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Excerpt
More information

1

Introduction: Forest basics

1.1 Characteristics of woodlands and forests

1.1.1 Wooded environments

Forests often appear monumental and unchanging. This is, however, mostly an illusion caused by our short human perspective. The earliest green plants possessing both roots and tissues specially adapted for the transmission of water belonged to the Psilopsida, which gave rise to the ferns and fern allies. It is from the ancestors of this group, which arose in the Silurian (*c*. 440 million years ago), that all trees – both ancient and modern – are ultimately derived (see Fig. 1.1). Amongst the many evolutionary trends found within this group were tendencies towards the production of (a) tall trunks and (b) seeds from which young plants, including trees, could develop relatively rapidly. Tree ferns, cycads, maidenhair trees, conifers, palms and the very large number of broadleaved genera remain in our woodlands and forests to this day (further detail on past forests can be found in Chapter 9). The amount and composition of the world's wooded areas have changed continuously over geological time, sometimes more rapidly than at others, and continue to do so, helped especially now by human activities. This book is mainly concerned with understanding today's forests in that light.

Wooded land currently covers between 30–35% of the world's land surface (depending on what is counted as forest) or around 39–45 million km^2. The Food and Agriculture Organisation of the United Nations (FAO) figures used in Table 1.1 give 30.3% or 39.5 M km^2 of the world's land area as forested, with 2.8% of that being under plantation (i.e. purposefully planted). Forests are obviously not equally spread around the globe, their distribution being very dependent upon climate (this is expanded upon in Section 1.6 below). This can be seen in Table 1.1 which breaks down forestry cover into world regions. Some of the least forested countries have primarily desert environments (Gulf

