Burundi
Cameroon
Cape Verde
Central African Rep.
Chad
Comoros
Congo, Democratic Republic
Congo, Republic
Côte d'Ivoire
Djibouti
Egypt
Equatorial Guinea
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea-Bissau
Kenya
Lesotho
Liberia
Libya
Madagascar
Malawi
Mali
Mauritania
Mauritius
Morocco
Mozambique
Niger
Nigeria
Reunion
Rwanda
Saint Helena
Sao Tome and Principe
Senegal
Seychelles
Sierra Leone
Somalia
South Africa
Sudan
Swaziland
Tanzania, United Republic
Togo
Tunisia
Uganda
Zaire
Zambia
Zimbabwe

Asia
Afghanistan
Armenia
Azerbaijan
Bahrain
Bangladesh
Bhutan
Brunei Darussalam
China
Cambodia
Cyprus
Georgia
India
Indonesia
Iran
Iraq
Israel
Japan
Jordan
Kazakhstan
Kuwait
Kyrgyzstan
Laos
Lebanon
Macau
Malaysia
Maldives
Mongolia
Myanmar
Nepal
North Korea
Oman
Pakistan
Philippines
Qatar
Saudi Arabia
Singapore
South Korea
Sri Lanka
Syrian Arab Republic
Tajikistan
Thailand
Turkey
Turkmenistan
United Arab Emirates
Uzbekistan
Vietnam
Yemen

Europe and former Soviet Union
Albania
Andorra
Austria
Belgium–Luxembourg
Belarus
Bosnia and Herzegovina
Bulgaria
Croatia
Czech Republic
former Czechoslovakia
Denmark
Estonia
Faeroe Islands
Finland
France
Germany
Gibraltar
Greece
Hungary
Iceland
Ireland
Italy

Continued

FAO statistical regions

Latvia
Liechtensten
Lithuania
Macedonia
Malta
Moldova, Republic of
Monaco
Netherlands
Norway
Poland
Portugal
Romania
Russia
Serbia
Slovakia
Slovenia
Spain
Sweden
Switzerland
United Kingdom
Ukraine

North and Central America
Anguilla
Antigua and Barbuda
Aruba
Bahamas
Barbados
Belize
Bermuda
British Virgin Is.
Canada
Cayman Is.
Costa Rica
Cuba
Dominica
Dominican Republic
El Salvador
Greenland
Grenada
Guadeloupe
Guatemala
Haiti
Honduras
Jamaica
Martinique
Mexico
Montserrat
Netherlands Antilles
Nicaragua
Panama
Saint Kitts and Nevis
Saint Lucia
St Pieree and Miquelon
St Vincent and the Grenadines
Trinidad and Tobago
Turks and Caicos Is.
United States of America

Oceania
American Samoa
Australia
Christmas Is.
Cocos Is.
Cook Is.
Fiji
French Polynesia
Guam
Kiribati
Nauru
New Zealand
New Caledonia
Niue
Norfolk Is.
Pacific Is.
Papua New Guinea
Pitcairn
Samoa
Solomon Is.
Tokelau
Tonga
Tuvalu
Vanuatu
Wake Island
Wallis and Futuna Is.

South America
Argentina
Bolivia
Brazil
Chile
Colombia
Ecuador
Falkland Is.
French Guiana
Guyana
Paraguay
Peru
Suriname
Uruguay
Venezuela

B Appendix

Industrial areas and species

This table provides the source of plantation area estimates used in this report, for each region. Estimates by Brown (1998) are shown to identify where calculations in the reports may differ. The differences are likely to relate to different interpretations of the definition of 'plantation'.

