1 Plantation Forests

As the population of the world increases and its economies grow, so does the amount of wood people use, for firewood, for building, for paper and for many other purposes. Large areas of native forests (that is, naturally occurring forests) are cleared every year and converted to other uses. Conservationists are becoming increasingly concerned about this. They are insisting that the native forests that remain be preserved and used much less for wood harvest.

Plantations are forests created by man, by planting seeds or seedlings, usually at a regular spacing. Most contain a single tree species, although plantations of a mixture of species are important in some parts of the world. Plantation forestry is often much like any other agricultural enterprise, aiming to grow highly productive forests on relatively small areas of land, so the land is being used most efficiently. To do so requires that much attention be paid to the silviculture of plantations, that is, to the tending of the trees to achieve some desired objectives. Silvicultural techniques are the principal topic of this book.

There is now a global trend to encourage the establishment of plantations; eventually, it is likely that they will produce a large proportion of the wood used around the world. As well, plantations are being grown to provide various environmental benefits and may or may not produce wood for consumption at the same time.

1.1 Plantation Forests Around the World

The most recent figures available on the area of plantation forests are given in Table 1.1. They were collated by the Food and Agricultural Organisation of the United Nations in 2000 (FAO 2001). They show that about 30% of the land surface of the world (excluding frozen parts such as Antarctica) is covered by forests and about 5% of those are plantations. The area of native forests has been declining; over the decade 1990–2000, an average of 16 million ha was cleared annually. By contrast, plantation areas have been increasing, by an average of about 3 million ha/year over the same period.

Table 1.1. The total area (millions of hectares) of land in various parts of the world, together with the areas covered by forests and forest plantations in 2000 (Source—FAO 2001)

Location	Land	Forest	Plantations
Africa	2,980	650	8
Asia	3,080	550	116
Europe	2,260	1,040	32
North and Central America	2,140	550	18
South America	1,750	890	10
Oceania	850	200	3
Total	13,060	3,870	187

About half the plantations of the world are being grown to produce wood for industrial use, that is, to be processed principally into building products or paper (Sect. 3.3). About one quarter of the plantations are for non-industrial uses, that is, for firewood, environmental protection and other products (including animal fodder, fruits, leaf oils and tannins). The purpose of the other quarter of the plantations around the world could not be determined when this information was collated. The largest areas of industrial plantations are in China (37 million ha), the USA (16 million ha) and India (12 million ha). Of non-industrial plantations, the largest areas are in India (21 million ha), China (8 million ha) and Indonesia and Thailand (4 million ha each).

Plantations already make a substantial contribution to the supply of wood throughout the world. It has been estimated (ABARE–Jaakka Pöyry Consulting 1999) that nearly 4 billion m^3 of wood would have been used throughout the world in 2000, just under half of which would have been for industrial use. The rest would have been firewood, largely for domestic use, principally in Asia and Africa. Plantations supply about one third of this industrial wood; the rest comes from native forests. This relatively large production from plantations, which make up a relatively small proportion of all forests (Table 1.1), emphasises that the productivity of plantations is much greater generally than that of native forests. This is a result of the attention paid to plantation silviculture.

Two groups of tree species dominate plantations around the world, the pines (scientifically speaking, members of the plant genus *Pinus*) and the eucalypts (the genus *Eucalyptus*). Pines make up about 20% of the plantations of the world and eucalypts about 10% (FAO 2001). The pines are softwoods and are native to a number of countries of the northern hemisphere. Botanically speaking, a softwood is any tree species (not just

pines) which produces its ovules (eggs in common parlance) and its pollen in cones; after the ovules have been fertilised by pollen, the scales of the cone protect the seeds as they develop. The eucalypts are hardwoods and are native to Australia, almost exclusively. A hardwood is any tree species which produces flowers; their seeds grow within, and are protected by, the ovary of the flower.

Not all softwoods have particularly soft wood, nor hardwoods particularly hard wood (the balsa tree, the species *Ochroma lagopus*, is a hardwood renowned for its soft, light wood). However, the properties of the wood of the two groups differ in various respects, which are important for their usefulness; this is discussed in Sect. 3.3.

Of course many tree species other than pines and eucalypts are used in plantations around the world. In one way or another, I make reference in this book to 81 different species used in plantations, 17 each of pines and eucalypts, 14 other softwoods and 33 other hardwoods. This is only a small proportion of all species used in plantations.

1.2 Purposes of Plantation Forests

On all the continents, there are large plantation areas grown to produce wood for industrial use. They often cover tens of thousands of hectares and are major commercial enterprises. Some are publicly owned and some are privately owned. They are important economically to the countries concerned, often earning export income and providing employment, both in their growing and in the processing of the wood they produce. Many such plantations are grown for only 10–15 years before harvesting (in forestry, the period from planting to final harvest of a plantation is known as a rotation). Usually, these produce wood for papermaking. Others are grown on 20–30 year rotations, by which time the trees will be large enough for their stems to be sawn to produce timber.

