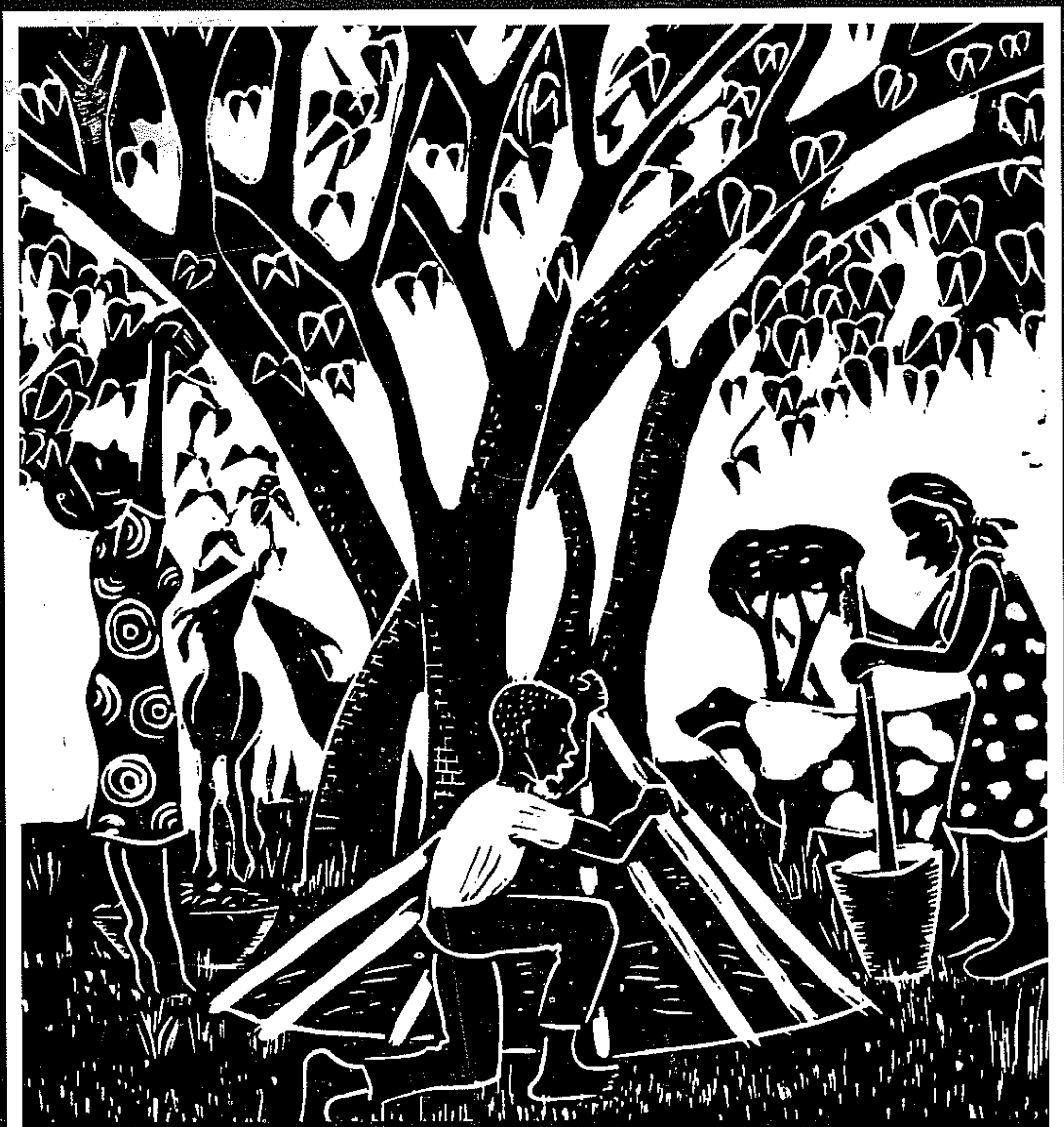
Management of Mopane in Southern Africa

Proceedings of a workshop held at Ogongo Agricultural College, northern Namibia, 26th to 29th November 1996