	Industrial plantation area			
Country	**Brown (1998)**	**Jaakko Pöyry**	**Species**	**Source**
	ha	ha		
Africa				
Algeria	419 856	419 856		Brown (1998)
Angola		171 500	*Eucalyptus* spp. (79%), *Pinus* spp. (21%)	Davidson (1995)
Burkina Faso		28 000	*Eucalyptus* spp. (25%)	Davidson (1995)
Burundi		132 000	*Eucalyptus* spp. (30%)	Davidson (1995)
Cameroon		23 000	*Eucalyptus* spp. (57%)	Davidson (1995)
Central African Republic		9 000	*Eucalyptus* spp. (17%)	Davidson (1995)
Chad		6 000	*Eucalyptus* spp. (17%)	Davidson (1995)
Comores		1 000	*Eucalyptus* spp. (50%)	Davidson (1995)
Congo		53 000	*Eucalyptus* spp. (66%)	Davidson (1995)
Ethiopia	19 124	19 124	*Eucalyptus* spp. (35%)	Brown (1998)
Gabon		30 000	*Eucalyptus* spp. (7%)	Davidson (1995)
Ghana		75 000	*Eucalyptus* spp. (19%)	Davidson (1995)
Kenya	118 844	118 844	*Eucalyptus* spp. (10%), *Softwood* spp. (90%)	Brown (1998)
Libya	57 500	57 500		Brown (1998)
Madagascar	111 710	111 710	*Eucalyptus* spp. (42%)	Brown (1998)
Malawi	91 681	91 681	*Eucalyptus* spp. (17%)	Brown (1998)
Mali		20 000	*Eucalyptus* spp. (25%)	Davidson (1995)
Mauritious		11 900	*Eucalyptus* spp. (25%)	Davidson (1995)
Morocco	228 157	228 157		Brown (1998)
Mozambique		40 000	*Eucalyptus* spp. (35%), *Pinus* spp. (50%), *Casuarina equisetifolia* (10%)	Davidson (1995)
Niger		17 000	*Eucalyptus* spp. (12%)	Davidson (1995)
Nigeria	118 354	118 354	*Eucalyptus* spp. (5%)	Brown (1998)
Rwanda	51 413	51 413	*Eucalyptus* spp. (60%)	Brown (1998)
Senegal	13 867	13 867	*Eucalyptus* spp. (25%)	Brown (1998)
South Africa	1 413 985	1 413 985	*Eucalyptus* spp. (36%), *Pinus* spp. (64%)	Brown (1998)

Sudan	63 869	63 869	*Eucalyptus* spp. (8%)	Brown (1998)
Swaziland	119 951	119 951		Brown (1998)
Tanzania	54 132	54 132	*Eucalyptus* spp. (9%)	Brown (1998)
Togo		24 000	*Eucalyptus* spp. (42%)	Davidson (1995)
Tunisia	124 800	124 800		Brown (1998)
Uganda		28 000	*Eucalyptus* spp. (36%)	Davidson (1995)
Zaire		60 000	*Eucalyptus* spp. (33%)	Davidson (1995)
Zambia		68 000	*Eucalyptus* spp. (38%)	Davidson (1995)
Zimbabwe	92 400	120 000	*Eucalyptus* spp. (25%), Softwood spp. (75%)	Davidson (1995)
Other Africa	366 076			
Total	**3 465 719**	**3 897 043**		

North and Central America

Canada		5 000 000	Softwood spp. (100%)	
Costa Rica	92 400	92 400		Brown (1998)
Cuba	228 918	228 918		Brown (1998)
Mexico		15 000	Softwood spp. (100%)	WRQ (1992)
United States	13 687 000	18 880 000	Softwood spp. (98%), Hardwood spp. (2%)	USDA (1999)
Other North and Central America	128 510			
Total	**14 136 828**	**24 216 318**		

South America

Argentina	677 486	800 000	*Eucalyptus* spp. (30%), *Pinus* spp. (49%), poplars and willows (3%)	Smith and Neilson (1996)
Brazil	2 234 278	4 200 000	*Eucalyptus* spp. (62%), Softwood spp. (36%)	WRQ (1995)
Chile	1 677 120	1 700 000	*Eucalyptus* spp. (14%), *Pinus radiata* (79%)	Smith and Neilson (1996)
Colombia	128 389	170 000	Hardwood spp. (50%), Softwood spp. (50%)	Smith and Neilson (1996)
Ecuador	83 333	83 333		Brown (1998)
Peru	83 059	83 059		Brown (1998)
Surinam		80 000		Smith and Neilson (1996); WRQ (1997c)
Uruguay	116 000	208 000	*Eucalyptus* spp. (80%), *Pinus* spp. (17%), poplars and willows (3%)	Smith and Neilson (1996); WRQ (1997c)
Venezuela	420 255	475 000		WRQ (1993)
Other South America	18 452			
Total	**5 438 372**	**7 799 392**		

