ECOLOGY: the life of trees

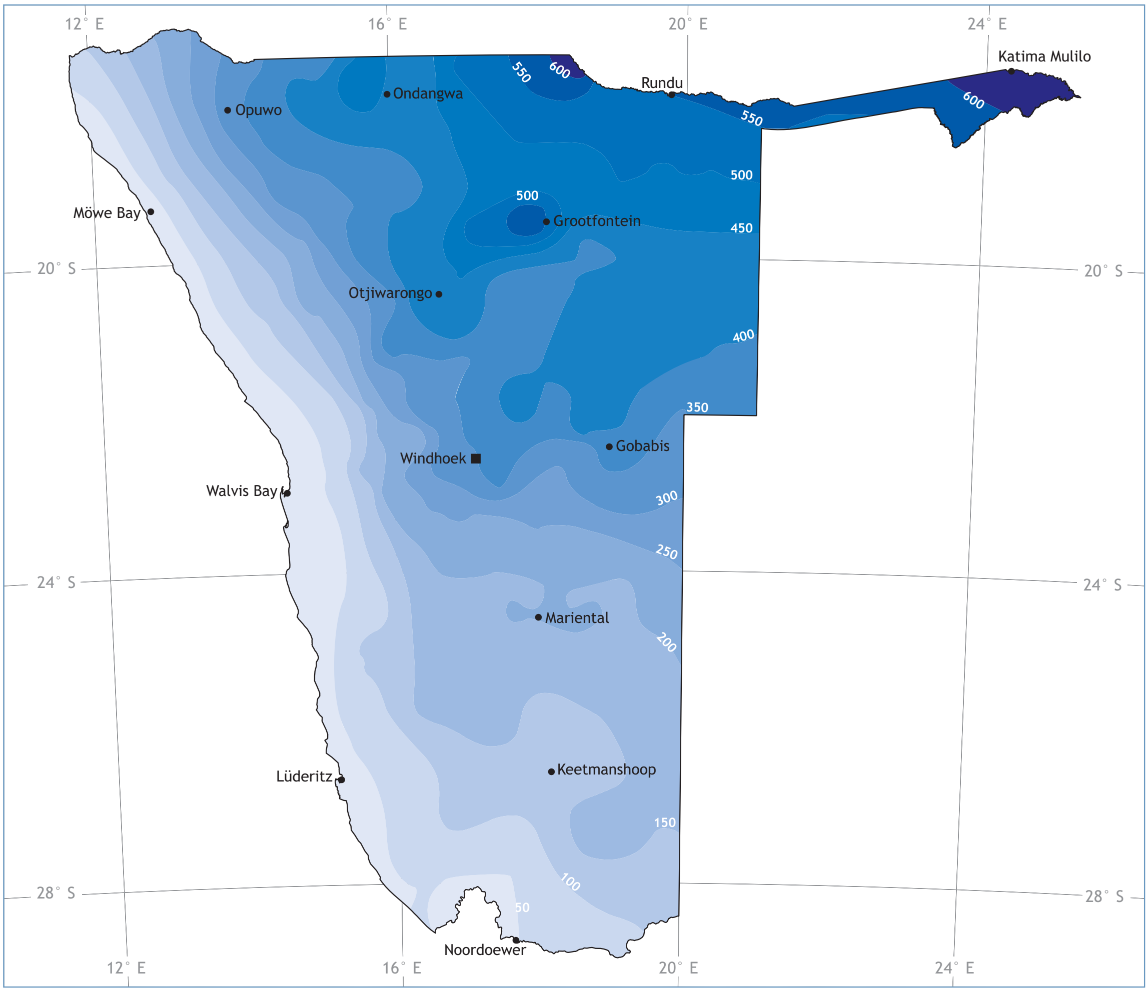
Many Namibians may wonder why are there no tall, evergreen forests in this country; why trees along rivers are taller than elsewhere; why different species grow on drier ground away from water courses; why timber resources are largely concentrated in the north-east; why there are so many Acacia species; and where most tree species are to be found in Namibia? Simple questions, but often hard to answer. This chapter presents a digest of information that should go some way towards providing answers. More importantly, we hope that other questions will be raised in the reader's mind to stimulate further questions, since it is through enquiry that knowledge on forests and woodlands will expand.

The chapter begins by exploring factors that affect the distribution and abundance of trees in Namibia. These are the influences that combine to determine patterns of distribution and abundance. The patterns represent what now grows and survives. However, reproduction is arguably more important than survival, and the second section reviews information on germination, recruitment and growth. These earlier parts provide a basis for the next two sections on woodland resources (types and diversity of woodlands, and wood resources) and what areas of woodland are perhaps most important. The final section looks at the introduction and establishment of exotic trees and plantations in Namibia.

THE ECOLOGY OF NAMIBIAN WOODLANDS

Ecology is the study of how living organisms interact with each other and with the natural environment. The focus here is on the latter, particularly in looking at how different aspects of the environment influence trees. There are six major factors that separately, and in combination, play major roles in determining where trees occur, how many there are, and the form in which they grow. The factors are climate, soils, fire, elevations, historical and human influences. Their roles vary from place to place, and often affect young and old trees differently. Some factors play crucial roles at certain

Silver-leaf Terminalia form an avenue over a track along the abandoned firebreak between the Caprivi State Forest and Zambia. This pioneer species is one of the first woody plants to colonise disturbed areas such as firebreaks and abandoned fields in areas of Kalahari sand. Climax species (such as Burkea, Kiaat and Zambezi Teak) should eventually replace the pioneers after many decades.



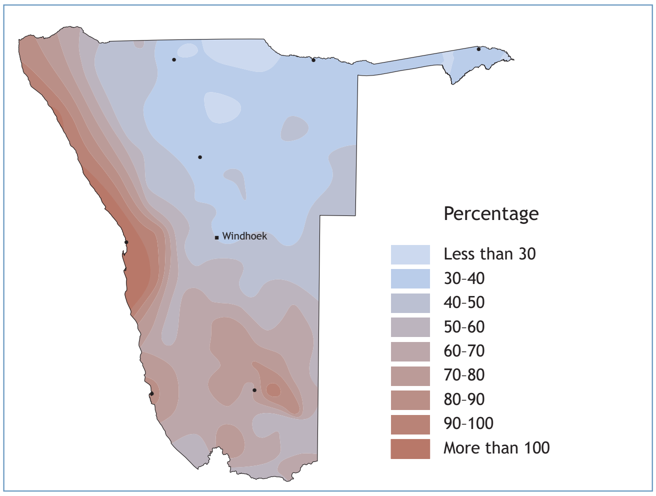


Figure 4.
Average rainfall (above) declines in a gradient from the north-east to the south-west.
Variation in rainfall (right) is greatest in the west and south, as shown by the co-efficient of variation of total annual rainfall[1].

times but have little influence at others. The effects are also often related to landscapes. For example, higher rainfall on hills – caused by moist air rising and cooling over the higher ground – leads to better tree growth. In this case, rainfall has the immediate or proximate influence, but the landscape of hills generates rain and has an ultimate effect on woodlands.

Climate

Of the many aspects to climate, rainfall, temperature and frost are most influential on Namibian woodlands and forests. Indeed, these have been fundamental in influencing the nature of trees across the whole African continent over the past 50 million years. By rainfall we really mean the availability of water, which is determined by how much water falls as rain, how it is concentrated in rivers, and how it is lost by seepage and evapotranspiration (the combination of water lost through direct evaporation and by transpiration of the leaves).

Rainfall varies rather evenly across the country, from the highest annual averages of approximately 650 millimetres in eastern Caprivi to less than 50 millimetres along the western coast (Figure 4). Much of the country is thus arid, offering little water for trees to grow (by contrast, the tall rain forests that blanket equatorial Africa receive 2,000 to 3,000 millimetres per year). The other key feature of rainfall in Namibia is that it is highly variable, within any given year as well as from year to year. Rain may fall at any time of the year in the south-western corner of the country, but elsewhere almost all rains fall within three to four months during the summer. For the rest of the year, the environment is dry, and often hot. The wet season is shortest in the driest parts of the country (Figure 5).

The long dry spells set severe limitations on tree growth, but Namibia also experiences substantial variation in rainfall from year to year, particularly in the driest western and southern areas where dry periods may last several years (Figure 4). Trees use several strategies to cope with aridity and variable access to water. Some species store water in their succulent leaves, branches or stems (for example, Baobabs and Kobas trees). Others grow only on deep soils, using their long roots to draw on underground water sources (Camel Thorns and Zambezi Teak are good examples). Many trees have waxy or hairy coatings on their leaves to reduce water loss. Wax reduces water vapour diffusion across the leaf surface, while hairy surfaces trap moist air to create a slightly humid zone on the leaf surface. This reduces the moisture gradient - and thus rate of diffusion - between the leaf tissues and dry outside air. Examples of trees with waxy leaves are Blue Sourplum and Ushivi, while trees with hairy leaves include Candle-pod Acacia, Velvet Wild-Medlar, and species in the genera of *Ozoroa*, *Grewia* and *Sterculia*. Many trees drop their leaves during the dry months, particularly the broad-leaved species that dominate north-eastern Namibia. However, in areas where rainfall is seasonally unpredictable some species do not lose their leaves, thus maintaining their ability to grow should unseasonable rains fall.

Trees in Namibia are also generally sparsely distributed, small in size and have slow rates of growth, largely as a consequence of variable and low supplies of water. Species that are least tolerant of water shortages are confined to north-eastern Namibia and water courses where they draw water from the moist sediments. Since they do best in these wetter areas, they out-compete and exclude other species from growing there. Those species that can grow in drier areas obviously do so, but

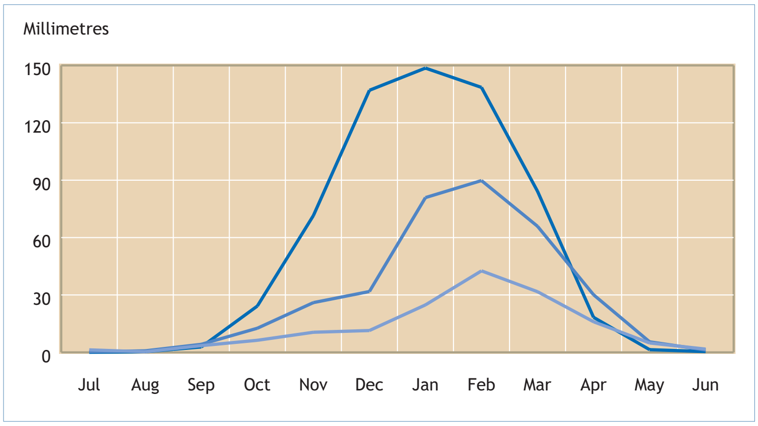


Figure 5.
Average rainfall (in millimetres) per month at Katima Mulilo (dark blue line), Windhoek (blue) and Keetmanshoop (pale blue). With an average of 148 millimetres per year, Keetmanshoop usually has only two rainy months each year, Windhoek (average of 352 millimetres) has about three wet months, and Katima Mulilo (annual average of about 628 millimetres) can expect rain during five months from December to April.

Trees alongside roads are often taller, and produce leaves earlier than those further away because they benefit from water that runs off the road surface. This is the old road between Katima Mulilo and Kongola (left). Much of the water used by a Wild Tamarisk growing in the dry Namib is provided by condensed drips of fog water (below). Every Bergdorn leaf has a silvery lining of tiny hairs that help reduce water loss (bottom).

the number of such species declines as the environment becomes increasingly dry. This is the main reason why there are more species in the north-east than in the drier southern and western areas (see page 43).

Perhaps the most important effect of rainfall is on germination and the early growth of young trees. Seeds often germinate only after a good soaking, and seedlings require the surface soil to remain moist long enough for their growing roots to reach wetter and deeper soil. Germination and early growth thus need repeated good falls of rain. Such events are usually rare in Namibia and many years may pass before new cohorts of trees are recruited (see page 36).

The flipside of water availability is water loss, which happens primarily through seepage and evapotranspiration. Unlike the deep humus-rich ground on which many forests grow elsewhere in the world, most soils in Namibia retain little water. Evaporation rates are also very high, volumes of water potentially evaporating each year being several times greater than the amounts received as rain. Rates of evaporation rise with increasing temperature, wind speed and decreasing humidity, and are thus highest during the hottest, driest and most windy periods (Figure 6). In addition to water lost through evaporation, plants transpire water pumped by their roots from the ground. The water is lost through stomata on the leaves. Rates of transpiration and water loss depend on the kinds of plants (some species use less water as a result of lower metabolic and growth rates), their access to water (those with plentiful supplies transpire more), temperature and humidity (more water is lost on hot, dry days), and season (transpiration rates in the summer growing season are higher than during the dormant winters).