Edited by Charlotte Flower, Grant Wardell-Johnson and Andrew Jamieson

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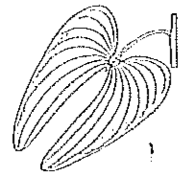
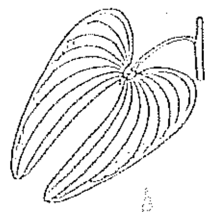
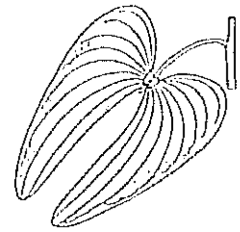




CHAPTER ONE

A REVIEW OF THE ECOLOGY AND MANAGEMENT OF *COLOPHOSPERMUM MOPANE*



Jonathan Timberlake [a]

ABSTRACT

Colophospermum mopane (mopane) is a well-known Caesalpinioid tree or shrub, locally dominant in savanna woodlands of the main river basins of sub-tropical southern Africa. It ranges from southern Angola and northern Namibia, through Botswana, Zimbabwe and southern Zambia to southern Malawi, Moçambique and northern South Africa, being found from 200 to 1,200 m in altitude. The major economic uses of the species are production of good quality firewood, termite-resistant rough construction timber, dry season browse and as a food plant for mopane worms. In addition, it can survive well on soils occupied by few other tree species. One of the main characteristics of mopane is that it can form almost mono-specific stands comprising trees of comparatively even size, especially on eutrophic clay-rich soils. These relatively uniform stands lend themselves well to silvicultural management. However, there appears to have been very little management experience with the species, despite its ecological and economic importance. This paper reviews current knowledge of the ecology and potential for management of mopane. Areas of priority for future investigation are also examined.

Key-words; *Colophospermum mopane*, ecology, distribution, management, productivity, uses.

INTRODUCTION

There has been increasing interest in the ecology and management of indigenous trees throughout Sub-Saharan Africa over the last 20 years (e.g. Piearce and Gumbo 1993, Clarke 1994), but unfortunately the rate of increase in interest appears to be exceeding the rate of increase in our knowledge. Sound management has to be based on sound knowledge, but this is often inadequate. In addition, much of what is known is scattered in obscure journals or in the "grey" literature, and much effort is needed to access it. Too often scientists and development workers are "re-inventing the wheel" because available information has not been fully compiled and evaluated; a luxury we can ill-afford given present severe budgetary and manpower constraints.

Colophospermum mopane (Kirk ex Benth.) Kirk ex J. Léonard, better known as mopane, is a Caesalpinioid tree or shrub species which has evoked considerable interest since the early years of this century (e.g. Timberlake and Crockford 1994). It dominates much of the vegetation in the lower-lying river basins of sub-tropical southern Africa, and often occurs naturally in stands more amenable to standard silvicultural practices than most species. The information available on mopane has recently been reviewed (Timberlake 1995). However, despite being extensively mentioned in the southern African literature, surprisingly little has been recorded on its productivity, growth rate, establishment, regeneration and response to cutting. Such information is vital for any management programme.

This paper summarizes the major characteristics of mopane with particular reference to its potential for management. Areas of priority for future investigation are suggested. It is based on a previous presentation (Timberlake 1996), to be published elsewhere.

BOTANY

Description

Colophospermum mopane is the only species in the genus *Colophospermum*, which belongs to the Detarieae tribe of the sub-family Caesalpinioideae of the Leguminosae or Fabaceae (Lock 1989). A recent revision (F. Breteler[1], pers. comm., 1997), however, suggests it should be placed together with the Indian genus *Hardwickia*. Mopane is a small to medium-sized tree 5 - 12 (20) m high with an erect narrow crown, although it often occurs as a shrub 1 - 2 m high (Palmer and Pitman 1972, Ross 1977, Coates Palgrave 1983). The normal diameter of a mature trunk at 1.3 m is 40 - 70 cm, although a diameter of 122 cm has been noted in Liwonde National Park in Malawi (C. Dudley[2], pers. comm., 1996).