Europe				
Spain	1 900 000			
United Kingdom	1 400 000			
France	954 000			
Portugal	835 000			
Other Europe	3 611 000			
Total	**8 700 000**	**25 159 000**		Kanowski (1993)
Former Soviet Union				
Russia	17 100 000	700 000		Sheveiko, Gareyev, and Hale (1998)
Other	5 100 000	21 200 000		
Total	**22 200 000**	**21 900 000**		Kanowski (1993)
Asia				
Bangladesh	153 270	189 000		Jaakko Pöyry (1997)
Bhutan		5 000		Jaakko Pöyry (1997)
Cambodia		7 000		Jaakko Pöyry (1997)
China	17 518 599	5 000 000	Chinese fir (60%), masson pine (6%), larch (2%), *Eucalyptus* spp. (10%), poplars and willows (6%)	Neilson (1998)
India	4 044 206	5 670 000		Jaakko Pöyry (1997)
Indonesia	2 623 680	1 800 000	*Tectona grandis* (77%), *Pinus* spp. (23%)	WRQ (1993)
Japan	10 670 000	10 300 000	*Pinus* spp. (10%), *Cryptomeria japonica* (44%), *Chamaecyparis obtusa* (24%), *Larix leptolepis* (11%), *Abies sachalinensis* (8%)	WRQ (1997a)
Laos		6 000		Jaakko Pöyry (1997)
Malaysia	86 170	160 000	*Acacia mangium* (75%), *Gmelina arborea* (7%), *Albizia falcataria* (8%), *Eucalyptus deglupta* (7%)	WRQ (1997b)
Myanmar	208 945	208 254	*Tectona grandis* (41%), *Pinus* spp. (2%), *Eucalyptus* spp. (11%), *Pyinkado* (10%), *Padauk* (3%)	Asian Timber (1997c)
Nepal		55 000		Jaakko Pöyry (1997)
North Korea	1 601 600	1 470 000		Jaakko Pöyry (1997)
Pakistan	27 400	88 000		Jaakko Pöyry (1997)
Philippines	79 209	60 000		Jaakko Pöyry (1997)

South Korea	1 629 571	2 200 000	poplars and willows larch, Korean white pine	Jaakko Pöyry (1997)
Sri Lanka		180 000		Jaakko Pöyry (1997)
Syria	112 140	112 140		Brown (1998)
Thailand		400 000	*Tectona grandis* (20%), *Eucalyptus* spp. (75%), *Pinus merkusii* (5%)	WRQ (1996)
Turkey	1 630 635	1 630 635		Brown (1998)
Vietnam	838 160	600 000		Jaakko Pöyry (1997)
Other Asia	274 281			
Total	**41 497 866**	**30 141 029**		
Oceania				
Australia	1 042 560	1 042 570	*Pinus* spp. (77%), *Eucalyptus* spp. (9%), *Araucaria* spp. (4%)	Bureau of Resource Sciences (1997)
Fiji		93 000	*Swietenia macrophylla* (54%), *Pinus caribaea* (46%)	International Development Ireland (1996)
New Zealand	1 542 266	1 630 000	*Pinus radiata* (90%), Hardwood spp. (3%), Douglas fir (5%)	New Zealand Ministry of Agriculture and Forestry (1998)
Papua New Guinea		35 000		Jaakko Pöyry (1997)
Samoa		1 900		Jaakko Pöyry (1995)
Solomon Islands		23 585	*Agathis macrophylla* (6%), *Campnosperma brevifolia* (39%), *Eucalyptus deglupta* (8%), *Gmelina arborea* (5%), *Swietenia macrophylla* (13%), *Terminalia* spp. (22%), *Tectona grandis* (3%), *Cedrela odorata* (3%)	Chaplin (1993)
Other Oceania	131 816			
Total	**2 716 642**	**2 826 055**		
World	**98 155 427**	**115 938 837**		

References

General

Alfaro, M. and de Camino, R. 1998, Melina *(Gmelina arborea)* in Central America, Draft Report to FAO project GCP/INT/628/UK, Rome.