The effects of temperature (heat, more correctly) on the distribution and abundance of trees is greatest on young plants. Tolerance towards temperature extremes increases as plants grow and age, and temperature is thus seldom a limiting factor for big trees. However, trees have to cope with seasonal and daily fluctuations in temperature, adjusting their metabolism to warm and cool conditions as appropriate. For example, temperatures often vary by over 20°C in a day. Examples of how temperatures fluctuate seasonally are given in Figure 7. Certain seeds are stimulated to germinate at specific temperatures, and the growth rate of young trees is often directly related to temperature. The warmer conditions are, the faster plants grow, but at very high temperatures plants lose too much water, causing wilting and sometimes death. Indeed, the main effect of high temperatures is to cause high rates of evapotranspiration and water loss.

Conversely, cool temperatures slow growth, and very low temperatures can result in frost. Again, young or small trees are most at risk. Many species simply cannot withstand frost and thus occur only in subtropical or other climates not prone to frost. The distributions of Welwitschia and Mopane are probably limited by frost, although Mopane occurs in frost areas in Etosha and Zimbabwe, often as shrubs.[2] Frost is most prevalent in the central eastern regions of Namibia (Figure 8), elsewhere occurring only sporadically and usually only in low-lying valleys. Thus, trees on higher ground are seldom affected. Amongst larger trees susceptible to frost, it is often only water in the growing tips on their outer branches that freezes.

Soils

Trees are influenced by two main properties of soils: moisture and nutrient content. Soils in many areas

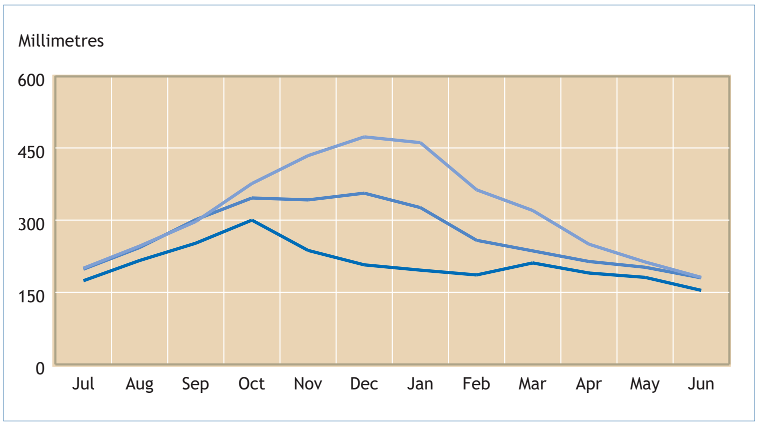


Figure 6. The highest rates of potential evaporation are in southern Namibia, and the lowest are in Caprivi. Keetmanshoop (pale line) has a potential annual evaporation rate of 3,814 millimetres, Windhoek 3,203 millimetres (blue line), and Katima Mulilo 2,504 millimetres (dark line). The graphs show that evaporation rates are generally highest in the windiest, driest, early summer months.

Figure 7.
Average temperatures and average monthly maximum and minimum temperatures at Windhoek, Rundu, Walvis Bay and Keetmanshoop.[3]

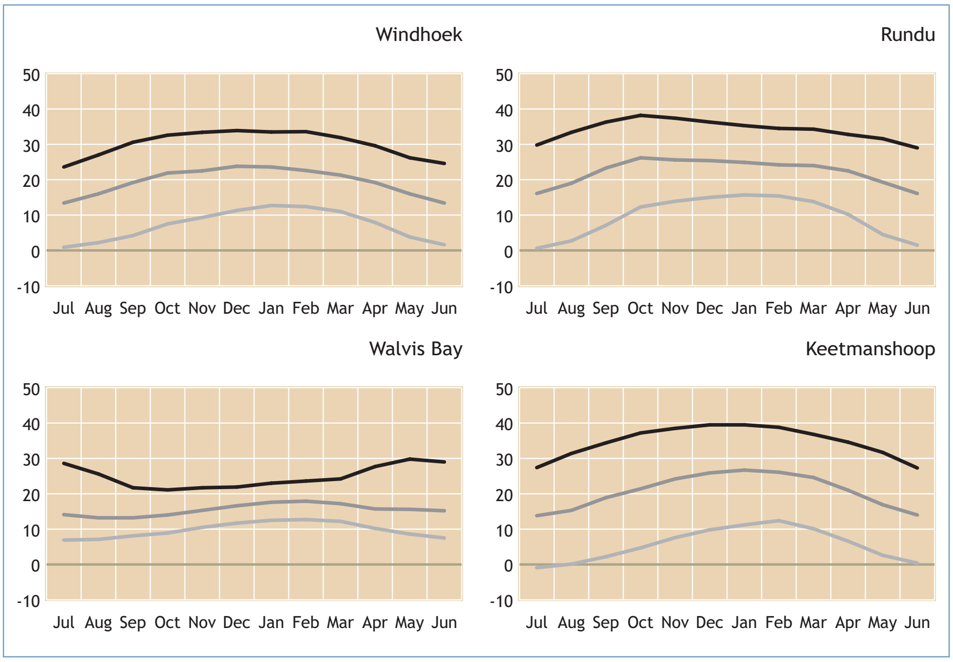
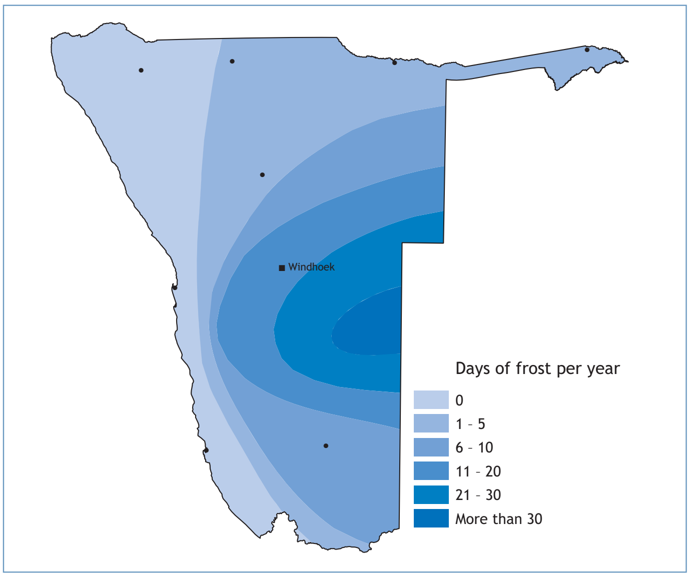


Figure 8.
The average number of days on which frost can be expected each year in Namibia.[4]



of Namibia make little moisture available to trees because they are shallow or sandy. The shallowest soils are in rocky areas where most rainwater is lost swiftly as surface flow, evaporation or seepage into rocky crevices. The surface layers of sand likewise dry quickly because water percoloates away rapidly. The nutrient contents of most Namibian soils are also very low, and the poor quality of soils is often more of a limiting factor to the growth and productivity of crops and indigenous plants than the arid climate. Sandy soils are always low in nutrients because they consist largely of quartz sand grains and thus contain little humus. Moreover, the Kalahari sands that cover much of north and eastern

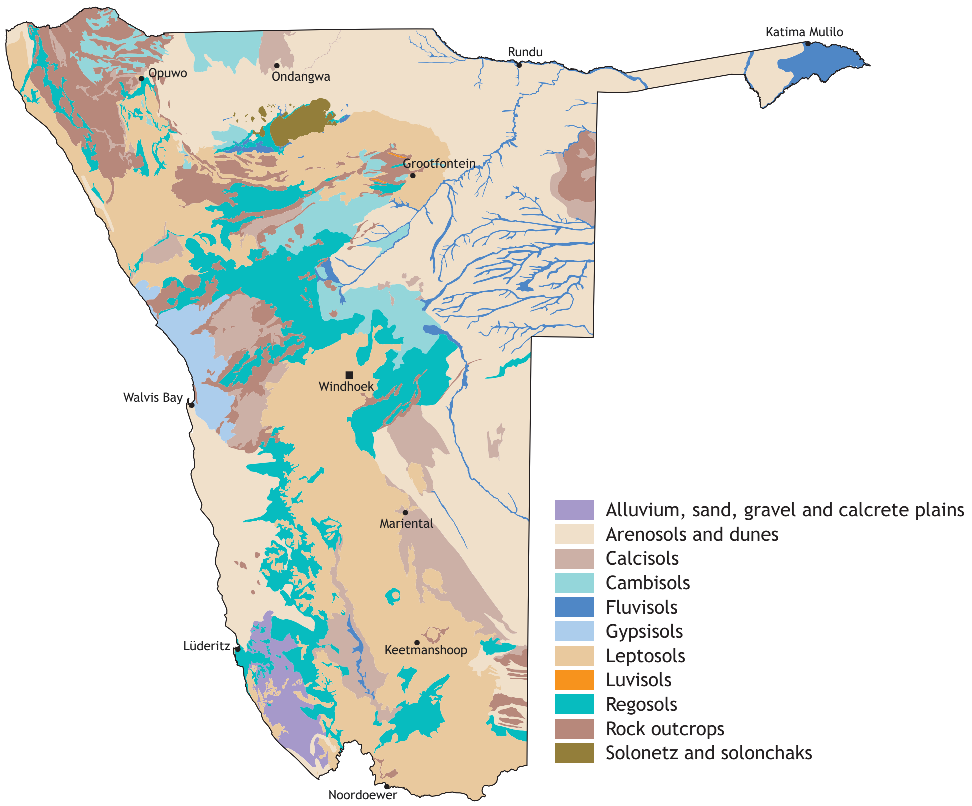


Figure 9.
Much of Namibia consists of arenosol sands, as shown in this map of major soil groups.[6]

Namibia (Figure 9) are inherently low in phosphorous. This is a constraint in itself, but the problem is compounded because low phosphorous levels limit the nitrogen content of soil.[5]

Other soils in most areas of Namibia are also low in nutrients, mainly as a consequence of the arid climate. Under wetter conditions, soils would be formed more rapidly by the weathering of rocks and more nutrients in the rocks would be released. Greater quantities of organic matter would also be available as a result of decomposition, because of more luxuriant plant production and because dead leaves and twigs would be blown away or burnt less frequently.

Soils in certain areas are so salty that only specialized plants – including very few trees – grow in them. The best example is Etosha Pan, but soils to the north in the Cuvelai drainage system also have high concentrations of salt due to high rates of evaporation. The most saline soils are called solonchaks and solonetzs. Gypsisols in the Namib gravel plains inhibit the growth of plants as well by having high concentrations of calcium sulphate salts. The salts are dissolved out of rock by water and then carried below the soil surface where they crystallize, sometimes into the well-known desert roses.

Tree growth is likewise constrained by waterlogged soils, such as those on floodplains along the Okavango and Kwando/Linyanti Rivers and between the Zambezi and Chobe Rivers in the eastern Caprivi. Water restricts the movement of air amongst the particles of soil with the result that the roots are unable to breathe.

These are soils that limit the presence of most woody plants. Other soils tend to be dominated by particular species that grow so well in them that they competitively exclude most other

species. A case in point is the almost mono-specific stands of Mopane on alluvial clays in the Cuvelai Dédrainage system and in fossil wetlands in eastern Caprivi. Kalahari sands are dominated by a much more diverse assemblage of characteristic species, which do not occur on other types of soil. While other species that prefer different soils might grow on the sands, their growth is usually so poor that they are dominated by species that do indeed grow well on sands.

Fire

The widespread bush fires that occur so frequently (see page 109) have a major impact on the structure of woodlands in north-eastern Namibia. The most important effect is in limiting the growth of young trees and in killing older, larger trees. This keeps the woodlands more open and savanna-like with a greater cover of grass. As a consequence, that part of the country would be more heavily wooded, and bush encroached, if fires were less frequent.

The densely wooded areas in this area of south-western Kavango are on Kalahari sands, while more clayey soils dominate the long sparsely covered inter dune valleys (left). The dunes were formed during very arid periods, most recently about 10,000 years ago. Many of the inter dune valleys have been cleared because the soils are better for crop growth than in the surrounding sands. Savanna woodlands, with their characteristic carpet of grass beneath scattered trees, are formed as a result of sporadic fires (above).

These effects are most prevalent in higher rainfall areas since grass cover in arid areas is usually too sparse to fuel the hot fires that limit tree growth.[7] In exceptional cases, patches of woodland in areas of high rainfall may escape being burnt over several years. Tree growth in these patches may then become so dense, and grass cover so low, that fires are unable to enter – and damage – the forests.