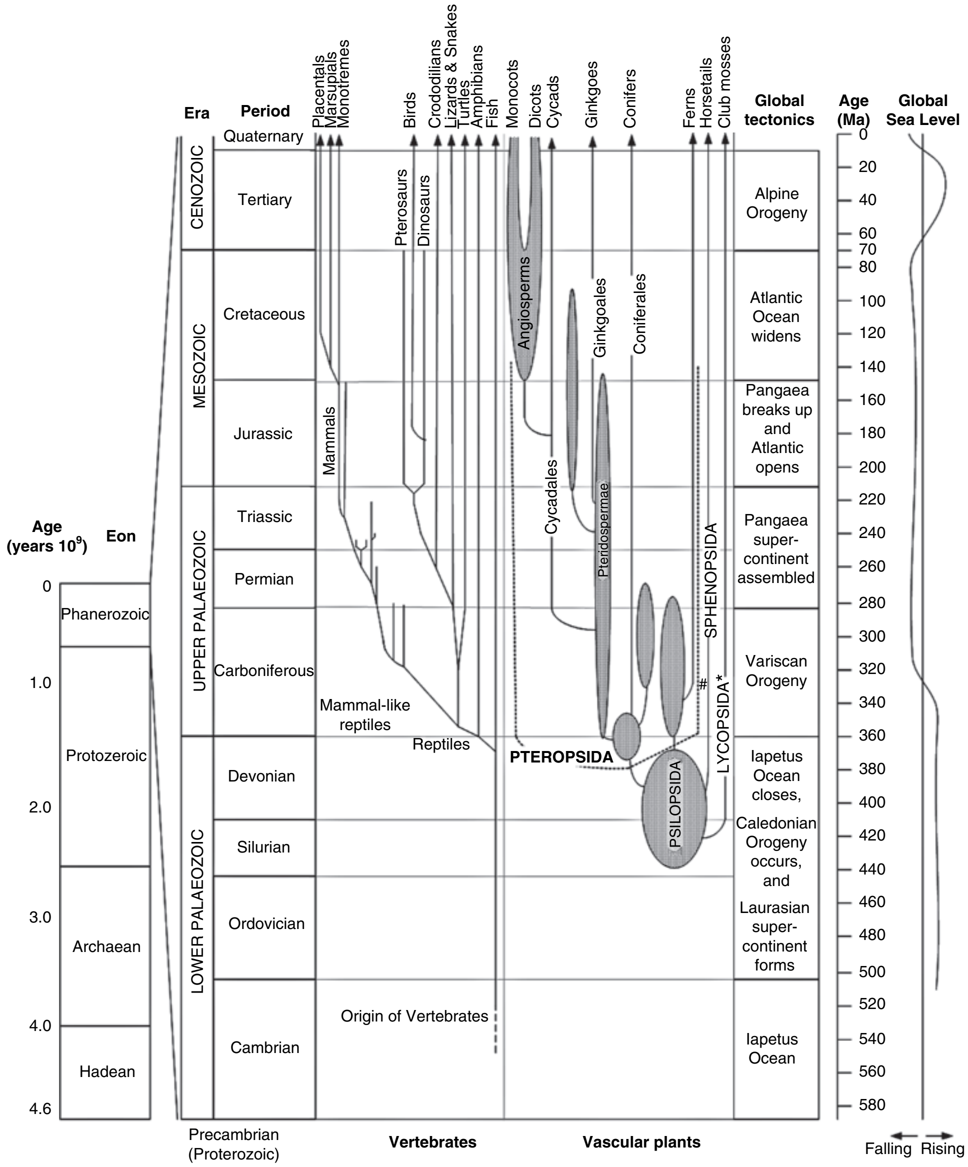

Figure 1.1 The stratigraphic column. Geological eons, eras, periods and time scale, indications of the origin and duration of the major vertebrate and vascular plant groups, together with estimated variations in sea level. Earth became solid *c.* 3.9 billion years ago at the end of the Hadean, and the beginnings of life were present within another 50 million years. Stromatolites and blue-green algae (known as cyanophytes or cyanobacteria) were present early in the Archaean era. The latter were the first photosynthesizing organisms on Earth. At first the oxygen they produced combined with iron-forming ferric oxides which sank to the bottom of the primitive seas. It then transformed the initially very adverse atmosphere and provided the oxygen required by animal

Table 1.1. *Forest cover in world regions, defined as including all natural forests and plantations. Taken from FAO (2005)*

World region	Forest area (M km^2)	Per cent of land area forested	Per cent of forest area that is under plantation
Africa	6.4	21.4	2.5
Asia	5.7	18.5	7.8
Europe	10.0	44.3	2.2
N and Central America[a]	7.1	32.9	2.5
Oceania[b]	2.1	24.3	1.9
South America	8.3	47.7	1.4
World	**39.5**	**30.3**	**2.8**

Notes:
[a] Including Greenland.
[b] Including Australasia and surrounding islands.

countries such as Kuwait and Egypt are all below 0.3% cover, and according to FAO figures, Oman and Qatar have no forest cover), or cold inhospitable climates (Iceland also has 0.5% forest cover). At the other end of the scale, the highest forest cover is found in northern boreal climates (Finland 74%) and on moist islands in the equitable Pacific such as the Cook Islands (67%) and the much larger Solomon Islands (78%). The five most forest-rich countries (the Russian Federation, Brazil, Canada, the United States and China) account for more than half of the world's total forest area (21 M km^2 or 53% – FAO, 2005). Deforestation and afforestation play an overriding part in how much forest is left in many areas of the world. After the last ice age the UK would

Caption for Figure 1.1 (cont.)
life. The Cambrian explosion, which began the Lower Palaeozoic, involved the sudden and abrupt production of myriads of life forms, including the complex and very varied trilobites, from simple precursors. Note that the Quaternary Period consists of the Pleistocene Ice Age, in which there have been a number of interglacials including the ongoing Holocene, which began 10 000 years ago and is part of the present Flandrian temperate stage with its global warming and ice melt. Our views on tracheophyte (vascular plant) relationships are constantly being modified as more and more fossil evidence accumulates: Bell and Hemsley (2000, p. 141) should be consulted for a more complex view. The Lycopsida (shown by the asterisk) included the clubmoss trees *Lepidodendron* and *Sigillaria*, and the Sphenopsida included *Calamites* (#). (Mielke, 1989; Benton, 1991; Briggs *et al.*, 1997; and After Bryson, 2004.)