An emerging type of industrial plantation is being grown to produce bioenergy (Evans 1997; Fuwape and Akindele 1997; Kuiper et al. 1998; Toivonen and Tahvanainen 1998; van den Broek et al. 2000; Updegraff et al. 2004; Weih 2004; Andersen et al. 2005; Hoffman and Weih 2005). The wood from such plantations is used to make energy, either through fermentation to produce ethanol (the chemical name for alcohol) for use as motor fuel or through burning the wood to generate electricity.

The primary stimulus for the establishment of bioenergy plantations comes from concerns about the global warming of the atmosphere, which is believed to be caused by the release of greenhouse gases. One of the most important of these is carbon dioxide, which is released when fossil

fuels (coal, oil and natural gas) are burnt. Greenhouse gases trap energy from sunlight, energy which would otherwise be reflected back into space from the surface of the earth; this leads to warming of the atmosphere.

It is argued that bioenergy plantations are carbon dioxide neutral. As will be discussed in Sect. 2.1, plants take in carbon dioxide from the air (about 50% of the structural matter of plants consists of the element carbon, derived from carbon dioxide from the air). If the wood grown in bioenergy plantations is burnt ultimately as fuel, it will release back to the atmosphere exactly as much carbon dioxide as the plantations took up. This contrasts with fossil fuels, where the carbon they contain was stored millions of years ago in the plant material from which they derived; burning them today adds additional carbon dioxide to that which is present normally in the atmosphere (carbon dioxide makes up about 0.035% of the atmospheric gases). Bioenergy plantations are usually grown on very short rotations (perhaps of 3–5 years); the small size of their trees at harvest is of no importance, because they are simply going to be burnt or used for fermentation.

Although they can be considered industrial plantations, bioenergy plantations also provide an environmental benefit by reducing the overall emissions of carbon dioxide to the atmosphere. Plantations are being used around the world to provide various other environmental benefits as follow:

- Clearing land of forests, for agriculture, for mining or for other reasons, can lead to soil erosion by wind or water. Tree roots hold the soil and plantation establishment on cleared land can prevent soil loss, siltation of waterways or can otherwise rehabilitate cleared sites (Costantini et al. 1997a; Mazanec et al. 2003; Coates 2005; Udawatta et al. 2005).
- Clearing forests for agriculture can allow the soil water table to rise, bringing salt close to the soil surface. High salinity can prevent growth of agricultural crops; this is becoming a serious problem in agricultural areas in various parts of the world. Re-establishment of trees on salt-affected sites can draw down the water levels in the soil, taking the salt with them and rehabilitating the soil (Lambert and Turner 2000; Theiveyanathan et al. 2004; Marcar and Morris 2005).
- Plantations can be used to dispose safely of sewage waste and some other forms of industrial waste (Myers et al. 1996; Labrecque et al. 1997; Rosenqvist et al. 1997; Hasselgren 1998; Weih 2004; Mercuri et al. 2005; Morris and Benyon 2005; Rosenqvist and Dawson 2005a). These are often rich in various nutrient elements (Sect. 2.1.4), which the trees take up; their disposal otherwise, often in streams or the sea, can lead to serious environmental damage.

- Scattering plantation areas throughout a region, which has been cleared largely for agriculture, can enhance biodiversity (the variety of plants and animals that live within a region) (Keenan et al. 1997, 1999; Bonham et al. 2002; Hobbs et al. 2003; Lindenmayer et al. 2003; Weih 2004; Kanowski et al. 2005). Plantations increase the variety of habitats available for animals and other plants, although generally not to the same extent as native forests.

Of course, when plantations are established principally to gain environmental benefits, it is often hoped they will provide wood for sale also. In this case, it can be just as important as with industrial plantations to use appropriate silvicultural practices to ensure wood is produced efficiently.

Finally, plantations have an important role as part of the mix of activities undertaken on farms; the combination of agriculture with forestry is known as agroforestry. In some cases, plantations are simply established on parts of a farm not being used for agricultural purposes. In others, the trees are grown in combination with other activities; other plant crops might be afforded protection by being grown between the trees, livestock might be permitted to graze between widely spaced trees or the leaves of the trees might be fodder for livestock. So diverse are agroforestry systems around the world that it is impossible to summarise them here. A number of excellent texts and papers describe them in detail (e.g. MacDicken and Vergara 1990; Jarvis 1991; Knowles 1991; Nair 1991, 1993; Huxley 1999).

1.3 About This Book

In writing this book, my principal problem was to deal with the enormous diversity of plantation forests. Different species are grown in different parts of the world, the products they yield differ, the climates in which they grow differ and the soil types on which they grow vary enormously. Unless there has been previous experience with plantations in a particular part of the world, it is impossible to say just how they should be managed there.

However, over many years forest scientists have gained considerable understanding of how plantations grow and develop and what problems are encountered with them. It is the scientific principles they have developed which this book attempts to describe. It concentrates on plantations where the principal objective is the commercial production of wood. Through an understanding of the science of plantation forestry, I hope plantation growers anywhere in the world will gain some appreciation of why their plantations behave as they do and what types of remedy might be necessary if