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[1] F. Breteler, University of Wageningen
[2] C. Dudley, Liwonde National Park

The leaves are distinctive, consisting of two large triangular leathery leaflets, sometimes likened to butterfly wings. They appear soon after the first soaking rains, when they are reddish-brown and glossy, but fall some time into the dry season, the time apparently determined by soil moisture status and, of course, wind and exposure. Trees are generally leafless from August to October.

The inconspicuous flowers appear from December to March after the appearance of leaves, while the distinctive kidney-shaped flat papery pods ripen around May. The flattened seeds have numerous reddish glands on them containing a resin, which may assist in ant dispersal (Ross 1977). However, seed dispersal appears to be primarily by wind (Jarman and Thomas 1969).

Physiology

Some work has been done on the physiology of mopane, notably that by Henning (1976) and that done under the Southern African Wood Studies Project, reported on by Prior (1991). More recently, Professor Wessels and co-workers at the University of the North in South Africa have initiated research into various aspects of physiology and anatomy. Mopane appears to be physiologically adapted to xeric (dry) conditions with low soil nitrogen and potassium (Eyles 1971, Smith 1972, Henning and White 1974, Chionski and Tuohy 1991), although growth is obviously more rapid when these factors are not limiting. Despite its alleged liking for sodic soils (see later), studies in India on planted mopane suggest that the species is not particularly tolerant of salinity (Jain and Muthana 1982, Muthana 1984).

The photosynthetic rate of mopane leaves is lower in the heat of the day (Prior 1991) and the leaflets are known to droop at this time on hot days.

Some interesting results on root distribution have been obtained by Smit and co-workers in the northern Transvaal. Total mopane root biomass in mopane shrubland was 10 - 30 t Dry Matter (DM)/ha, with most fine roots (0 - 1.0 mm diameter) in the top 20 cm of soil and a linear decrease with soil depth (Roux *et al.* 1994). Coarse roots (>100 mm diameter) showed an increased concentration with soil depth up to 40 - 60 cm. The root systems are thought to extend horizontally to 7.6 times the plants' height (Smit *et al.* 1994).

Symbiosis

Mopane, as with nearly all Caesalpinioideae, does not have symbiotic nitrogen-fixing rhizobia associated with its roots (Grobbelaar and Clarke 1972, Corby 1974). Therefore it does not fix nitrogen. In contrast to many miombo species (miombo is a widespread deciduous woodland type of south and central Africa dominated by trees of the genera *Brachystegia, Julbernardia* and *Isoberlinia* (Frost 1996)), but similar to various tree species from the Kalahari sands, mopane is endomycorrhizal (Högberg and Piearce 1986). These symbiotic root fungi probably assist the tree in obtaining some of its nutrient requirements.

Pests

Mopane appears to have remarkably few serious pathogenic pests and diseases. The trunks are often hollow where the heartwood has been broken down by *Phellinus rimosus*, a heart-rot fungus (Piearce 1986) and this is perhaps the major reason why mopane timber has never really entered commerce.

Two well-known caterpillars can defoliate mopane trees, although the trees normally put on new leaves again later. These are the mopane worm, the larva of the moth *Imbrasia belina* (Velcich 1963, Van Voorthuizen 1976, Styles 1995) and the larva of the wild silk moth *Gonometa rufobrunnea* (Hartland-Rowe 1992). It is interesting to speculate on what ecological effects these "micro-herbivores" might have on mopane ecology on a landscape scale. Styles (C. Styles[3], pers. comm., 1996), working on mopane in the Kruger National Park, has found that these defoliating caterpillars are only found on mopane growing on granite soils and not on mopane growing on basalt soils nearby. This is possibly due to differences in soil nutrient status (perhaps sodium) being reflected in differences in leaf nutrient content.

USES

Many uses have been reported for mopane in the region, not surprisingly for such a common and widespread species. These include medicines from the bark, roots and gum (Watt and Breyer-Brandwijk 1962, Coates Palgrave 1956, Gomes e Sousa 1966, Palmer and Pitman 1972), tannin from the bark (Watt and Breyer-Brandwijk 1962) and resin from the seeds (Coates Palgrave 1956, Timberlake and Crockford 1994). It has potential for rehabilitation of some degraded lands owing to its ability to survive under difficult soil conditions. The tree is also important as browse and shelter for wildlife. Mopane squirrels (*Paraxerus cepapi*) use hollows in the trunk, as do nesting hornbills (*Tockus erythrorhynchus*) and bats (e.g. *Scotophilus leucogaster*) for roosting (Fenton 1983). In some areas forks of mopane trees support a large fibrous mass of leopard orchids (*Ansellia africana*), and Trigona bees (mopane bees) live in small holes. The main three uses - wood, browse, mopane worms - are described more fully below.