Apsey, T.M. and Reed, F.L.C. 1995, *World Timber Resources Outlook: Current Perceptions — A Discussion Paper,* 2nd edn, Council of Forest Industries, Vancouver.

AUSNEWZ 1998, *AUSNEWZ Pulp and Paper,* Tasmania.

Bayfield, M. and Meister, A. 1998, *East Coast Forestry Review,* Report to Ministry of Agriculture and Forestry, New Zealand.

Bourke, I.J. 1996, 'Global trends in marketing of environmentally certified forest products', in *Outlook 96*, Proceedings of the National Agricultural and Resources Outlook Conference, 6–8 February, Canberra, vol. 1, *Commodity Markets and Resource Management,* ABARE, Canberra, Australia, pp. 168–76.

—— 1998, International Trade in Forest Products and the Environment, Paper presented to I Congreso Venezolano de Pino y Eucalipto, Maturin, Venezuela, 30 September–4 October.

Brown, C. 1998, The global forest products outlook study – thematic study on plantations, Draft Consultancy Report to FAO Forestry Department, Food and Agriculture Organisation, Rome.

Burns, K., Walker, D. and Hansard, A. 1999, 'Plantations: Australia's position in the emerging global sector', in *Outlook 99*, Proceedings of the National Agricultural and Resources Outlook Conference, 17–18 March, Canberra, vol. 1, *Commodity Markets and Resource Management,* ABARE, Canberra, pp. 217–26.

Carrere, R. and Lohmann, L. 1996, *Pulping the South: Industrial Tree Plantations and the World Paper Economy,* Zed Books, London.

Davidson, J. 1987, *Bioenergy Tree Plantations in the Tropics: Ecological Impacts and Their Implications,* IUCN Commission on Ecology, Paper 12, Gland, Switzerland.

de Fégely, A.R. and Parsons, M.J. 1997, 'Forest products trade – the supply challenge from plantations in New Zealand, Chile and Brazil', in *Outlook 97*, Proceedings of the National Agricultural and Resources Outlook Conference, 4–6 February, Canberra, vol. 1, *Commodity Markets and Resource Management*, ABARE, Canberra, pp. 191–8.

Department of Water Affairs and Forestry 1997, *Commercial Timber Resources and Roundwood Processing in South Africa*, Department of Water Affairs and Forestry, Johannesberg, South Africa.

Evans, J. 1992, *Plantation Forestry in the Tropics — Tree Planting for Industrial, Social, Environmental and Agroforestry Purposes*, 2nd edition, Clarendon Press, Oxford, United Kingdom.

—— 1996, 'The sustainability of wood production from plantations: evidence over three successive rotations in the Usutu Forest, Swaziland', *Commonwealth Forestry Review*, vol. 75, no. 3, pp. 234–9.

—— 1997, *The Sustainability of Wood Production in Plantation Forestry*, Proceedings of the XI World Forestry Congress, Antalya, Turkey, 13–22 October.

FAO 1993, *The Challenge of Sustainable Forest Management: What Future for the World's Forests?*, Rome.

—— 1995a, *Forestry Statistics for Today and for Tomorrow, 1945–1993: 2010*, Rome.

—— 1995b, *Forest Resources Assessment 1990: Global Synthesis*, Forestry Paper 124, Rome.

—— 1997a, *State of the World's Forests*, Rome.

—— 1997b, *Provisional Outlook for Global Forest Products Consumption, Production and Trade to 2010*, Rome.

—— 1998a, 'GFPM forest products outlook', Draft, Report, Rome.

—— 1998b, *FRA 2000 Terms and Definitions*, Forest Resources Assessment Programme, Working Paper 1, Rome.

—— 1998c, *Yearbook of Forest Products*, Rome.

—— 1998d, *Global Fibre Supply Model*, Rome.

—— 1999, *State of the World's Forests*, Rome.

Gauthier, J.J. 1991, 'Les bois de plantation dans le commerce mondial des produits forestiers', in *L'emergence des Nouveaux Potentiels Forestiers dans le Monde*, AFOCEL, Paris, pp. 9–20.