The other major impact of fires is on the species composition of woodlands. Some species are more vulnerable to fires than others. Unfortunately most valued timber species are sensitive to fires, and there would probably be many more Zambezi Teak, Ushivi and Kiaat trees if broad-leaved woodlands in north-eastern Namibia burnt less often.

Altitude

The distribution of trees is greatly affected by relief and elevations in many parts of Namibia (Figure 10). However, these effects are largely due to other environmental factors that vary themselves in relation to topography, hence the earlier example of higher rainfall over raised ground and its effect on plant growth (see page 27). Many hills or raised plateaus are at higher elevations because they differ geologically from surrounding lower areas, and soils formed on areas of higher relief therefore differ from those below. For this reason, the characteristic tree communities (dominated by Bergsering, Propeller Tree and Omundjimune) on dolomite hills around Otavi, Grootfontein and Tsumeb are quite different from the mosaic of Acacias, Tamboti, Purple-pod Terminalia and Sickle-bush that grow on the loams, turf and calcrete soils in the nearby valleys.

Temperatures on raised ground are usually lower than those in lower places (except on cold winter mornings when cold air settles in valleys). However, there are few mountains in Namibia

The Acacias in the foreground grow on loamy soils below a hill just south of Windhoek. The cover of Kudu Bush, Camphor Bush, Yellow-bark Acacias increases down the hill, probably because soils are deeper lower down than at the top.

that are high enough for temperature zones to be noticeable. Such zones have conspicuous effects on tree growth on mountains in East Africa, where temperatures drop by an average of 6°C per 1,000 metres of elevation. Many of these mountains have a belt of tropical forests at their bases, while only stunted shrubs grow in the cold alpine zones at the highest altitudes. Perhaps the only Namibian mountain where temperature changes might substantially affect vegetation is the Brandberg, which rises to 2,579 metres from about 700 metres above sea level on the surrounding plains.

Historical effects

History has an impact on tree distributions in two ways. The first is through historical chance, and its effect is mainly on the short term. Seeds drop

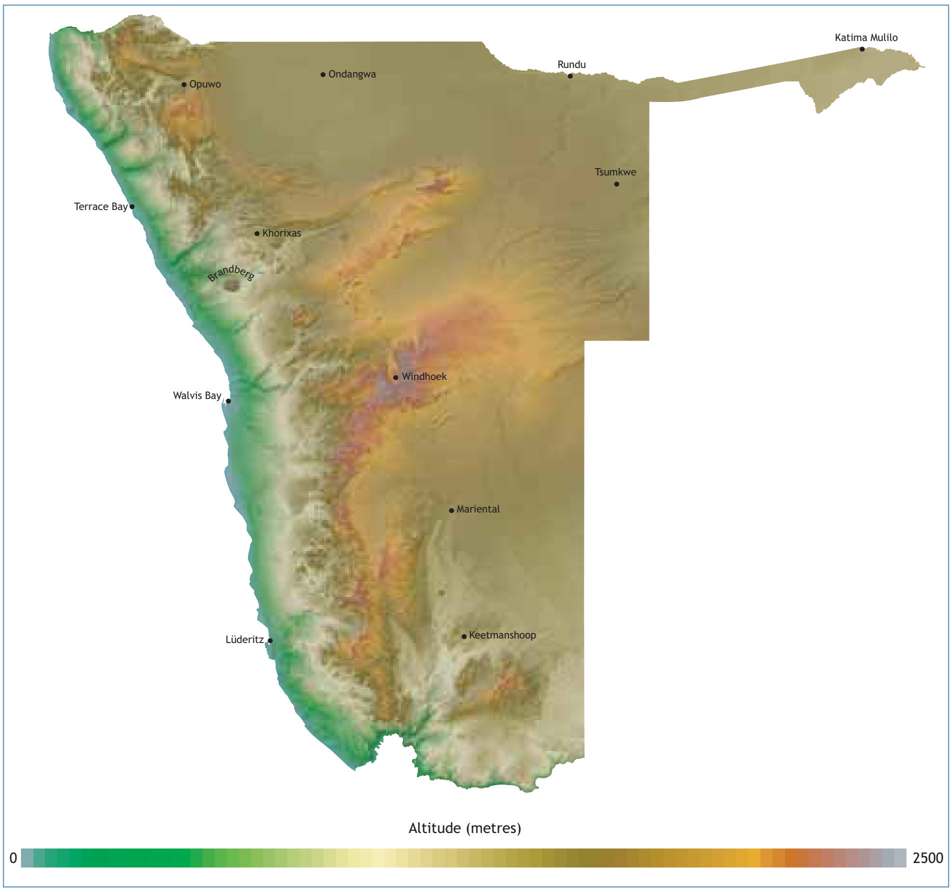


Figure 10. Most of the country lies between 800 and 1,200 metres above sea level, but much of the high ground around Windhoek is above 2,000 metres.[8]

in odd places, some might germinate, others get eaten by birds or rodents, for example. A seed that finds itself along a watercourse has a better chance of becoming a tree than a seed dropped elsewhere. Likewise, a seedling that happens to be found by a browsing animal will not become a tree, nor will a seedling that happens to be in the path of a raging fire. Other seedlings are luckier and their survival is thus often due to chance.

History also has longer-term effects, the study of which is called biogeography. Many of these effects are due to climate change. A local example is provided by the concentration of Commiphora species (paper-bark trees) in north-west Namibia (see page 49) and another area of high Commiphora diversity in north-east Africa. In both areas, most species are isolated as relics from a much drier period when Commiphoras were distributed widely across Africa. Nowadays, there are few species between south-western and north-eastern Africa because the environment is more tropical in the intervening zone.

Human influences

The abundance of Marula trees in north-central Namibia provides another example of possible historical effects. It is widely thought that the trees were introduced from elsewhere and nurtured over hundreds of years by Owambo people. Similarly, Prosopis and other alien tree species were introduced to southern Namibia more recently. People have also done much to damage woodlands and forests in Namibia. Large areas have been cleared of trees for the planting of crops or building of homes and fences, especially in northern Namibia (see page 105). Many trees have been cut for firewood around major centres of habitation, and tens of thousands of Tamboti trees were cut for use as mine props at Tsumeb, Kombat and Abenab. Bush encroachment is very likely to be a consequence of fire control and over-grazing by livestock farmers (see page 113). The growth of trees along some of the westward flowing ephemeral rivers has perhaps been limited by the construction of many dams on farms in the catchment areas. The dams reduce the flow and frequency of flood waters to riparian trees.

Intricate patterns reveal the paths of caterpillars that have munched their way through the leaves of a Buffalo Thorn.

Minor influences

In addition to the major effects described above, several other factors can have important influences on tree distribution and abundance. For example, fungi known as mycorrhiza live in association with the roots of some plants, and enable the roots to absorb water and nutrients more efficiently. Mopane have these fungi, which might allow the trees to grow in relatively nutrient-poor soils. All manner of herbivores, such as insects and large mammals, may affect the growth and structure of plants. For example, elephants have caused substantial damage and loss to riverine forest in the Mahango Game Reserve (see page 116), and caterpillars often strip foliage and retard the growth of trees. Day length plays a major role in controlling growth at high latitudes, where plant growth responds to the substantial changes in the number of hours of sunlight each day. Smaller changes occur in Namibia, but some trees nevertheless probably accelerate their growth as the days lengthen and then slow down as shorter, winter days approach. Finally, there is evidence that rising carbon dioxide levels may enhance plant growth, and it is possible that some degree of bush encroachment might be due to the greater abundance of carbon dioxide in the atmosphere in recent decades.[9]

In concluding this section on factors affecting the distribution and abundance of trees, three points need to be made. First, a multitude of factors are at play, and they vary in effect from place to place and from one day or period to the next. Second, the availability of water is the crucial factor to affect trees in Namibia. But this is not a simple matter of how much rain falls. Rather, water availability is affected by a host of other factors: temperature, humidity, wind speed, soils, human activities and landscapes. Third, trees are much more affected by environmental factors when they are young. This is when they are most likely to be influenced by fire, shortages of water, the effects of temperature extremes and browsing by animals, for instance. What happens to a tree in its early life is pivotal, and it is to aspects of germination and growth that the chapter moves.

GERMINATION, GROWTH AND RECRUITMENT

The trees that we see and use are short-lived manifestations or expressions of genes that reproduce and survive over millions of years. Our focus is on the here and now – what trees are growing, how long they might survive, and what resources they may provide. But from the view of genes that control and produce tree growth, reproduction is arguably much more important than survival. This can create an interesting conflict of views between our short-term perspectives and the biological requirement to replicate.

Trees reproduce in several steps. Mature trees produce flowers, which must be pollinated to develop fruit and seeds. In turn, these need to ripen and harden for dispersal and to survive as dormant seeds. Dormancy may last from a few months to several years before germination occurs, which is followed by rapid growth as trees struggle to mature and reproduce again. These are the main stages of sexual reproduction. Some species – such as the White Puzzle Bush – also reproduce asexually by producing runners, which are roots that later develop into individual trees.

All stages of reproduction are subject to trials and tribulations, often made more trying by aridity and poor soils in Namibia. To produce flowers, mature trees need energy that is additional to their normal metabolic energy requirements for growth and maintenance. Flowers and fruit attract large numbers of predators, as do seeds after falling to the ground. To germinate, seeds must fall in appropriate microenvironments, which have suitable soils and climatic conditions. Some seeds, for example those of Camel Thorns, germinate more readily once they have passed through the digestive tracts of herbivores, such as cattle or kudus.[10]

The seeds of most species only germinate when it is warm and good rains have fallen. More crucially, the rains must be followed by successive falls and relatively high humidity so that the soils remain moist. These conditions are essential if young seedlings are to survive more than a few weeks. Such events in many parts of Namibia occur infrequently or episodically, and it is for this reason that it is often hard to find young trees. The younger Ana Trees and Camel Thorns in the central Namib along the Kuiseb River are all thought to have germinated and survived following good soaking rains and river flows in 1934, 1974 and 2000 and 2001.[11] Thus, conditions suited to the recruitment of new trees only occurred four times over a period of 70 years.

Finally, predators, competitors, pests, fire, drought or other hazards easily kill small trees. Their vulnerability decreases as they become older and bigger, which means that it is vital that they grow rapidly. More immediately, young seedlings have to grow their roots quickly to tap water from moist soil beneath the surface. Growth rates can indeed be rapid. For example, the roots of young Ana Trees and Camel Thorns can grow at between 1.0 and 1.3 centimetres per day, and so a seedling could have roots reaching half a metre down after one month.[12] Young trees in areas prone to fires also need to grow quickly, especially in developing a thick coating of bark to protect the layer of