Wood

The heartwood of mopane is hard, heavy and resistant to termite attack, with a density of around 1,200 kg/m^3 (Goldsmith and Carter 1981). The most common use of the timber is for fence posts, hut poles, mine props and in the past, railway sleepers and parquet flooring. It is occasionally used for furniture but is generally considered too heavy and liable to splitting. Many potentially suitable trunks have heart-rot and thus are not usable (Coates Palgrave 1956, Van Wyk 1972).

Mopane is well-known as a good quality firewood (Tietema *et al.* 1991) as it burns slowly and produces much heat. In places where it occurs it is generally the most desired species. The energy content has been measured as 21,570 kJ/kg (Tietema *et al.* 1991), higher than that of seven other species measured (including various species of *Acacia* and *Combretum*).

Browse

The leaves and young twigs of mopane are an important source of browse for cattle, goats and wildlife. This browse is principally utilized in the dry season when the turpentine smell from the leaves has diminished. Another major reason is that dried mopane leaves remain on the plants and very little other forage is available at that time. In some parts of its range, mopane has been known to avert large-scale stock losses from drought in bad years providing enough crude protein and bulk intake to tide animals over until the grass flush following the first rains. Crude protein levels range from 8.4 % in September to 16.6 % with leaf flush in November (Bonsma 1942, Myre and Coutinho 1962, DHV 1980). Calcium and phosphorous levels are also comparatively high, ranging in the former northern Transvaal from 0.12 - 0.23 % and 1.15 - 3.23 %, respectively (Bonsma 1942).

Very few data are available on nutritive value through the year, with many quoted figures being based on Bonsma's (1942) work. This is another major area for investigation. Data are required of nutritive values through the year (with particular reference to the drier months) with notes on soil type, stage of growth (coppice or tree) and rainfall. There are no published reports of anti-nutritional factors (e.g. condensed tannins) in the leaves, but this may partially reflect a lack of studies rather than a lack of factors. Some researchers at the University of the North are now addressing this question.

Mopane is a major forage source for elephant (Guy 1981b, Lewis 1986 and 1991, Viljoen 1989) and these animals occasionally push over trees to reach the young growth, causing major local ecological impact on the woodlands (Dudley *et al.* in prep.).

Mopane worms

In Botswana, southern Zimbabwe and the former northern Transvaal one of the best-known and economically important products from mopane are mopane worms or "macimbi". These are the edible larvae of the Saturniid moth *Imbrasia belina* (Velcich 1963, Van Voorthuizen 1976, Styles 1995). Individual trees or sizeable patches of veld can be almost totally denuded by these caterpillars. They are collected, dried and then sold in urban areas; the industry has been estimated at UK£ 4.42 million (Z$ 65 million) annually in Botswana alone (Styles 1995). The caterpillars are usually eaten roasted or fried and contain 47 - 65 % protein (Van Voorthuizen 1976, Styles 1995) and a fat content of 51 % (Velcich 1963). The sustainable exploitation of this mopane product could perhaps yield a larger financial return per hectare, to some of the poorest of rural people, than any other single form of land use. However, as with many other invertebrate products, the variability in production between years is very high leading to potentially unstable market conditions.

DISTRIBUTION AND ECOLOGY

Distribution

Mopane is a xeric species of the savanna woodland zone of south central Africa. It is often dominant on heavier-textured soils of the wide, flat valley bottoms of the Limpopo, Zambezi, Okavango, Cunene, Shire and Luangwa rivers (Cole 1986, Mapaure 1994), but is found over much of southern Angola, northern Namibia, northern Botswana, Zimbabwe, southern Zambia, southern Malawi, northern South Africa and Moçambique. Within this broad area it is commonest on depositional clay-rich soils, but is also found on other clay-rich soils such as on termitaria, drainage lines and where the illuviated clay horizon of granite duplex soils is exposed (Timberlake *et al.* 1993).