Grainger, A. 1988, 'Estimating area of degraded tropical lands requiring replenishment of forest cover', *International Tree Crops Journal*, no. 5, pp. 31–61.

Hardiyanto, E.B. 1998, Fibre availability — how successful have plantation programmes been?, Paper presented at Asia Pacific Pulp and Paper Conference, Singapore, 26–27 October.

Horgan, G. 1996, *An Analysis of Exotic Plantation Forestry Investment in New Zealand*, Forest Research Institute, New Zealand.

Hyde, W.F., Newman, D.H. and Sedjo, R.A. 1991, *Forest Economics and Policy Analysis: An Overview*, World Bank Discussion Paper 134, Washington DC.

IIED (International Institute for Environment and Development) 1996, *Towards a Sustainable Paper Cycle: An Independent Study of the Sustainability of the Pulp and Paper Industry*, London.

Japan Lumber Importers Association 1998, Internet site of the US Department of Agriculture, Foreign Agricultural Service: http://www.fas.usda.gov

Japan Overseas Plantation Center for Pulpwood 1998, *Overseas Industrial Plantation by Member's Companies*, Tokyo.

Jaakko Pöyry 1995, *Global Fibre Resources Situation: The Challenges for the 1990s*, New York.

—— 1997, *Business Opportunities in the Asia Pacific Pulp and Paper Industry – A Close Look at Resources, Markets and Industry*, Singapore.

—— 1998, *Asian Turmoil: Reshaping the Asian Pulp and Paper Markets and Industry*, Canberra.

Kanowski, P. 1997, Afforestation and plantation forestry, Paper presented at the XI World Forestry Congress, Antalya, Turkey, 13–22 October.

—— 1993, The complex future of plantation forestry, Paper presented at conference on 'Marketing Forest Products', Exeter College, Oxford, 31 August.

Kile, G. 1997, A biological assessment of the sustainability of fast growing plantation forests in the Asia Pacific, Paper presented at Third Annual Asia Pacific Pulp and Paper Summit, Singapore, 29–30 September.

Love, G., Yainshet, A. and Grist, P. 1999, *Long Term Consumption of Forest Products in Australia*, ABARE Research Report 99.5, Canberra.

Lund, H.G. 1998, *Definitions of Forest, Deforestation, Afforestation and Reforestation*, Integrated Resource Inventories and Assessments, Manassas, United States.

McLaren, J.P. 1996, *Environmental Effects of Planted Forests in New Zealand*, New Zealand Forest Research Institute Bulletin 198, Rotorua, New Zealand.

Mather, A.S. (ed.) 1993, *Afforestation: Policies, Planning and Progress*, Bellhaven Press, London and Florida.

Ministerial Council on Forestry, Fisheries and Aquaculture 1997, *Plantations for Australia: The 2020 Vision*, Canberra.

Nambiar, E.K.S. 1996, 'Sustained productivity of plantations forests is a continuing challenge to tree improvements', in Dieters, M.J., Moutherson, A.C., Nikles, D.G., Harwood, C.E. and Walker, S.M. (eds), *Tree Improvement for Sustainable Tropical Forestry*, Proceedings of the QFRI-IUFRO Conference, Caloundra, Queensland, 27 October–1 November, pp. 6–18.

Neilson, D. 1998, The Asian fibre basket – what is the current situation?, Paper presented at Asia Pacific Pulp and Paper Summit, Singapore, 26–27 October.

Nilsson, S. 1996, *Do We Have Enough Forests?* IUFRO Occasional Paper 5, IUFRO, Austria.

—— and Schopfhauser, W. 1995, 'The carbon-sequestration potential of a global afforestation program?', *Climate Change*, no. 30, pp. 267–93.

Palmberg-Lerche, C. and Ball, J. 1998, Present status of forest plantations in Latin America and the Caribbean and review of related activities in tree improvement, Paper presented at the First IUFRO/FAO Latin America Congress, 'El Manejo Sustentable de los Recursos Forestales, Desafio del Siglo XXI', Valdivia, Chile, 22–28 November.

Pandey, D. 1992, *Assessment of Tropical Plantation Resources*, Department of Forest Survey, Swedish University of Agricultural Science, Umea, Sweden.