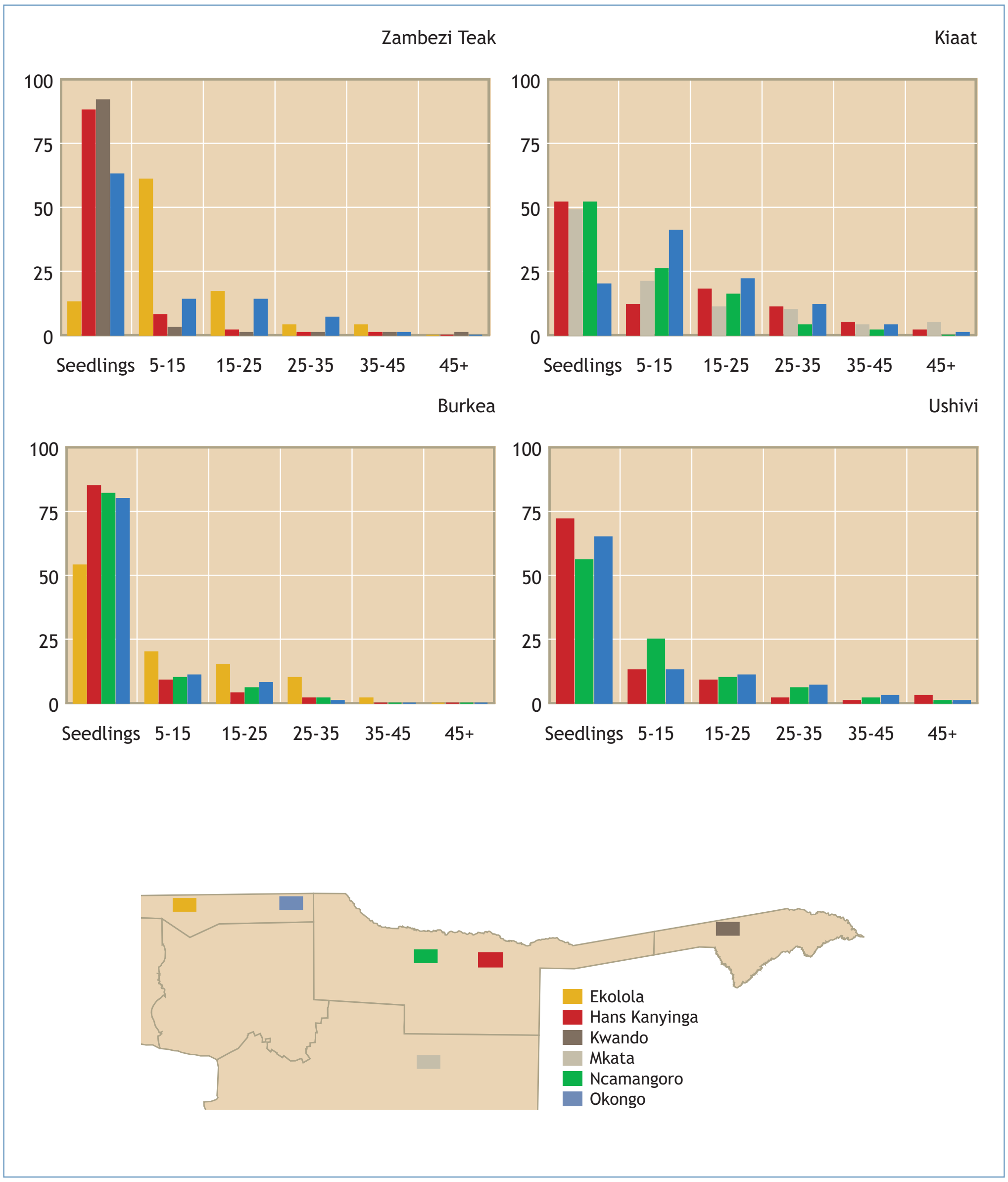
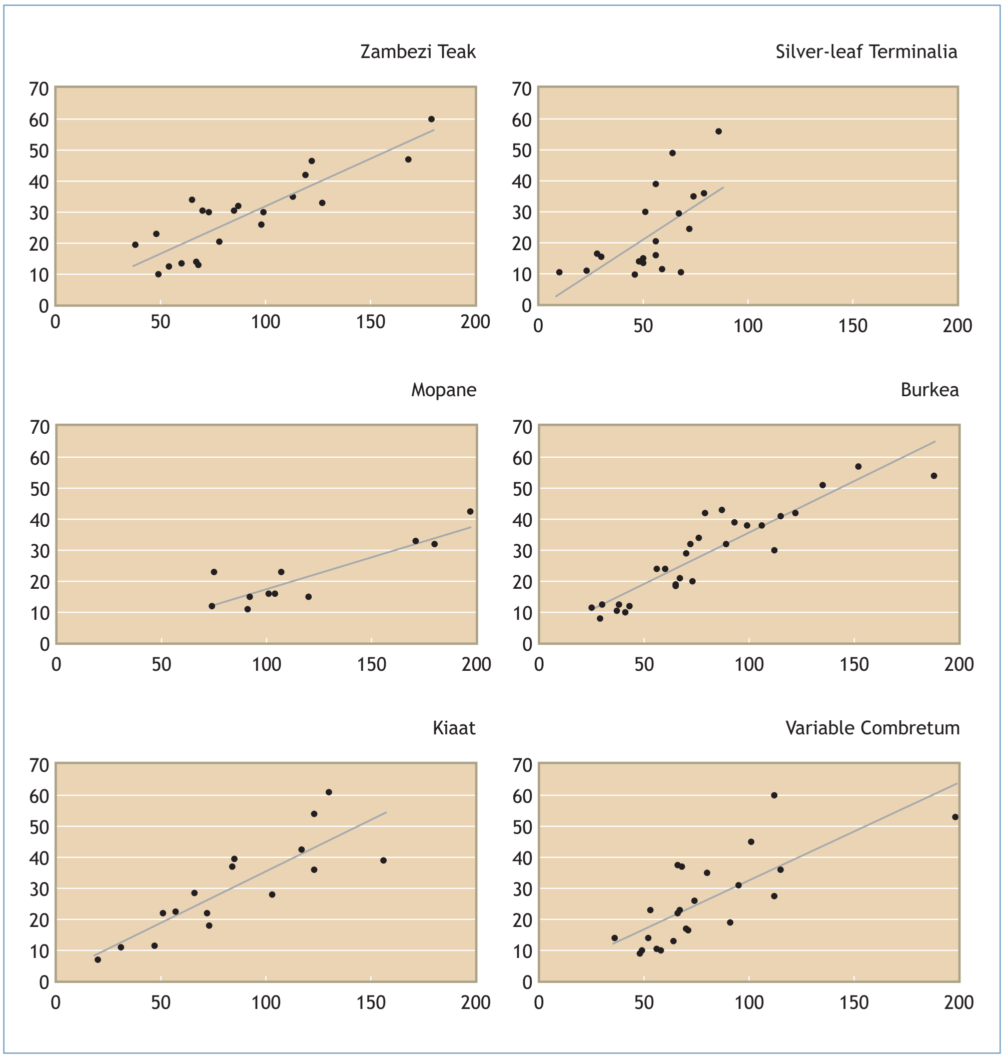


Figure 11. The majority of trees in any area are small, as shown in these graphs for Zambezi Teak, Kiaat, Burkea and Ushivi. The graphs show the percentages of all trees in various inventory areas in different size classes (along the x-axis).[13] The inventory sites are shown on the small map.

cambium cells through which water and nutrients are transported.

That it is difficult for Namibian trees to reproduce is clear. But how their reproduction translates into recruitment – the rate at which new trees are recruited to populations – is much less clear. Perhaps less information is available on this aspect of tree biology in Namibia than on any other quality. The lack of information is particularly troublesome for purposes of woodland management because it is difficult to know whether timber and other tree populations are stable, or whether they are declining or increasing. Using size as a proxy for age, examples of the population age structure of four timber species in the north-east are given in Figure 11. Most populations are characterized by large numbers of

Figure 12. Relationships between the diameter of trees (in centimetres on y-axis) and estimated ages (in years on x-axis) for Zambezi Teak, Silver-leaf Terminalia, Mopane, Burkea, Kiaat and Variable Combretum in Caprivi and north-central Namibia.[14]



thin saplings, and then declining numbers of larger, older trees. This is particularly true for Burkea and Zambezi Teak. By contrast, Kiaat and Ushivi populations have relatively fewer younger trees but more older trees, and so their survival rates might be better than those of the two former, more prolific species.

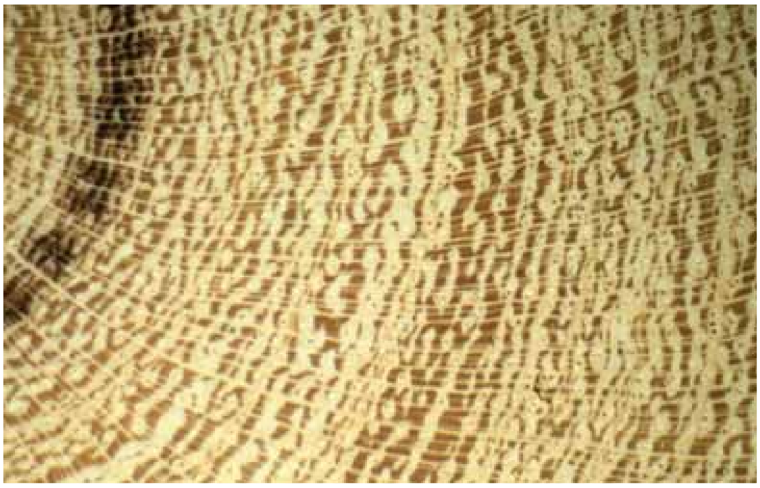
The abundance of small trees suggests that many young individuals are available to grow into larger trees in the years ahead. However, the interpretation of data in Figure 11 is complicated by the fact that the surveys did not distinguish whether trees with thin trunks were indeed young or older, damaged trees that had sprouted new growth. In addition, to be sure that there are enough smaller trees to take the place of larger ones requires information on survival and growth rates. Measuring survival is made particularly difficult by the fact that the environments in which these trees occur are often disturbed severely by sporadic droughts and high-intensity fires. It is also not known if older trees that coppice or sprout new growth (with new thin trunks) can later develop into tall trees that can reproduce and possibly be harvested for timber.

Some estimates of growth rates have been made for several species based on counts of growth rings, which were calibrated to radiocarbon dates (Figure 12). A number of interesting results emerge from these studies. First, many of the biggest trees were aged at between 100 and 200 years old. However, no Silver-leaf Terminalia trees older than 100 years were recorded. Whether they normally die before this age is not known. Second, Zambezi Teak and Kiaat – as potential sources of timber – grew for approximately 130 years before reaching diameters of about 45 centimetres at breast height; roughly the diameter of a trunk that could be harvested to produce sizeable planks. Third, average growth rates varied between the fastest by Silver-leaf Terminalia (0.45 centimetres/year), Burkea and Kiaat (both 0.33), Variable Combretum (0.31), Zambezi Teak (0.30) and the slowest by Mopane (0.21 centimetres/year). Fourth, this study compared growth rates for the same species in Caprivi and north-central Namibia. Those of Zambezi Teak, Silver-leaf Terminalia and Burkea were considerably faster in Caprivi, while Mopane grew more rapidly in the north-central regions. Finally, growth was faster during years of good rain than in drier ones. Perhaps this is one explanation for the variation in growth rates between individuals of the same species. Those with rapid growth might have been lucky in receiving good rains more often than the slower growers.

The considerable ages of larger trees are impressive. Camel Thorns aged between 200 and 400 years old have been found at Tsondab Vlei and in the Kgalagadi Transfrontier National Park near the Namibia/Botswana border. Other noteworthy ages are those of Ushivi trees being about 300 years old and up to 600 years for Welwitchias.[15] The two Welwitschias aged using carbon dating were relatively small and so larger plants could be much older.

WOODLAND AND FOREST RESOURCES

Woodlands and forests can be described and mapped in various ways: in terms of species composition, growth structure, biomass, or relative importance as resources, for example. These measures are explored below, but a useful way to start is to consider the three main landscapes in which Namibian woodlands occur: river valleys, plains, and hills. The landscapes also help us assess vegetation locally because each is characterized by different woodland structures. A look around Windhoek illustrates the point. Such taller trees as Sweet Thorn, Camel Thorn and Buffalo Thorn characterize river valleys; flatter ground is dominated by Black Thorn, while hillsides are largely covered in Yellow-bark Acacias and Kudu Bush.



Tree rings are used to estimate the ages of trees, since each ring corresponds to growth over one year. It is sometimes claimed that rings are unreliable indicators of age in arid environments. To validate their ages, however, the rings can be calibrated against fluctuations of carbon isotopes. Some Camel Thorns at Tsondab and Sossus Vleis have been dead for about 600 years, while others died some 300 years ago.[16]

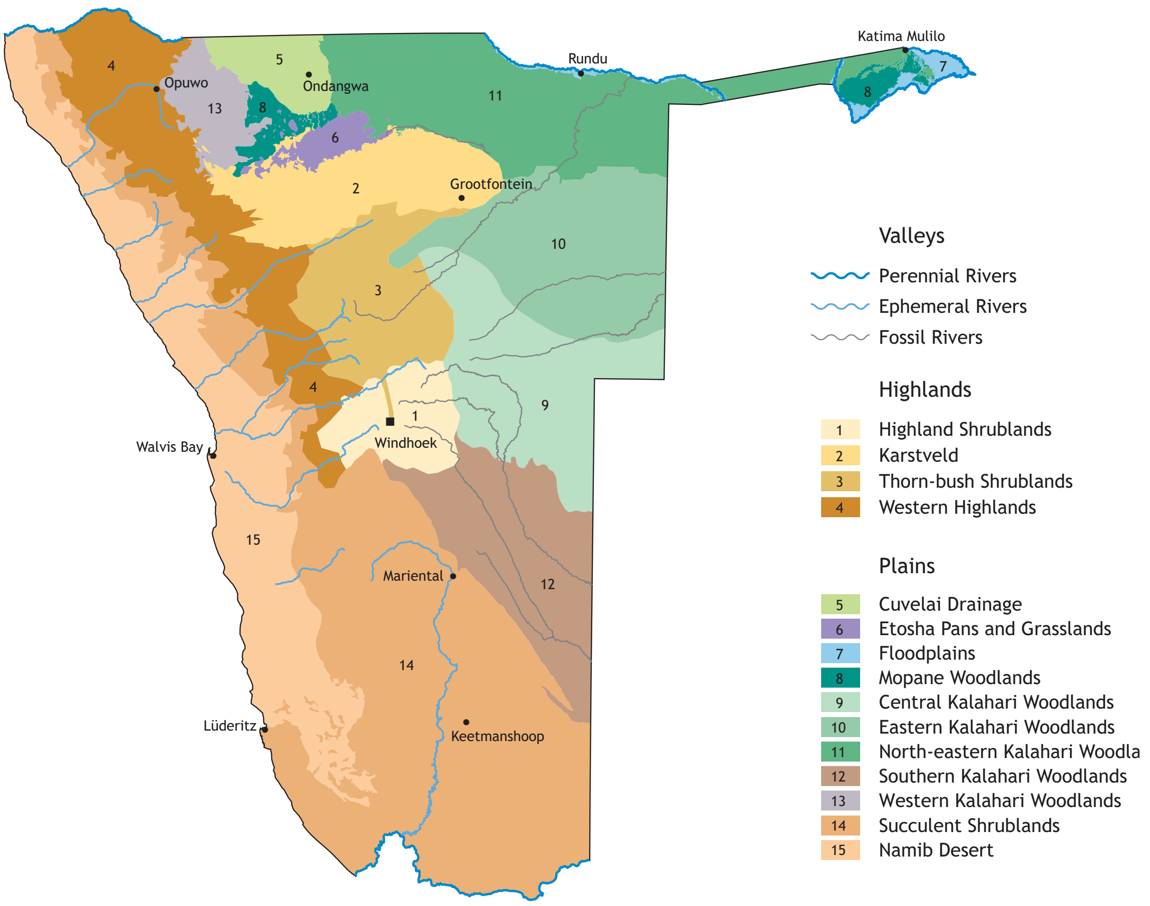


Figure 13. Major types of woodlands grouped into three landscapes.[17]