The altitudes over which it is found varies from 200 MAMSL in Moçambique to 1,200 MAMSL in Zimbabwe, although most mopane vegetation lies within the range 300 - 1,000 MAMSL (Timberlake 1995). In Zimbabwe it is generally encountered below 1,000 m (Timberlake *et al.* 1993). Most mopane woodland lies in the 400 - 700 mm annual rainfall zone, but the species can be found in drier areas such as in drainage lines in north-western Namibia receiving less than 100 mm annual rainfall (Viljoen 1989) and in areas receiving up to 800 mm annual rainfall elsewhere.

Frost is often stated to be a major factor limiting distribution of mopane (e.g. Van Voorthuizen 1976, White 1983), with the species restricted by the 5 °C mean daily isotherm for July (Henning 1976). Why the mean value should be significant rather than the absolute value is not too clear, but in western Zimbabwe it is not uncommon to find the species in areas prone to severe annual frosts (often -5 °C or below).

It would appear that the distribution of mopane is determined by different factors in different parts of its range, depending partly on the soil type, length of growing season and the occurrence of other woody plants that could outcompete it.

Mopane vegetation

For such a widespread species, mopane is unusual in that the number of characteristically associated species are limited (i.e. mopane woodland has a low alpha-diversity) and these associated species do not differ greatly across its range (low gamma-diversity). The herbaceous layer is often poor, predominantly comprising annuals (Timberlake 1995).

Generally mopane occurs in almost exclusively dominant stands with very few other woody species, except those associated with termitaria, drainage lines or rock outcrops - a rather unique feature among vegetation types in this part of Africa. The ecological mechanism resulting in such monospecific communities is unclear - perhaps it is the aggressive shallow-rooting nature of the species, or the comparative unsuitability of the soils for other species, or perhaps some chemical factor. Also remarkable is the even-sized appearance of the stands indicating episodic or cohort recruitment. There is often little apparent regeneration in many areas. However, whether these even-sized stands are in fact even-aged has not yet been investigated.

The separation of mopane vegetation from the surrounding miombo or Combretaceae-dominated vegetation on sandy soils can be remarkably abrupt. Sometimes a tight mosaic is found, such as described by Timberlake *et al.* (1993) for the middleveld of Zimbabwe, with mopane on the small patches of clay-rich depositional soils and typical miombo species on the eroding rocky or coarse-textured sites.

Soils

As mentioned previously, mopane is essentially a species of eutrophic clay-rich soils, many of them depositional. It rarely occurs on true sandy soils. Where it does appear to occur on sand a clay layer will usually be found just below the surface. Despite many statements that mopane is an indicator of sodic soils, this only seems to be at higher altitudes on the central plateau where the illuviated clay horizon of granite-derived duplex soils is somewhat sodic (Dye and Walker 1980). The shallow-rooted mopane survives on these infertile soils while most other woody plants cannot (Thompson 1960).

Although somewhat shallow-rooted, mopane prefers deeper soils and it is on such soils that it grows best and retains its leaves longest. On comparatively deep deposits of old alluvium, possibly dating from the Pleistocene pluvials, so-called "cathedral mopane" is found. These are stands of tall, well-formed trees from 14 to 26 m tall, often with large boles.

Another phenomenon exhibited by mopane is the not-uncommon expanses of shrub mopane, often surrounded by much larger trees. Suggested causes include frost damage, fire, past cultivation, elephant damage and rooting restrictions due to soil type. Although undoubtedly there are stands of coppice or pollarded mopane in wildlife areas due to localized damage by elephant (Lewis 1991; J. Dudley[4], pers. comm., 1996), the major factors are believed to be limitations on rooting depth imposed by heavy soils or cracking clays, root pruning due to the self-churning clays, or seasonal waterlogging (Timberlake 1995).