have been fairly extensively forested but by World War I was down to around 6% cover, a figure which has now increased to 11.8%. From Table 1.1 it can be seen that the degree of planting of artificial plantations (as opposed to regenerating 'natural' forest) varies tremendously around the world. Forest area under plantation is greatest in Asia (7.8%); elsewhere it is less than 2.5%, giving a figure of 2.8% for the world forest as a whole. This adds further complexity to the way in which humans have influenced forest cover.

Nevertheless, it is estimated that about half of the forest that has grown under modern climatic conditions since the end of the Pleistocene, around 8000 years BC, has been lost, largely due to human activities. The spread of agriculture and domesticated animals, increasing population and cutting of forests for timber and fuel have all taken their toll. Some 13 M ha (0.13 M km^2) of forest are being lost globally each year (FAO, 2005). When new forests are taken into account the net loss of forest between 2000 and 2005 was still 7.3 M ha per year, an area the size of Sierra Leone or Panama. The only silver lining is that we are not losing forests as quickly as we did between 1990 and 2000 when the net loss was 8.9 M ha per year. Global net loss of forest has been estimated as 0.18% per year between 2000–2005 (FAO, 2005). It is perhaps not surprising that the UNEP World Conservation Monitoring Centre has identified over 8000 tree species that are threatened with extinction at a global level and are concerned for the estimated 90% of all terrestrial species that inhabit the world's forests. See Section 11.1.2 for rain forest losses.

1.1.2 Differences between woodlands and forests

The terms forest and woodland are commonly used almost interchangeably, and if there is any differentiation, then most people see a forest as a remote, large, dark forbidding place while a woodland is smaller, more open and part of an agricultural landscape. These views are very close to the normally accepted definitions of the two terms. A **woodland** is a small area of trees with an open canopy (often defined as having 40% canopy closure or less, i.e. 60% or more of the sky is visible) such that plenty of light reaches the ground, encouraging other vegetation beneath the trees. Since the trees are well spaced they tend to be short-trunked with spreading canopies. The term **forest**, by contrast, is usually reserved for a relatively large area of trees forming for the most part a closed, dense canopy (although canopy closure as low as 20% is accepted in some definitions). A forest does not have to be uniform over large areas, and indeed is often made up of a series of **stands**, groups of trees varying in such features as age, species or structure, interspersed with open places such as meadows and lakes and areas where grazing animals are limiting tree development. **Since these terms overlap, throughout this book we will use the term forest as the collective term for wooded areas, including woodland, unless otherwise specified**.

These definitions are obviously based on the trees as the dominant organisms. This is a convenient way of setting wooded areas apart but it should be borne in mind that a complete forest or woodland is the sum of the tens of thousands of other plants, animals and microbes. More recently, definitions of forests as complete ecosystems have tried to take this holistic message to heart (see Helms, 2002). However, even the simple definitions given above are not without their problems. The figures given in Table 1.1 from the FAO are based on defining a forest as having just 10% tree cover or more with a minimum size of 0.5 ha and so include some very open areas. Amongst European countries the minimum requirements to be called a forest vary widely: a cover of 5–30%, area of 0.05–2 ha and a width of 9–50 m (Köhl *et al*., 2000). The addition of estimates from individual countries gives western Europe 1 256 000 km^2 of forest, but using the extremes of the definitions above results in a variation of 113 000 km^2 (9%) around this figure. Such vagueness in definitions makes international comparisons very difficult and hampers conservation efforts. Lund (2002) suggests that there are at least 624 definitions of 'forest' used around the world!

In Britain, care is needed to distinguish the above from **Forest** (with a capital letter). From early Norman times (1070), a Forest was an area reserved for hunting usually by the monarch and administered under Forest Law. This definition says nothing about trees and indeed many Forests, such as the Royal Forest of Dartmoor in south-west England, were, and still are, almost treeless. As Oliver Rackham (1990, p. 165) neatly put it '. . . a Forest was a place of deer, not necessarily a place of trees'.