Woodland types

The three landscapes form the basis for features that characterize woodland types across the country, as shown in Figure 13. River valleys, which include the smallest dry river courses and the large Zambezi and Orange Rivers, form the first landscape. Only the biggest river systems and valleys are shown on the map, but all support woodlands that are taller, denser and different in species composition from those in surrounding areas. Broad-leaved trees form the riparian forests that line the banks of *Perennial Rivers*. In northern Namibia these are often Jackal Berry, Mangosteen, and various Combretum and fig species. Trees fringing the Orange River, on the other hand, are mainly Rhus species, Wild Willows, Wild Tamarisk and Sweet Thorns. *Ephemeral Rivers* and *Fossil Rivers* are dominated by Acacia species, especially Camel and Sweet Thorns. The majority of west-flowing *Ephemeral Rivers* carry water in most years (see page 53), while the *Fossil River* courses that mainly flow east seldom flow because their catchments are largely in sandy areas. Very little surface run-off occurs even after the heaviest falls, and most of the *Fossil River* valleys were carved during much wetter periods long ago.

One might assume that the main feature of all these riverine trees is that they benefit from water carried down the valleys. However, soil depth has an equally important effect in determining the nature of woodlands in river valleys. The Kunene and Orange River largely flow over rocky terrain while the Zambezi, Chobe, Kwando and Okavango Rivers flow across deep sediments in most areas. As a result, these four rivers are largely flanked by floodplains. But it is along *Ephemeral* and *Fossil Rivers* that the effect of soil depth is particularly noticeable. River courses in rocky areas are usually lined with Sweet Thorns, Karee and Namaqua Rock Figs, their roots seeking out cracks in the underlying rocks. By contrast, Camel Thorns, Leadwood, and Ana Trees are most abundant along stretches where deeper sediments have filled in ancient river valleys. Many of the sediments are wind-blown sands. Remarkably, the roots of Camel Thorns have been measured to extend as deep as 40-50 metres where they tap river and rainwater from local falls trapped in the sands. Soils in the lowest stretches of ephemeral rivers are most fertile and deepest because of the accumulation of sediments washed down during sporadic flows. However, water flows are more frequent in the upper reaches, often petering out before reaching the lower stretches of river. Most valleys broaden downstream where they support more expansive riverine woodlands.

The second landscape of hills and mountains is found mainly in the western, rather arid half of Namibia. The majority of trees are sparse and short as a result of the dry conditions, even though the elevated areas may get slightly more rain than nearby lowlands. In addition, hilly areas are generally rocky which means that the soils are extremely shallow and that trees need roots that can penetrate cracks and crevices between the rocks. The western highlands support four woodland types: *Highland Shrublands*, *Karstveld*, *Thorn-Bush Shrublands*, and the *Western Highlands* (Figure 13). Most species are

While few trees grow in southern Namibia, there is an astounding diversity of succulent shrubs, a great many of which occur nowhere else in the world.

The endemic Brandberg Acacia is most abundant around the Brandberg, but also occurs in a narrow belt stretching north-west towards the Kunene River.

thorny, have small leaves, and many are succulents. A high proportion of endemic species are found in the four units, especially so in north-western Namibia where Commiphora species are particularly prominent (see page 49). The only fairly tall and dense woodlands are those on dolomite hills in the eastern parts of the *Karstveld* near Otavi, Grootfontein and Tsumeb. Two significant highlands are isolated from the western belt of rocky, hilly ground. These are the Waterberg and Karas Mountains. Both have tree communities distinct from those on nearby lowland plains.

As the third major landscape, plains characterize four stretches of Namibia. The coastal plain or *Namib Desert* is the first, a very arid strip some 50 to 150 kilometres wide between the Atlantic Ocean and the escarpment. The few woody species in the *Namib Desert* are either small shrubs, including the famous Welwitschia, or larger trees on sand dunes along the eastern flanks of the Namib. The second zone of plains across southern Namibia is also very dry, and most woody plants are consequently dwarf shrubs. With the notable exception of Quiver Trees, most trees are confined to drainage lines. These are the *Succulent Shrublands,* a unit renowned for its very high diversity of endemic dwarf shrubs.

The third stretch of plains extends over much of the southern, eastern and northern parts of Namibia, and continues north and east across much of Angola, Zambia and Botswana. These plains are dominated by Kalahari sand, and five of the woodland units in Figure 13 are found here: *North-eastern Kalahari, Eastern Kalahari, Western Kalahari, Central Kalahari* and *Southern Kalahari Woodlands.* Soil type and rainfall are the major features affecting the structure and species composition of these woodlands. The more rocky, often calcrete, ground along the western margins of the plains is dominated by Acacia species, while broad-leaved species characterize the sands to the east and north. Trees in the northern, wettest parts are taller and denser than anywhere else. Burkea, Zambezi Teak, Kiaat, Ushivi, Variable Combretum and several other Combretum species are the common, well-known trees in the *North-eastern Kalahari Woodlands.* The other units to the west and south are progressively distinguished by shorter and sparser trees of Silver-leaf Terminalia, Shepherd's Tree and various Acacias.

The fourth zone of plains consists of two wetlands, one in the north-east and the other in north-central Namibia. Freshwater *Floodplains* cover much of the area between the Zambezi and Chobe Rivers, and also form wide margins to the Kwando/Linyanti and Okavango Rivers. A large part of eastern Caprivi is *Mopane Woodlands* growing on clayey soils that were wetlands perhaps 50,000 years ago. Another area of *Mopane Woodlands* in north-central Namibia likewise grows on soils formed in a wetland long ago. Mopane is also a very common species in the *Cuvelai Drainage,* which is characterized by a network of grassy oshana channels that carry floodwater from heavy local rains and from higher areas to the north in Angola. Very high flows of water in the oshanas reach the Etosha Pan, where the water evaporates to leave a salty substrate on which no woody plants grow. The pan and surrounding areas form the *Etosha Pans and Grasslands.* Soils in the grasslands are salty too, and support few trees.

Diversity of woodlands

The first part of this chapter describes the environmental factors that influence the distribution and abundance of trees. The combined effect of all these factors is that the kinds of woody plants (of which

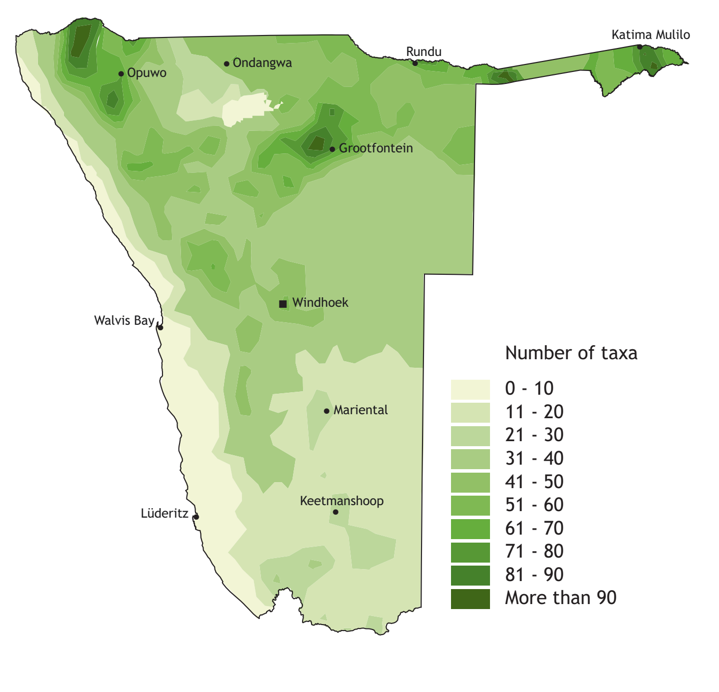
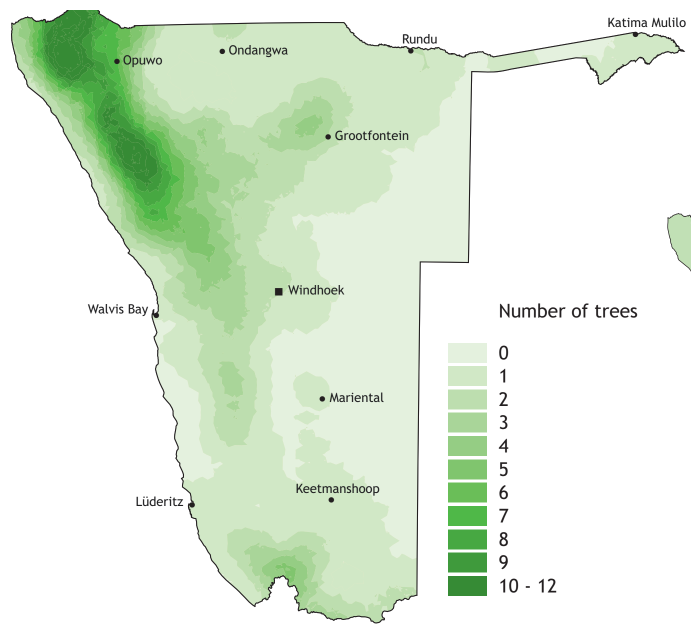
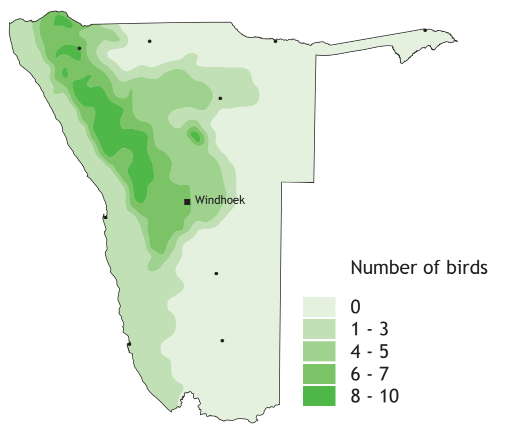
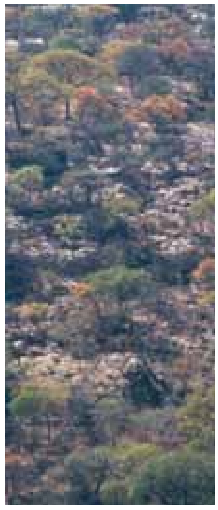


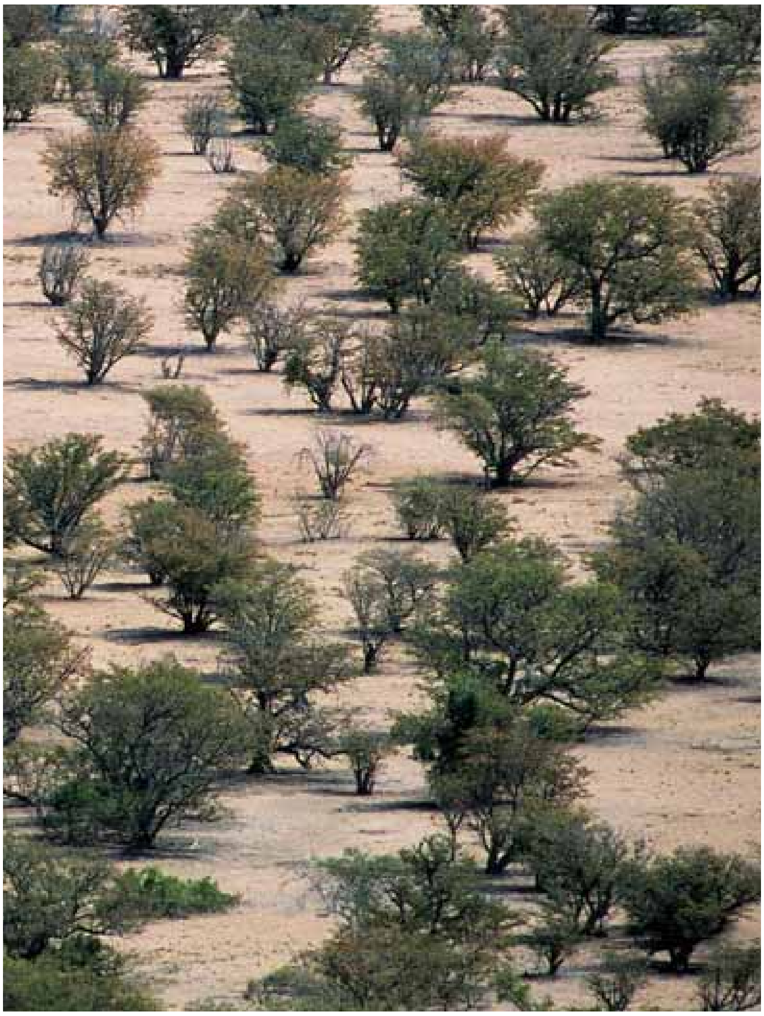
Figure 14.
The diversity of trees in Namibia, as shown by the average number of species and subspecies of trees recorded throughout the country. The map was generated from data collected by the Namibian Tree Atlas project.[18] Coverage was extensive but in all such projects the more field observations are made, the more species are usually recorded. The number of species is therefore conservative, and most areas are likely to have slightly more species than now shown on the map.