—— 1995, *Forest Resources Assessment 1990: Tropical Forest Plantation Resources*, Forestry Paper 128, Food and Agriculture Organisation, Rome.

—— 1997, Major issues of tropical forest plantations, Paper presented at the XI World Forestry Congress, Antalya, Turkey, 13–22 October.

—— and Ball, J. 1998, 'The role of industrial plantations in future global fibre supplies', *Unasylva*, vol. 49, no. 193, pp. 37–43.

Penm, J. and Hoctor, L. 1999, 'Commodity overview', *Australian Commodities*, vol. 6, no. 1, pp. 6–12.

Powers, R.F. 1991, 'Are we maintaining the productivity of forest lands? Establishing guidelines through a network of long term studies', in Harvey, A.E. and Neuenschwander, L.F. *Proceedings – Management and Productivity of Western Montane Forest Soils*, Boise, Indiana, 10–12 April 1990, General Technical Report INT-280, pp. 70–81.

Roberds, J.H. and Bishir, K.W. 1997, 'Risk analyses in clonal forestry', *Canadian Journal of Forest Research*, no. 27, pp. 425–32.

SBS 1998, *The Brazilian Forestry Sector: Facts and Figures*, Brazilian Society for Silviculture, Brazil.

Sedjo, R.A. 1983, *The Comparative Economics of Plantation Forestry: A Global Assessment*, Resources for the Future, Washington DC.

—— 1996, 'Local timber production and global trade: the environmental implications of forestry trade', in Adamowicz, W.L., Boxall, P., Luckert, M.K., Phillips, W.E. and White, W.A. (eds), *Forestry Economics and the Environment*, CAB International Press, Guildford, United Kingdom, pp. 49–68.

—— 1997, *The Forest Sector: Important Innovations*, Discussion Paper 97–42, Resources for the Future, Washington DC.

—— and Botkin, D. 1997, 'Using forest plantations to spare natural forests', *Environment*, vol. 39, no. 10, pp. 14–20, 30.

—— and Lyon 1990, *The Long Term Adequacy of World Timber Supply*, Resources for the Future, Washington DC.

—— and —— 1995, *A Global Pulpwood Supply Model and Some Implications*, Final Report to IIED, Resources for the Future, Washington DC.

—— and —— 1996, *Timber Supply Model 96: A Global Timber Supply Model with a Pulpwood Component*, Discussion Paper 96–15, Resources for the Future, Washington DC.

Sharma, N., Rowe, R., Openshawand, K. and Jacobson, M. 1992, 'World forests in perspective' in Sharma, N. (ed.), *Managing the World's Forests: Looking for Balance between Conservation and Development*, Kendall/ Hunt Publishing, Dublique, Iowa.

Simons 1994, *Global Timber Supply and Demand to 2020*, Simons Consulting Group, Vancouver, Canada.

Sohngen, B., Mendelsohn, R., Sedjo, R. and Lyon, K. 1997, *An Analysis of Global Timber Markets*, Discussion Paper 97–37, Resources for the Future, Washington DC.

Solberg, B. (ed.) 1996, *Long Term Trends and Prospects in World Supply and Demand for Wood and Implications for Sustainable Forest Management*, European Forest Institute Research Report no. 6, Finland.

Stewart, P.J. 1987, *Growing Against the Grain*, Council of Protection for Rural England, Oxford, United Kingdom.

Sutton, W.R.J. 1999, Does the world need planted forests?, Paper presented at the Intersessional Expert Meeting on the Role of Planted Forests, Santiago, Chile, 6–9 April.

Undersecretariat for Afforestation 1999, *The National Afforestation and Forestry Action Plan*, Ministry of Agriculture and Land Reclamation, Arab Republic of Egypt.

Whiteman, A. 1991, A comparison of the financial and nonmarket costs and benefits of replanting lowland forests, Paper presented to the Scottish Environmental Economics Discussion Group, Stirling University, United Kingdom, 13 August.

Wiersum, K.F. 1984, *Strategies and Designs for Afforestation, Reforestation and Tree Planting*, PUDOC, Wageningen, Netherlands.

Wood Resources Quarterly 1993, 'Profile report, Indonesia – restructuring the markets of the Pacific rim', *Wood Resources Quarterly*, vol. 5, no. 4, pp. 10–23.