1.2 The value of woodlands and forests

As noted above, woodlands and forests cover between 30–35% of the world's land surface. Agriculture covers another 40% but since wooded areas are structurally bigger (i.e. taller and more complex), it is the wooded land that holds most living material of all the land vegetation types. Global wooded land holds in excess of 422 billion (10^9) tonnes of biomass just in the wood. Because they are so large and extensive, with many niches, it is inevitable that the world's forests are among the most important repositories of terrestrial biodiversity.

Forests also provide a wide array of goods and services. Forest products play a central role in the life of many rural communities: timber and fuel (in the

1990s, 3.5 billion m^3 of wood were consumed globally each year, with more than half used as fuelwood), food, animal fodder and medicines. Forests also play an important cultural role, in many ways defining some cultures such as in indigenous peoples of rain forests; without the forest their culture is diminished. Forests are also important in reducing soil erosion and in water conservation (see Chapters 2 and 6).

Urban dwellers benefit tremendously from forests. Global trade in primary forest products such as logs, sawn wood, panels, pulp and paper reached nearly $273 billion in 1997. It is not just timber; a large number of fruits and spices we use come from trees and woodland plants. Wild forests are still a valuable source of some of these. For example, almost all the Brazil nuts (*Bertholletia excelsa*) we eat (around 40 000 tonnes a year – Mori and Prance, 1990) are still collected in the wild (see Section 6.3.4 also). Forest plantations can also be a rich source of edible fungi; Chilean radiata pine plantations are already exploited in this way. At least 46 types of mushroom and nine types of truffle grow in forests and are potentially a most valuable food source. Wooded areas also have a large part to play in global carbon storage and sequestration (see Chapter 11).

On an individual level, trees and urban woodlands are beneficial to people. To name a few examples, they:

- Produce oxygen (a mature beech *Fagus sylvatica* produces sufficient oxygen over a year for ten people).
- Release many compounds into the atmosphere including monoterpenes which seem likely to have positive health effects (see Maloof, 2005).
- Absorb noise, dust, pollution and carbon dioxide.
- Reduce skin cancer (by blocking out sunlight), ironically in the mid-twentieth century the medical profession in the western world advocated extensive sunbathing to increase vitamin D levels.
- Reduce mental health problems by improving our moods and outlook.
- Improve post-surgery recovery rates in hospital wards which overlook wooded settings.

1.3 Tree biology and how it influences woodland ecology

1.3.1 Fitness of various species for particular uses

All tree species possess a unique combination of morphological, physiological and reproductive traits which fit them for particular niches in the ecosystems they occupy. In the case of exotic plantations the silviculturally and economically most suitable tree species may have originated in a far distant country. Two quite different examples illustrate this.

The **Monterey or radiata pine** *Pinus radiata* is an impoverished and stunted tree in its natural range on a handful of sites on the coast of California, mostly notably, the Monterey Peninsula. It has been left marooned in less than favourable growing conditions as its range has been reduced by climate changes since the last ice age. Yet elsewhere it is capable of magnificent growth and has been extensively planted in many parts of the world including New Zealand and South America. In New Zealand it now accounts for some 90% of the exotic trees grown and develops so rapidly that it can be harvested at an age of 25 years, whereas even Douglas fir (whose timber may sell for roughly double the price) would normally have to grow for 45–60 years under the same conditions. It also has excellent form, wounds incurred when lower side branches are pruned heal rapidly, and it does not coppice so any unwanted trees die when felled. Its seeds are easy to collect and store and have a high germination rate, while bare-root seedlings and cuttings can be grown rapidly without shading and withstand weeding with herbicides. Planting stocks have a survival rate $>95\%$ on a wide range of sites; the tree grows well and predictably even on infertile soils, its vigorous early growth often outstripping gorse and other weeds while in some situations its roots penetrate to a depth of 5 metres. The tree also has a degree of tolerance to frost, snow, salt winds and severe drought. Its genetics have been widely studied, clones being developed to suit particular conditions. This shade-intolerant species is most easily grown under clear-felling regimes and tends to shade out other species when planted in mixtures: the multi-species commercial forests that thrive in Europe are not found in New Zealand.