Figure 15.
The distribution and abundance of endemic trees and birds.[19]

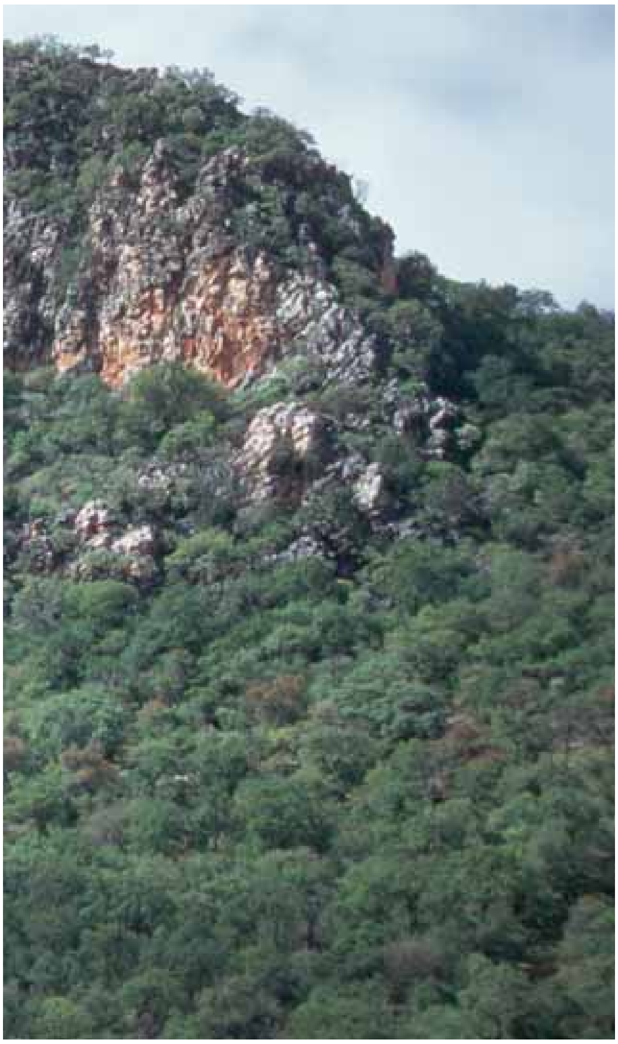








A first selection of types of forests and woodlands in Namibia as shown in Figure 13. To the left, Mopane Woodlands, *below a scene over the* Cuvelai Drainage*, and from left to right at the bottom: forest fringes on a* Perennial River, *dense woodland along an* Ephemeral River, North-eastern Kalahari Woodlands, Highland Shrublands, *and plains on the eastern margin of the* Namib Desert.



More diversity of forests and woodlands, from top left to right: sand dunes in the Namib Desert, Thorn-bush Shrublands *beneath the Omatako Hills, the* Etosha Pan and Grasslands, *shrubby growth form of* Mopane Woodland. *Dense woodland on hills in the* Karstveld *(bottom left) and a broad valley in the* Western Highlands *(below).*

there are about 400 species and subspecies, collectively called taxa) are very unevenly spread as indicated in Figure 14. Readers interested in more information should consult the *Tree Atlas of Namibia*.[20] There are four 'hot spots' where more than 90 taxa occur: in the north-western highlands south of the Kunene River, in the dolomite hills around Otavi, Tsumeb and Grootfontein, along the Okavango River near Bagani and the Mahango Game Reserve, and south-east of Katima Mulilo near the Bukalo, Sikanjabuka and Zilitene Community Forests (see page 93). The lowest number of species is in southern and western Namibia, and in Etosha Pan where there are no trees.

The ranges of most trees stretch beyond our borders. However, the distributions of 80 taxa are very largely confined to Namibia, and their conservation is thus mainly our responsibility. These are called endemics, and the great majority occur in north-western Namibia (Figure 15) where they grow on rocky highlands. Some of the species extend into similar habitats across the Kunene River in southern Angola, and also across the Orange River into South Africa. It is interesting that the distribution of endemic trees and birds is so similar, suggesting that endemic species in both groups evolved at similar times and for comparable reasons.

The 80 species, subspecies and varieties that are endemic to Namibia.[21] Most do not have well-known common names.

Acacia montis-usti	*Commiphora saxicola*	*Heteromorpha papillosa*
Acacia robynsiana	*Commiphora virgata*	*Kirkia dewinteri*
Adenia pechuelii	*Commiphora wildii*	*Lycium grandicalyx*
Aloe pillansii	*Cyphostemma bainesii*	*Maerua gilgii*
Aloe ramosissima	*Cyphostemma currorii*	*Manuleopsis dinteri*
Balanites angolensis subsp. *welwitschii*	*Cyphostemma juttae*	*Moringa ovalifolia*
Boscia microphylla	*Cyphostemma uter*	*Neoluederitzia sericeocarpa*
Cadaba schroeppelii	*Didelta spinosa*	*Obetia carruthersiana*
Caesalpinia merxmuellerana	*Diospyros acocksii*	*Ozoroa concolor*
Caesalpinia pearsonii	*Ectadium latifolium*	*Ozoroa dispar*
Caesalpinia rubra	*Ectadium rotundifolium*	*Ozoroa namaensis*
Ceraria fruticulosa	*Ectadium virgatum*	*Ozoroa okavangensis*
Ceraria longipedunculata	*Ehretia namibiensis* subsp. *kaokoensis*	*Ozoroa schinzii*
Ceraria namaquensis	*Elephantorrhiza rangei*	*Pachypodium lealii*
Combretum wattii	*Elephantorrhiza schinziana*	*Pachypodium namaquanum*
Commiphora anacardiifolia	*Entandrophragma spicatum*	*Rhigozum virgatum*
Commiphora capensis	*Erythrina decora*	*Rhus volkii*
Commiphora cervifolia	*Erythrophysa alata*	*Salsola arborea*
Commiphora crenato-serrata	*Erythroxylum zambesiacum*	*Sesamothamnus benguellensis*
Commiphora dinteri	*Euclea asperrima*	*Sesamothamnus guerichii*
Commiphora discolor	*Euphorbia congestiflora*	*Sesamothamnus leistneri*
Commiphora giessii	*Euphorbia damarana*	*Strophanthus amboensis*
Commiphora glaucescens	*Euphorbia eduardoi*	*Turnera oculata* variety *oculata* and *paucipilosa*
Commiphora gracilifrondosa	*Euphorbia monteiroi* subsp. *brandbergensis*	*Welwitschia mirabilis*
Commiphora krauseliana	*Euphorbia venenata*	
Commiphora multijuga	*Euphorbia virosa virosa*	
Commiphora namaensis	*Grewia olukondae*	
Commiphora oblanceolata	*Haematoxylum dinteri*	

Sixteen of the endemic tree species belong to the genus Commiphora. This is one of the most diverse genera in Namibia, with a total of 26 Commiphora taxa in the country. There are also 29 Acacia taxa and 19 Combretum species and subspecies. The diversity of taxa in these three genera is shown in Figure 16. Commiphoras are mainly found in north-western Namibia; this at least partly reflects their preference for arid areas and there is another centre of diversity of Commiphoras in north-eastern Africa. Acacia taxa are more widespread, with pockets of high diversity south of Opuwo, around Otjiwarongo, Otavi, Tsumeb and Grootfontein, and east of Etosha Pan. Combretums are more tropical and the majority of Namibian taxa occur in the wettest areas of the north-east.

The abundance of wood

What wood resources does Namibia have, where are they, and what do they amount to? Some first answers to these questions come from the approximation of tree cover in Figure 17. The darkest areas, with the highest wood biomass, have more than 40 cubic metres of wood per hectare. By complete contrast, Etosha Pan, much of the Namib Desert and many parts of southern Namibia have little or no wood. Areas with a high wood biomass often provide the best habitats for animals that browse or depend on trees in other ways. They also offer more fuel wood and poles for building rural homes, and in some areas also good quality timber for furniture. The table on page 51 shows estimates of average wood biomass collected by the National Forest Inventory Project at 23 sites, mainly in northern Namibia. A total of about 15,3 million hectares was covered by the inventories.

Harvestable Zambezi Teak is very largely confined to the Caprivi State Forest, where volumes of 2.7 cubic metres/hectare have been estimated. However, these are rapidly being decimated by frequent fires (see page 107). Other timber species are more widely and sparsely distributed at less than 0.3 cubic metres/hectare for Kiaat, and less than 0.2 cubic metres/hectare for Ushivi and Burkea. From estimates of total wood volumes and the proportion that might be used for timber in each region, there might be about 2.5 million Zambezi Teak and Kiaat trees suitable for furniture-quality timber in Namibia. At an average of about 0.8 cubic metres of timber per tree, all these trees amount to a standing stock of just over 2 million cubic metres of timber.[22]

While most timber resources are in north-east Namibia, their distribution in those regions is patchy. The patches are often small and limited to places where soils and perhaps other environmental conditions are most conducive to the growth of Zambezi Teak, Kiaat and Ushivi trees. An example of this patchiness is given in Figure 19. The map is based on an interpretation of satellite images to highlight

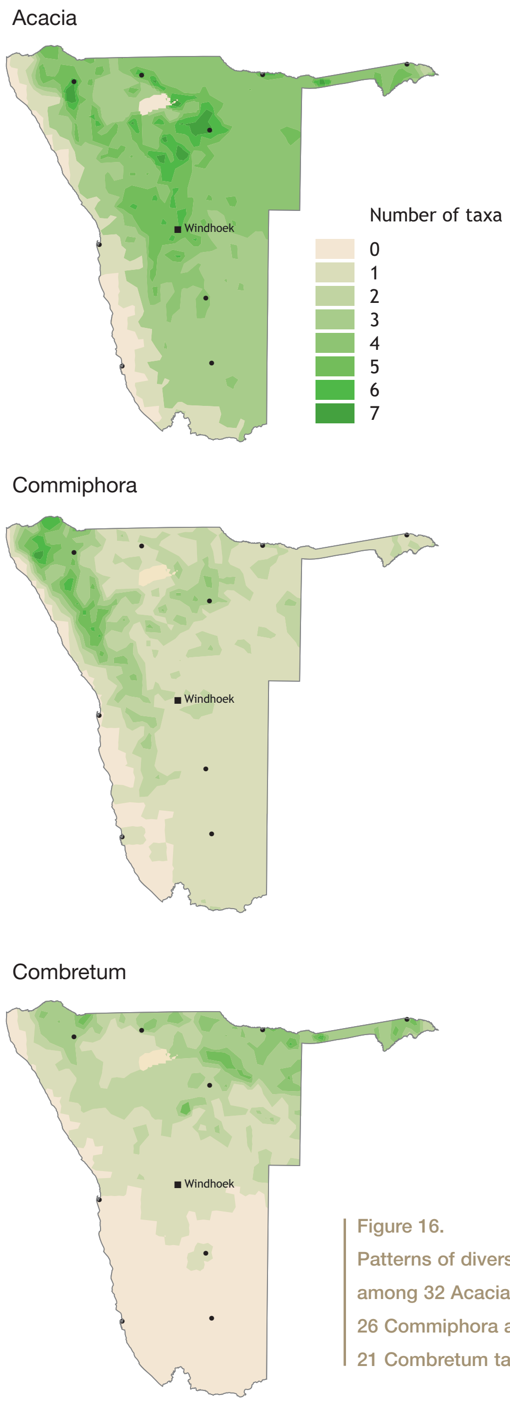


Figure 16. Patterns of diversity among 32 Acacia, 26 Commiphora and 21 Combretum taxa.[23]