—— 1995, 'Brazil country profile', *Wood Resources Quarterly*, vol. 8, no. 2, pp. 11–28.

World Bank 1991, *The Forest Sector – A World Bank Policy Paper*, Washington DC.

Zhang, S., Chen, X. and Li, W. 1999, Outlook of plantations in China, Draft Report, Chinese Academy of Forestry, Beijing.

Zuidema, G., van den Born, G.J., Alcamo, J. and Kreileman 1994, 'Simulating changes in global land cover as affected by economic and climatic factors', *Water, Air and Soil Pollution*, no. 76, pp. 1–2.

Global Outlook for Plantations Database

ABARE 1998, *Australian Forest Products Statistics*, Canberra, March.

Ali, A.R.M. 1997, 'Plantations the key to Malaysia's timber needs', *Asian Timber*, vol. 16, no. 6, p. 18.

Asian Timber 1997a, 'India continues to face raw material shortage', *Asian Timber*, vol. 16, no. 12, p. 16.

—— 1997b, 'State of the world's forests', *Asian Timber*, vol. 16, no. 7, p. 28.

—— 1997c, 'Sustainable forestry in Myanmar', *Asian Timber*, vol. 16, no. 2, p. 17.

—— 1998a, 'Opportunities abound in South Africa', *Asian Timber*, vol. 17, no. 5, pp. 23–6.

—— 1998b, 'Myanmar goes downstream', *Asian Timber*, vol. 17, no. 6, p. 17.

Brown, C. 1998, The global forest products study – thematic study on plantations, Draft consultancy report to FAO Forestry Department, Food and Agriculture Organisation, Rome.

Bureau of Resource Sciences 1997, *National Plantation Inventory of Australia*, Canberra.

Chaplin, G. 1993, *Silvicultural Manual for the Solomon Islands*, Solomon Islands Forest Record no. 6, Forestry Series no. 1, Overseas Development Administration, London.

Costa, P.D. 1998, 'Opportunities for forestry investment in Brazil', *Asian Timber*, vol. 17, no. 7, pp. 15–18.

Davidson, J. 1995, 'Ecological aspects of Eucalyptus plantations', in *Proceedings of the Regional Expert Consultation on Eucalyptus*,

4–8 October 1993, FAO Regional Office for Asia and the Pacific, Bangkok, pp. 35–72.

Department of Water Affairs and Forestry 1997, *Commercial Timber Resources and Roundwood Processing in South Africa*, Department of Water Affairs and Forestry, Johannesberg, South Africa.

—— (no date), *Forestry in Malaysia*, online: http://www.mtc.com.my/forestry/reference/formal/1Date.htm

Diro, P.A. 1998, *Private Sector Participation in the Government Woodfuel and Afforestation Program: Kenya*, Pan-African Paper Mills website.

Fenton, R. and Neilson, D.A. 1996, *The Forest and Forest Industry Sectors of Japan*, D.A. Neilson and Associates, Rotorua, New Zealand

—— 1998, *The Forest Industry Sectors of Malaysia and Indonesia, the Reality?*, D.A. Neilson and Associates, Rotorua, New Zealand.

Forestry Department 1997, *Country Profile for Forestry Sector Outlook in Myanmar*, Myanmar.

International Development Ireland 1996, *Feasibility Study for the Fiji Pine Plantations in Vanua Levu, Fiji*, Final Report for the Ministry of Finance and Economic Development, Fiji.

International Tropical Timber Organisation 1997, *Forest Industry Structure and the Evolution of Trade Flows in the Asia Pacific Region – Scenarios to 2010*, Food and Agriculture Organisation, Rome.

Jaakko Pöyry 1995a, *Analysis of the Market Hardwood Fibre Supply to 2010, Main Report and Country Profiles*, Helsinki, Finland.

—— 1995b, *China's Forest Industry: Present Status and Emerging Business Opportunities*, Helsinki.

—— 1996, *Future of the Indian Pulp and Paper Industry, Challenges and Opportunities*, Helsinki, Finland.

—— 1997, *Business Opportunities in the Asia Pacific Pulp and Paper Industry – A Close Look at Resources, Markets and Industry*, Singapore.