The genus *Eucalyptus*, which consists of around 500 species of trees and shrubs, has a native distribution largely confined to Australia, but extending into New Guinea, eastern Indonesia and Mindanao (Hora, 1981). **Eucalypts** show a most remarkable range of size and habitat and various species of this vigorous and adaptable tree, which evolved in isolation even from New Zealand, are now widely planted in many parts of the world, especially California which has the largest range of eucalypt species in the USA. The smallest is less than a metre in height, whereas mountain ash *E. regnans* can live for 300 years and is the tallest hardwood tree in the world, growing to more than 100 m on deeper well-watered soils in the foothills of Victoria, South Australia. The river red gum *E. camaldulensis*, a robust tree up to 35 m high, is found in most of Australia and can live for 500 years; older trees shelter parrots in their cavities. Tasmanian blue gum *E. globulus*, which reaches 35–45 m in height, is the species most widely planted in the Mediterranean area and California. Conditions in tropical North Australia vary from the normally extremely hot and dry to the suddenly deeply flooded when tropical rainstorms cause the rivers to overflow. This is an area well suited to extremely territorial frilled lizards which feed mainly on insects and make rapid two-legged dashes from tree to tree to avoid attack by predatory birds. Ghost gums *E. papuana* grow in New Guinea and arid parts of northern Australia, while in the southern state of Victoria snow gums *E. pauciflora* grow high on the Australian Alps, tolerating winter temperatures as low as −20 °C and providing food and shelter to parrot populations which feed on their fruits. It is on the lower slopes of these hills that the mountain ash flourishes on good soils with adequate water.

Almost all eucalypts are evergreen, having leaves that are hard and rich in nutrients. Apart from the koala (see Section 5.7.2), few animals can digest them. The bark of ghost gums is shed to the ground leaving a strikingly white surface, which reflects sunlight, and the leaves tend to hang down, thus staying cooler. Fire affects almost the whole of Australia, whose trees are well adapted to it, many of them having developed the ability to coppice or sucker in response to millennia of natural fires. Eucalypt fires develop rapidly and burn intensely. Many trees can survive all but the most severe fires and some species need fire to release their seeds. Buds buried beneath the bark produce new leaves and branches and life often resumes within a few weeks. Jarrah *E. marginata* is one of many species with a lignotuber, like a huge wooden radish, which enables it to coppice.

1.3.2 Tree morphology

Trees have arisen independently in a large number of plant families as a strategy which outgrows other plants in competition for light, and in so doing have evolved a large **perennial woody skeleton** to display, in a large tree, over half a million leaves. Such a tall structure is also a good platform for displaying flowers to wind or animal pollinators, and the height helps falling seeds to disperse further. These evolutionary trends have resulted in trees being the tallest and largest of all living things. The **tallest trees** in the world are currently the **coastal redwoods** of California (*Sequoia sempervirens*) at 115.5 m (358 ft) although the tallest tree ever, a mountain ash *Eucalyptus regnans* in Australia, may have been over 150 m (500 ft) – see Section 1.3.1 above. California also boasts the **largest tree, a giant sequoia** *Sequoiadendron giganteum* growing in the Sierra Nevada Mountains, called General Sherman. The General is 83.8 m tall with a width at the base of 11 m, giving an estimated mass of 2030 tonnes (by comparison, the blue whale, the largest animal, weighs only around 100 tonnes).