PRODUCTIVITY

Biomass

Because mopane occurs under a wide range of climatic conditions and soil types, standing biomass estimates could be expected to vary greatly. Mopane generally comprises more than 90 % of the total biomass of mopane woodland (Martin 1974, Guy 1981a). Reported figures for mopane in mature woodland range from 61 t DM/ha (Martin 1974) in northwest Zimbabwe to 80 t Fresh Weight (FW)/ha in northern Botswana (Tietema 1989). For drier low woodland or shrubland vegetation types in southern Zimbabwe, Kelly and Walker (1976) found a biomass of 17 - 18 t/ha. In Sengwa, northwest Zimbabwe, Martin (1974) found that only 3.7 % of the total mopane woodland biomass was browse (leaf + growing twig), but only one percent of this was available to most ungulates (i.e. was under 2.5 m in height).

Stocking density

Stocking density obviously depends primarily on the size of individuals within the stand. Self-thinning is known to occur (Scholes 1990). Reported densities for mature woodland range from seven trees per hectare in arid northwest Namibia (Viljoen 1989) to 481 trees/ha in southeast Zimbabwe (Kelly and Walker 1976), but a typical figure for mature, non-stunted mopane woodland in the 500 - 700 mm rainfall zone is around 200 - 400 trees/ha (Timberlake 1995).

Productivity estimates

Predictive biomass equations have been derived from various estimates of standing biomass (e.g. Martin 1974, Kelly and Walker 1976, Guy 1981a, Tietema 1989 and 1993, Scholes 1990, Smit 1994, Mushove *et al.* 1995), most of them based on measurements of stem diameter, crown width and height from a few trees. The majority of equations have been tabulated by Timberlake (1995). Many of them have high correlation coefficients, but as they are all from drier regions of the species' distribution they may not be applicable to the higher rainfall areas of Malawi and Zambia, nor to "cathedral" mopane. Productivity assessments of leaf biomass alone have been produced by Kelly and Walker (1976), Scholes (1990) and Tafaune (1993).

Growth rates

Little is known on growth rates in natural stands of mopane, and these data are often not comparable owing to different assessment techniques (fresh weight *versus* dry weight, and differences in the separation of trees and shrubs, wood and foliage). Generally growth rates are thought to be low, but this may in part be due to the adverse soil conditions under which mopane often grows. Tietema (1989) reports annual growth of mopane trees in woodland in northern Botswana of 10 t/ha, while Kelly and Walker (1976) in southern Zimbabwe report around 1.5 t FW/ha/year, and Guy (1981a) in northwest Zimbabwe reports 1.2 t FW/ha/year.

Defined growth rings are present in mopane (Goldsmith and Carter 1981), but there appears to have been no attempt to determine if these relate to annual growth. However, growth ring diameter does not appear to be related to mean annual rainfall and is of little significance in explaining variability in ring size between sites (Mushove *et al.* 1995). This is an area which requires further study as nothing seems to be known on age and mortality of stands.

Lack of knowledge on growth rates under various condi-

[4] J. Dudley, Hwange National Park, Zimbabwe, February 1996

tions is obviously a major limitation in the ability to manage and utilize mopane. Future studies should clearly separate the various factors affecting growth. Such research should distinguish between whether; (a) productivity is for the species or the woodland type, (b) what the age or size class distribution of the stand is, (c) whether coppice shrub or mature trees are being measured, (d) what the soil type and topographic position of the site is, (e) what the rainfall was for the year of assessment and for immediately previous years, and (f) what herbivory the plants were subjected to.

MANAGEMENT

For such an ecologically and economically important species, with so much potential for silvicultural management, there is a surprising lack of knowledge on management practices and effects. Thinning and coppicing have been reported on (e.g. Coe 1991, Mushove and Makoni 1993), but there appears to be no published experience on stand establishment or mortality. Mopane coppices readily, probably an adaptation to a combination of periodic drought, fires and damage from megaherbivores.

In eastern Botswana, Coe (1991) found that basal area increased by 11 to 21 % after one year with thinning from *circa* 8,000 stems/ha to 1,500 - 3,400 stems/ha. In Malawi (Nyasaland Government 1943) 50 % thinning of a stand gave better coppice regeneration than clear-felling owing to less competition from the resulting grass growth.