Japan Overseas Plantation Center for Pulpwood 1998, *Overseas Industrial Plantation by Member's Companies*, Tokyo.

Jayne, V. and Cummins, T. 1998, *Out of Africa*, NZ Forest Industries, Wellington, New Zealand.

Leong, J. 1999, 'Succeeding in China's furniture market', *Asian Timber*, vol. 18, no. 1, p. 11.

Li, H. 1997, *China: Forest Resources, Products and Market Opportunities*, Miller Freeman, San Francisco.

McCarthy, R.B. 1992, *A Review of Fast Grown Plantation Programs in Chile, Uruguay, Brazil, Spain, Portugal and South Africa*, Gottstein Memorial Trust Fund, Clayton, Victoria.

McLaren, J.P. 1996, *Environmental Effects of Planted Forests in New Zealand*, New Zealand Forest Research Institute Bulletin 198, Rotorua, New Zealand.

New Zealand Ministry of Agriculture and Forestry 1998, *New Zealand Forest Industry Facts and Figures '98*, New Zealand Forest Owners Association, New Zealand Ministry of Agriculture and Forestry, and New Zealand Forest Industries Council, Wellington, New Zealand.

Neilson, D. 1998, The Asian fibre basket – what is the current situation?, Asia Pacific Pulp and Paper Summit, Singapore, 26–27 October.

Pillay, K. and Ali, A.R.M. 1998, 'Forest plantation potential in Malaysia', *Asian Timber*, vol. 17, no. 2, p. 18.

Powers, R.F. 1991, 'Are we maintaining the productivity of forest lands? Establishing guidelines through a network of long term studies', in Harvey, A.E. and Neuenschwander, L.F. *Proceedings – Management and Productivity of Western Montane Forest Soils*, Boise, Indiana, 10–12 April 1990, General Technical Report INT-280, pp. 70–81.

Sheveiko, S., Gareyev, R. and Hale, S. 1998, 'Russian forest industry sector – paradise lost?', *Asian Timber*, vol. 17, no. 6.

Smith, M.R. and Neilson, D.A. 1996, *The New Forestry Eldorado – A Review of the Forestry Sectors in Chile, Argentina, Uruguay and Paraguay*, Business Media Services and D.A. Neilson and Associates, Rotorua, New Zealand.

Suchek, V.I. 1996, 'Forest Resources and Plantation Forestry in Brazil Related to Business Opportunities', in World Forest Institute 1996, *Brazil's Forest Industry*, World Forest Institute Conference Proceedings, Portland, Oregon, 6–7 November.

Teck, A.W. 1997, 'Vanishing forests in Vietnam', *Asian Timber*, vol. 16, no. 7, p. 22.

US Department of Agriculture 1999, Plantation area, by species group, date of establishment and owner, D. Brooks, Forest Service, US Department of Agriculture, personal communication, April.

Wood Resources Quarterly 1997a, 'Focus report: the outlook for Japanese wood chip imports', *Wood Resources Quarterly*, vol. 10, no. 2, pp. 12–34.

—— 1997b, 'Profile report, Malaysia – forest rich: fibre poor', *Wood Resources Quarterly,* vol. 9, no. 4, pp. 13–24.

—— 1997c, 'Uruguay country profile', *Wood Resources Quarterly*, vol. 10, no. 3, pp. 14–23.

—— 1990, 'Brazil country profile', *Wood Resources Quarterly*, vol. 2, no.4, pp. 10–17.

—— 1991, 'Argentina country profile', *Wood Resources Quarterly,* vol. 4, no. 2, pp. 11–17.

—— 1992, 'Mexico country profile', *Wood Resources Quarterly*, vol. 5, no. 1, pp. 11–17.

—— 1993, 'Profile report, Indonesia – restructuring the markets of the Pacific rim', *Wood Resources Quarterly*, vol. 5, no. 4, pp. 10–23.

—— 1995, 'Brazil country profile, *Wood Resources Quarterly*, vol. 8, no. 2, pp. 11–28.

—— 1996, 'Chile country profile', *Wood Resources Quarterly*, vol. 9, no. 2, pp. 13–27.