Figure 17.
The biomass of wood varies greatly, from the highest volumes in the north-east to the lowest in the west and south where there are few trees.[24]

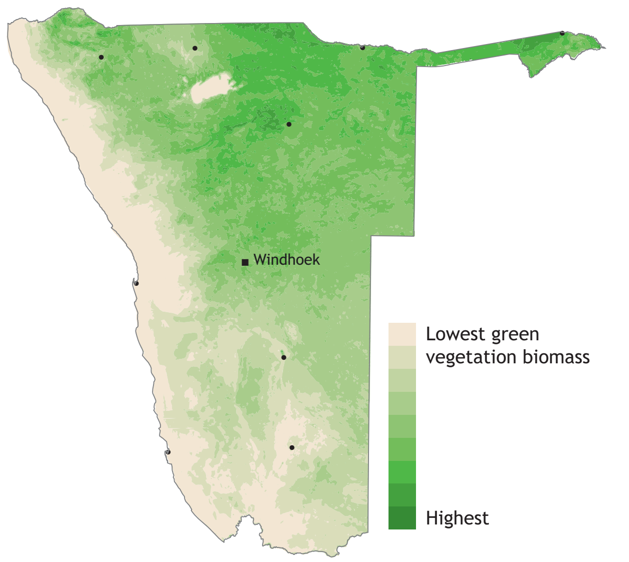
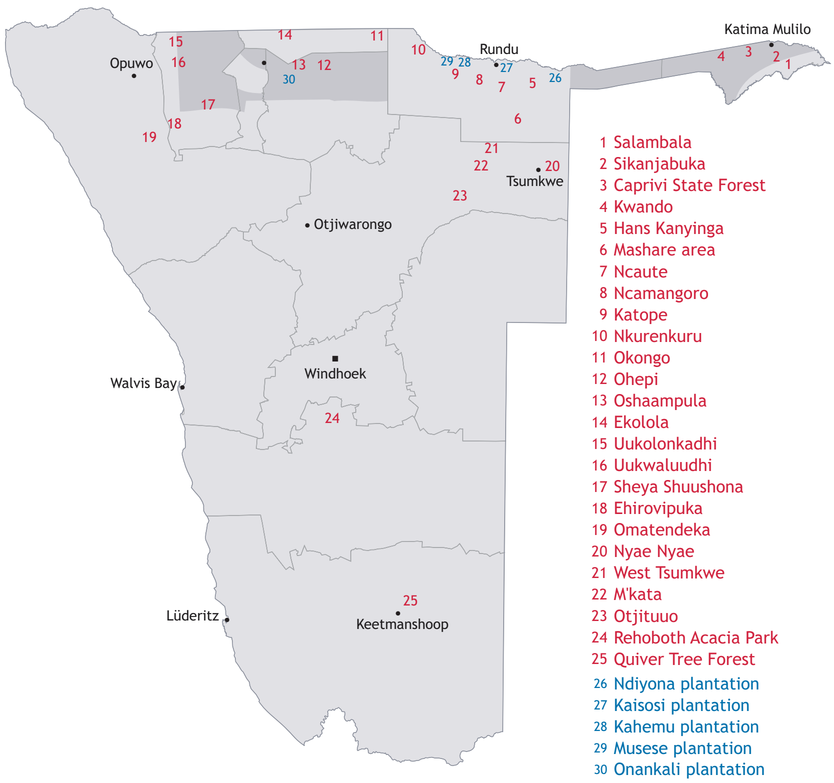


Figure 18.
Places at which inventories were conducted over the past eight years. In addition to the inventory sites and areas listed in the next table, regional inventories were conducted over large areas in Caprivi (16,479 km^2), Omusati (13,839 km^2), Oshana (2,597 km^2), Oshikoto (16,464 km^2) and Otjozondjupa (88,203 km^2).



Estimates of wood and timber biomass.[25] Timber is limited to Zambezi Teak, Kiaat, Ushivi and Burkea trees with diameters at breast height of more than 45 centimetres and straight trunks longer than 2 metres.

Location	Region	Area (square kilometres)	Wood biomass (cubic metres per hectare)	Timber biomass (cubic metres per hectare)	Percentage timber of all wood
Salambala Conservancy	Caprivi	84	18.0	0.00	0.0%
Sikanjabuka Community Forest	Caprivi	49	52.0	0.00	0.0%
Caprivi State Forest	Caprivi	1,461	33.3	2.99	9.0%
Kwando Community Forest	Caprivi	199	23.1	0.74	3.2%
Rehoboth Acacia Park	Hardap	87	9.7	-	-
Nkurenkuru Concession Area 1	Kavango	56	48.0	0.56	1.1%
Nkurenkuru Concession Area 1	Kavango	122	33.4	0.78	2.3%
Hans Kanyinga Community Forest	Kavango	121	40.4	0.35	0.9%
Mashare area	Kavango	1,863	22.6	0.28	1.2%
Ncaute Community Forest	Kavango	119	32.7	0.26	0.8%
Ngamangoro Community Forest	Kavango	219	32.0	0.15	0.5%
Katope Community Forest	Kavango	38	24.4	0.74	0.9%
Omatendeka Community Forest	Kunene	1,212	4.0	0.00	0.0%
Okongo Community Forest	Ohangwena	559	43.2	0.19	0.4%
Ekolola Community Forest	Ohangwena	6	43.8	-	-
Sheya Shuushona Community Forest	Omusati	1,282	1.1	0.00	0.0%
Ehirovipuka Community Forest	Omusati	785	3.6	0.00	0.0%
Uukwaluudhi Community Forest	Omusati	825	6.3	0.00	0.0%
Uukolonkadhi Community Forest	Omusati	830	14.3	0.00	0.0%
Ohepi Community Forest	Oshikoto	52	28.0	-	-
Oshaampula Community Forest	Oshikoto	7	20.8	-	-
Nyae Nyae area	Otjozondjupa	1,412	19.9	0.00	0.0%
M'kata pilot forest area	Otjozondjupa	11	14.6	0.25	1.7%
West Tsumkwe area	Otjozondjupa	6,079	17.8	0.3	1.7%
Otjituuo forest area	Otjozondjupa	694	1.6	0.03	2.0%

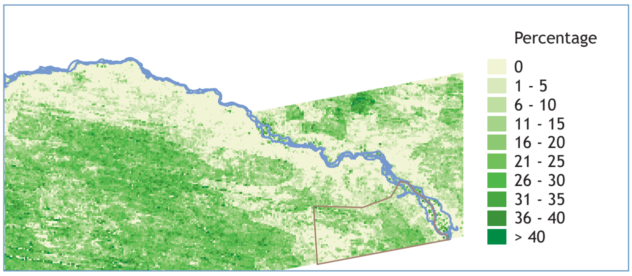


Figure 19.
Tree cover as a proxy for wood and perhaps timber biomass in the Mukwe area of the Kavango Region. Note that along the river, much of the woodland has been cleared.[26]

varying levels of tree cover as an approximation of tree density. Areas of high tree cover may, or may not, be those with the greatest timber biomass, and more work on the ground would be required to investigate whether the clumps of dense tree cover are timber or other species.

SOME IMPORTANT FORESTS AND WOODLANDS

To list and describe 'important' forests and woodlands is a difficult, but worthwhile task. Difficult, because choices must be made using value systems that may be somewhat arbitrary and temporary. What is valued today is different from what was important 100 years ago, and might differ from resources considered essential 50 years from now. But the task is worthwhile because there are areas of woodland and forest with resources that need to be highlighted specially. This brief account does not claim to document all significant forests and woodlands in Namibia. Rather, it serves to illustrate the presence of forests and woodlands about which Namibians should be concerned. It also builds on the concept of Important Plant Areas and Environmentally Strategic Forests promoted by the National Botanical Research Institute in Windhoek and Directorate of Forestry, respectively. Strategic Forests are areas judged to be important in terms of biodiversity, socio-economic and river catchment values, and where 'the management of forests will mainly produce environmental public goods and external benefits'.[27] The order in which the areas are described does not imply any judgment of importance.

North-eastern Broad-leaved Woodlands harbour the greatest resources of wood and timber in the country. They also support a high diversity of species and animals associated with trees. Dominant and characteristic species are Burkea, Kiaat, Zambezi Teak, Silver-leaf Terminalia, Camel Thorn, and several Combretum species (see Figure 16). The whole area encompasses the *North-eastern Kalahari* and *Eastern Kalahari Woodland* units mapped in Figure 13 and lies on Kalahari sands, which are poorly suited to crop cultivation. Relatively few people live in the woodlands as a result, and only small areas of trees have been cleared. Frequent fires have resulted in the loss of many trees, particularly in the Caprivi Game Park and Caprivi State Forest (see page 111). The woodlands contain the great majority of Namibia's good quality timber.

Much of Namibia would be more devoid of life were it not for the linear oases formed by *Ephemeral Riverine Woodlands*, ribbons of trees that enable many animals and people to live in areas where they would otherwise not be able to subsist. The leaves and pods of such species as Ana Trees, Camel Thorns and Sweet Thorns provide forage of high nutritional value to livestock and wildlife, particularly because there is little to eat in the surrounding dry landscape. In this respect, the biggest, most significant ephemeral riverine woodlands are in arid areas in the south (the Fish, Löwen, Konkiep, Gamseb, Auob and Nossob Rivers, for example) and west (from north to south: Khumib, Hoanib, Hoarusib, Huab, Uniab, Ugab, Omaruru, Khan, Swakop, Kuiseb, Tsondab and Tsauchab). The Omatako, Eiseb, Epukiro, Nossob and Auob Rivers and are important lifelines in eastern Namibia.

The biggest threats to woodlands along ephemeral rivers are the damming of water in upstream tributaries and water abstraction. Both damming and abstraction reduce the availability of water to trees, largely by causing the water table in the underlying sediments to drop. Ana Trees are particularly affected. These effects are usually felt after successive dry years in which there are no flows (Figure 20). Another major threat to riverine woodlands is heavy browsing pressure, especially on young trees, which results in low rates of regeneration and recruitment.

Two forests along ephemeral rivers are frequently noted as having special value. These are the *Rehoboth* and *Tsumis Camel Thorn Forests* where there are very large numbers of old and tall Camel Thorns. Respectively, the two forests lie along stretches of deep sands in the Oanob and Tsumis Rivers.

There are two zones of Mopane woodland in

Namibia: one in Caprivi and the other to the west where it forms the *North-central Mopane Woodlands*. The particular value of these large stands of Mopane trees and shrubs lies in the resources they provide to the many people living there. Of greatest value is wood for cooking fuel, poles for building homes, branches and brush for fencing, browse for goats and cattle, and Mopane worms for food. Taller trees predominate in the northern areas of this zone, while the southern area is characterized by large expanses of Mopane shrubs. Most tall trees have been cut in many areas, but Mopane fortunately coppices and many people now only harvest new growth.

Riparian Forest lines the banks of permanent rivers. The Orange and Kunene rivers have relatively narrow fringes of forest consisting of a few species. Wild Willow, Sweet Thorn, Wild Ebony and Orange River Karee characterize those along the Orange River while riparian woodlands along the Kunene are dominated by Mopane, Ana Trees, Jackal Berry and Makalani Palms. Riparian forests in north-eastern Namibia, by contrast, are comprised of a much greater variety of dense trees, many of them tall and luxuriant. They form the most biologically diverse habitat in the country, and thus provide food and refuge to many different animal species. Only small patches of riparian forests remain along the Okavango River because most have been cleared for farming or, in the Mahango Game Reserve, damaged by elephants. The main species are Mangosteen, Sycamore Fig, Jackal Berry, Marula and Mukondekonde.