Tietema (1989) suggested that weight gain for mopane is around 1 t/ha/year at a density of 10,000 stems/ha, and the desired stem sizes (5 - 25 cm basal diameter) can be achieved in 5 - 10 years from coppice (Tietema *et al.* 1988). In Namibia it was found that the best growth was obtained by keeping coppice growth at one or two stems per rootstock (Erkkilä and Siiskonen 1992). Trials in southern Zimbabwe (Mushove and Makoni 1993) show that mopane trees cut at 1 m height produced more and taller coppice shoots than those cut at 10 cm height.

Although mopane is a species of so-called "climax" woodland, it is in many respects a secondary colonizer, that is a species which comes in slowly after the initial colonizers and almost modifies the environment to perpetuate itself. It is not a pioneer, unlike many of the Acacias. Mopane is also rather slow-growing and has difficulty in establishing itself in the face of competition from grasses (Thompson 1960). There is therefore a low probability of successfully establishing stands from seed in plantations or degraded areas. An exception might be on the exposed, infertile, sodic clay subsoils in granite areas where grass growth is minimal. The objective of this, however, would presumably be for establishment of woody cover to control erosion rather than for economic production of browse and / or wood.

CONCLUSIONS

Mopane is a widespread species over much of south central Africa, and where it is found it is often the dominant tree, occurring in what is almost a monoculture. This plantation-like feature is enhanced by its occurrence in even-sized stands, an ideal situation for silvicultural intervention. The analogy with a plantation breaks down, however, when it is realized that establishment is very difficult and growth relatively slow. Although it may be economically impractical to develop new "plantations", the possibility is there for sustainable management of existing stands, many of which are situated in economically-impoverished areas with few land use options and on land not suitable for agriculture.

Ecologically, it fills a major role in providing woodland cover where few other tree species occur. It is a major wildlife habitat, from elephants to mopane squirrels, and hornbills to mopane bees and leopard orchids. It is a major source of forage for such animals as kudu, eland and elephant. Economically, the species is an important source of rough construction timber, of firewood, of dry-season browse and, during the rainy season, of edible mopane worms.

Given its importance, suprisingly little is known of such aspects of the biology of mopane as; (a) whether the even-sized stands are in fact even-aged, (b) what factors determine recruitment of stands, (c) what factors determine the differences between shrub and tree mopane, (d) what environmental and ecological factors determine its distribution, (e) growth rates, (f) the best methods for managing coppice, and their sustainability, (g) browse values through the year on different soil types, and (h) any anti-nutritional factors. Further research, much of it of a collaborative nature, is required to obtain answers, partial or complete, to these questions so that the rapidly-diminishing stands of mopane in southern Africa can be sustainably and usefully managed, and representative areas conserved.

ACKNOWLEDGEMENTS

My thanks go to Woody Cotterill, Ian Maclausland and Jenny Timberlake for comments on a draft. Much of the review work was carried out while at the Research and Development Division of the Forestry Commission under the DFID Forestry Research Support Project.

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ISSUES RAISED DURING PARTICIPANTS' DISCUSSION

Have there been any studies on floristic range?
Not really, just piecemeal. In Frank White's study there is a list of associated species across its range.

Is it true mopane is an indicator of shallow soils?
Not really. It tolerates soils that have an impeded layer, so are shallow in that sense, but not when they are shallow over bed rock. It is not an indicator as such, although it does occur when there are impeded soils.

The browse estimate gives 3 to 7 % above ground biomass, did this include fallen leaves?
No; the figure came from a destructive harvesting, and so the measurement was on the leaves available at browse height; it did not include leaves that had fallen or those that could fall [and therefore be eaten from the ground].

Is the tree a pioneer species in ecological terms?
It tends to occur on soils where nothing else occurs. In cleared areas you do not get mopane, but rather Acacias, so it is not as such a pioneer species. It does not compete with grassland and cannot tolerate shade.

Do farmers cut branches for browse at all?
In southern Zimbabwe there were records of this happening during a severe drought, but normally it is not practised.

[Editors' note: Cutting branches for browse has been recorded in northern Namibia, see plate 12]