In order to grow so large, most trees (palms and other monocotyledonous trees being an exception – see Thomas (2000) for details of these) have a similar

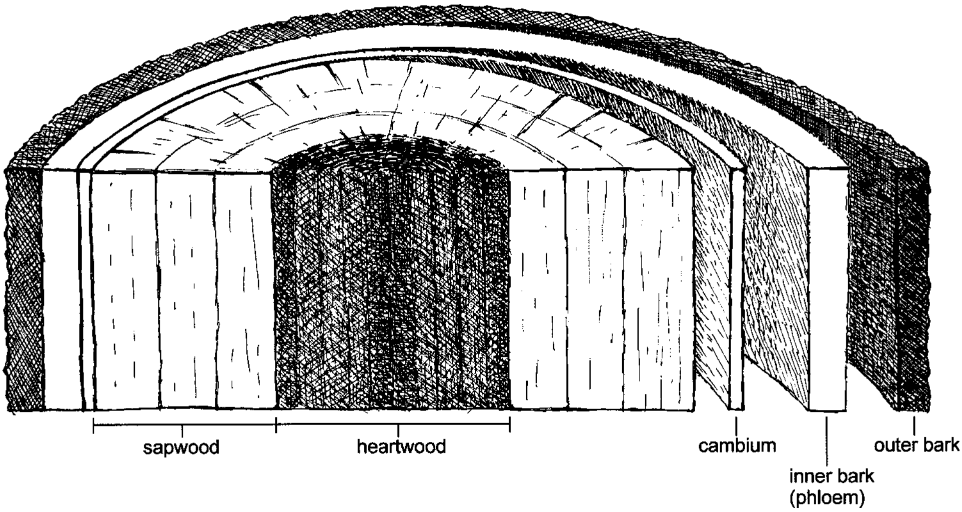

Figure 1.2 Tree cross-section. (From Thomas, 2000. *Trees: Their Natural History*, Cambridge University Press. Reprinted with permission.)

and distinctive structure (Fig. 1.2). The **outer bark** on the outside serves a dual function as a waterproof layer (to keep water in) and a defence against attacking organisms. The cork cambium in the bark is responsible for the production of corky cells whose walls are suberized by fatty compounds which render them impervious to gases and liquids. The bark is punctuated by lenticels, however, which allow vital gas exchange. In the cork oak *Quercus suber*, which is extensively grown in Portugal and Spain, this outer layer grows so rapidly that a thick layer of cork, renowned for its use for wine bottle corks, can be stripped off every 8–12 years.

The **inner bark or phloem** is made up of living cells that transport sugary sap usually from the **sources** (the leaves) to the **sinks** (the growing points and food stores). This nutrient-rich layer is utilized by a wide range of insects and pathogens which can have important repercussions to a woodland, such as the transmission of Dutch elm disease by the elm bark beetles (*Scolytus* spp.), discussed further in Section 5.4. Inside the phloem is the **cambium**, responsible for growing new phloem on the outside and new xylem on the inside. The phloem tends not to accumulate because it is stretched and crushed by the expanding tree, but the xylem on the inside accumulates each year to form the wood of the trunk. In seasonal climates, annual rings are created as the wood grows and the age of a tree can thus be determined by counting the rings. **Dendrochronologists** also measure the width and density of these rings and have linked these to various climatic factors, allowing them to calculate past yearly weather patterns. The influence of pathogens on tree-ring development

Figure 1.3 An old bristlecone pine growing in the White Mountains, California, one of the oldest living things in the world. (Photograph by Peter A. Thomas.)

is described in Chapter 5; masting is also likely to have an influence. The **oldest recorded living trees** are the **bristlecone pines** *Pinus aristata* var. *longaeva*[1] (Fig. 1.3) growing at 3000–3500 m in the White Mountains of California. The oldest known individual, Methuselah, has been dated at over 4700 years old by counting the rings, yet in 1974 it is reported to have given rise to 48 living seedlings. The oldest recorded specimen, inadvertently felled, lived to

[1] A difference of opinion exists over the correct scientific name. Americans like to call the bristlecone pine, *Pinus longaeva*. *The World Checklist of Conifers* (Welch and Haddow, 1993), however, calls it *Pinus aristata* var. *longaeva*.