The forests along the Kwando River are in good condition but increasing elephant numbers pose a threat. Knob-thorn, Camel Thorn, Sycamore Fig, Apple-leaf, Mangosteen, Umbrella Thorn, Sickle-leaved Albizia and Purple-pod Terminalia are dominant species. There are few forests along most of the Zambezi River, especially downstream of Schuckmannsburg where floodplains line the river. Woodlands on moist soils close to the river and on islands in the east Caprivi floodplains are dominated by Water Pear, River Rhus and Jackal Berry, while on drier soils Mobola Plum, Sausage Tree, Camel Thorn, Knob-thorn, Apple-leaf, Natal Mahogany and Musese are characteristic. Maningimanzi, just east of Katima Mulilo, is a special zone of woodlands growing on sands around old river channels which flood when the Zambezi is high. Here the dominant trees are Silver-leaf Terminalia, Musese, Burkea and Mupako on the sands, and Water Pear, River Rhus, Natal Mahogany, Mangosteen, Pod Mahogany and Sausage Tree on the clay soils closer to the channels.

PLANTATIONS AND EXOTIC TREES

This chapter has been concerned with indigenous forests and woodlands, but many exotic trees have

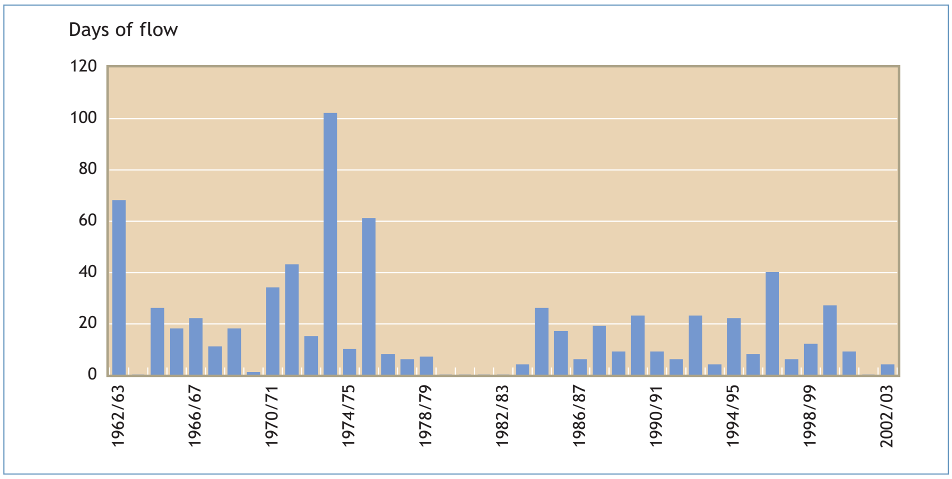


Figure 20.
Water flows down ephemeral rivers are highly variable, as shown by the number of days on which the Kuiseb River flowed at Gobabeb each year. Years of frequent flow lead to the germination and survival of young trees, while successive years in which there is no flow cause water tables to drop and trees to die.[28]

An inventory of Rehoboth Acacia Park revealed there to be about 75,000 Camel Thorns in an area of 8,732 hectares. The average height of the trees was 10.6 metres.[29]

also been introduced to Namibia. Some were planted deliberately and remain in plantations, gardens and orchards, while others have become feral and potentially invasive. The earliest introductions could have been in the 1500s, when Wild Tobacco may have been traded and spread south from West Africa. However, more systematic efforts to introduce trees began in the late 1800s when the German administration started to grow trees experimentally. Up until the end of the German rule in 1915, some 201 different trees had been tried, 23 of them indigenous to Namibia. Trials for Casuarinas started in 1892, while 28 varieties of Eucalypts were planted in 1894 alone. A plantation for Date Palms was started at Ukuib in 1901, and the first Prosopis were planted in 1905.

Fifteen plantations, covering a total area of about 300 hectares, have been established in Namibia.[30] Most of these cover just a few hectares and were intended more as experiments than as plantations to produce timber. Figures on accumulated Eucalyptus wood stocks are available for five of the plantations: Onankali 10 m^3/hectare, established in 1976; Kaisosi 23 m^3/hectare, established in 1979; Kehemu 59 m^3/hectare, established in 1987; Ndiyona 77 m^3/hectare, established in 1975; and Musese 128 m^3/hectare, established in 1967 (see Figure 18 on page 50).[31] The estimates were made at roughly the same time (in 1999 and 2001), which means that the wide variation in growth is probably related more to the productive potential of the sites than to the age of the plantations. These rates of growth and production are also extremely low. For example, a general rule of thumb applied in South Africa is that commercial forests should produce at least 12 cubic metres (m^3) per hectare each year if they are to be viable.[32]

Casuarinas and Sausage Trees are being grown at Siya, west of Rundu, but most plantations consist largely of Eucalypts. A wide range of species and varieties of these Australian trees have been tried, but none have grown well. Also, in the absence of any new information or prospects, it remains unlikely that Eucalypts will be grown successfully in Namibia, and perhaps so for two reasons: the low and erratic rainfall, and the generally poor quality soils. Moreover, any efforts to produce wood efficiently would require a great deal more maintenance (thinning, weeding, pest control and watering) than has been given to plantations recently.[33]

From a conservation point of view, strong arguments against planting alien trees are also often made, mainly to guard against the possible spread of invasive species and to preserve indigenous habitats. In this respect, the Directorate of Forestry is often criticized for promoting the propagation of exotic species. Some of these are known to be potentially invasive, for example Mango and Guava. However, many people – including senior and influential political leaders – are less concerned with potential environmental problems and advocate that much more afforestation should occur in Namibia. Clearly, there is a need to grow trees for fruit, fuel and construction wood, but the short and long-term advantages and disadvantages of all such efforts need to be assessed carefully before implementation.

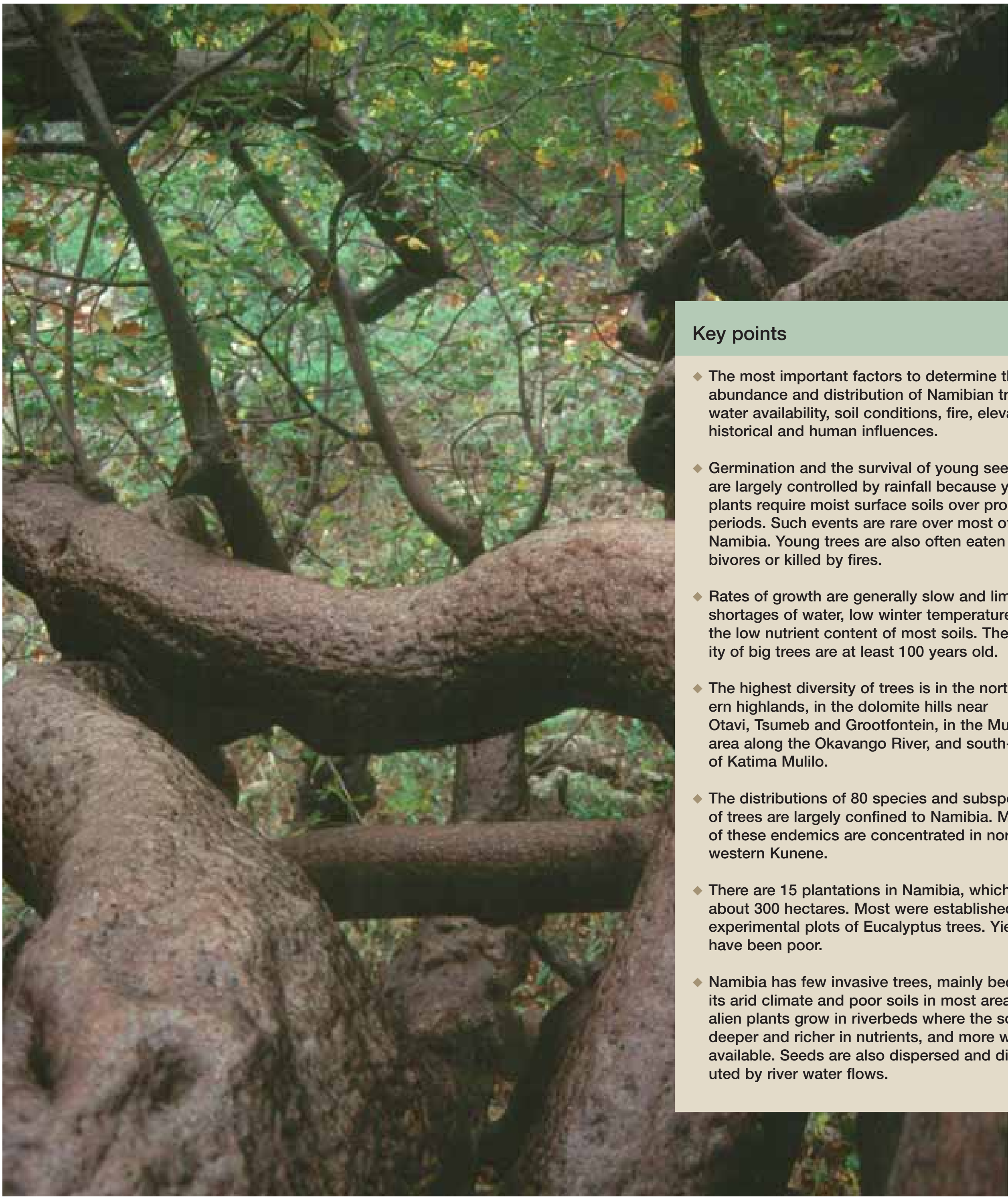
Compared to many other countries with wetter climates, Namibia has few invasive alien plants. This is because of the generally low, variable rainfall and poor soils in most areas. As a result, most alien plants in Namibia grow in riverbeds where the soils are deeper and richer in nutrients, and more water is available. Seeds are also dispersed and distributed by river water flows. A recent review of aliens lists six tree species as invasive.[34] Three are species of Prosopis, which are collectively considered to be the most important and well-known invasive plants. However, little information is available on their impacts on indigenous habitats. They may displace and prevent other trees, such as Ana Trees and Camel Thorns, from growing along ephemeral rivers, and they may reduce flooding and lower groundwater levels. Although Prosopis are widespread, they are really only abundant along certain rivers and tributaries, notably those in the Swakop, Nossob and Auob river systems. Prosopis also provide valuable fuel wood, shade and fodder in many more arid areas where these resources are scarce. The other tree species listed as invasive aliens are Syringa (growing wild in a few places along the Omatako Omuramba), Wonderboom (largely restricted to disturbed areas in towns), and Wild Tobacco (which are widespread in towns and along rivers in the western half of the country).

Unlike other stretches of the Okavango River, the forested areas on islands near Andara remain pristine because people cannot easily reach the islands and many are holy burial grounds for Mbukushu chiefs.

In addition to the availability of water, soils and nutrients, several other factors influence the occurrence of invasive aliens. These are the absence of natural enemies, the activities of people in translocating plants and altering habitats (many exotic trees grow on cleared land), a lack of awareness, and the absence of legal controls and policies to prevent the introduction and spread of exotic species that could be invasive. There are also a number of characteristics that predispose certain species to being potentially more invasive than others. These features include high rates of seed production and plant growth and the ability to tolerate a wide variety of environmental conditions.

In summary, invasive alien trees are rather localized in Namibia, largely as a result of aridity and the absence of suitable soils in most areas. However, there is need for policy, legislation and vigilance to ensure that invasive species do not become a problem, especially in the northern areas where rainfall and soil conditions are best suited to the growth of exotic species. This, of course, is also where Namibia's most valuable indigenous woodland resources are concentrated.

Images and values provided by a Namibian Resin Tree on a ridge in the Brandberg (top) are very different from those offered by a copse of Prosopis along a road near Windhoek (below). The Resin Tree adds majesty and beauty to a rugged, unspoiled landscape, while the Prosopis trees offer valuable fodder and fuel wood, and possible threats to other natural resources.



Key points

- The most important factors to determine the abundance and distribution of Namibian trees are: water availability, soil conditions, fire, elevations, historical and human influences.
- Germination and the survival of young seedlings are largely controlled by rainfall because young plants require moist surface soils over prolonged periods. Such events are rare over most of Namibia. Young trees are also often eaten by herbivores or killed by fires.
- Rates of growth are generally slow and limited by shortages of water, low winter temperatures and the low nutrient content of most soils. The majority of big trees are at least 100 years old.
- The highest diversity of trees is in the north-western highlands, in the dolomite hills near Otavi, Tsumeb and Grootfontein, in the Mukwe area along the Okavango River, and south-east of Katima Mulilo.
- The distributions of 80 species and subspecies of trees are largely confined to Namibia. Most of these endemics are concentrated in north-western Kunene.
- There are 15 plantations in Namibia, which cover about 300 hectares. Most were established as experimental plots of Eucalyptus trees. Yields have been poor.
- Namibia has few invasive trees, mainly because of its arid climate and poor soils in most areas. Most alien plants grow in riverbeds where the soils are deeper and richer in nutrients, and more water is available. Seeds are also dispersed and distributed by river water flows.