TECHNICAL PAPER 13

Maesopsis eminii and its status in the East Usambara Mountains

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1995

East Usambara Catchment Forest Project

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Tanga 1995

SUMMARY

The ecology of *Maesopsis* in eastern and equatorial Africa is reviewed and related to conditions in the East Usambara Mountains. Five key factors which have enabled the success of *Maesopsis* at Amani and the surrounding areas are identified. The climate is similar to that at Bukoba (possibly the source of the original seed). An era of widespread logging disturbance in the forest opened the canopy in numerous places. The soils are continually moist but well-drained and reasonably fertile. There is little litter accumulation because of fast decomposition. Seeds are produced over a long period each year and are widely and abundantly dispersed by hornbills.

The present situation at Amani as far as *Maesopsis* is concerned is reviewed. In terms of expanding *Maesopsis* populations, the public lands are presently of greater concern than the forest area. Four options for removing *Maesopsis* are outlined. Mechanized logging and pit-sawing could be considered, possibly in combination, for the denser stands. The use of draught animals for extraction is considered to offer the lowest intensity of disturbance where sensitive areas are to be cleared of *Maesopsis*.

The rate of spread of *Maesopsis* into the forests has declined since logging ended. There is no clear evidence that *Maesopsis* is suppressing or preventing the regeneration of indigenous pioneer or later successional species, nor that it retains sites.

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1. INTRODUCTION

Although *Maesopsis eminii* is among the most widely distributed of African forest tree species it did not come to scientific notice until 1895 when Adolf Engler described the specimen collected by Dr F Stuhlmann during the Emin Pasha expedition which passed through the Bukoba area in 1890. More comprehensive comments were published (Engler, 1906) a decade later which acknowledged the importance of the tree as a timber resource. It has been assumed that the Bukoba area was the source area for the seed taken to the Usambaras - probably to Lushoto first and from there to Amani - but documentation to confirm this has not been seen. Stuhlmann seems likely to have influenced the introduction, since he founded the Amani Institute and was its head until 1908, and would have been well aware of the Uganda populations of the species as well as the more restricted ones in Tanzania. Within the next two decades *Maesopsis* in Kenya, Tanzania, Uganda and Zaire became a widely valued and utilized timber.

Maesopsis eminii is regarded as a typical guineo-congolian species, its range corresponding quite closely to the African lowland rain forest zone. There is no fossil record, however. Nor are there close relatives - the suggestion has even been made that within the family (Rhamnaceae) it justifies its own subfamily (Johnston, 1972). It is thus difficult to interpret the significance of the variation reported and the phylogeny remains unclear. Nevertheless, a distinctive pattern of geographical variation is evident. Through the range from east to west there is a change in the size reached at maturity. A smaller form, which occurs from Sierra Leone to the Congo Republic, has been distinguished as subspecies *berchemioides* (Hallé, 1962). Plants from Zaire and the Central African Republic and further east and south (to Angola and Zambia) have been referred to subspecies *eminii*. A clinal pattern of variation would also explain the contrast in size between trees of the eastern and western parts of the range. It would also be consistent with the reports of trees exceeding 40 m in height in Tanzania and Uganda but only reaching 35 m in Zaire and 25-30 m in Angola and further west. However, any clinal effects which reflect genetic variation are confused with ecological differences. Electrophoresis studies, or an alternative method of differentiating provenances are needed to separate the two effects.

The variation in size is of economic significance - the trees west of Zaire are too small to constitute a timber resource. For this reason and because the area of primary interest for the East Usambara Catchment Forest Project is within East Africa, attention here centres on the eastern part of the range. Additional information on *Maesopsis* in West Africa is given by Mondal (1986). In contrast with the uniformly low elevations and strongly seasonal rainfall regimes where the species grows in West Africa, further east populations occur in a wide variety of climatic conditions and over a wide elevation range.

There are standard floras containing treatments of the Rhamnaceae for almost all the eastern part of the range of *Maesopsis* (Johnston, 1972; Exell & Mendonça, 1954; Evrard, 1960). In combination with comments in the ecological and forestry literature, particularly by Eggeling & Harris (1939), Eggeling (1947), Fenton, Roper & Watt (1977) and Mugasha (1981), these floras indicate areas of concentration at the periphery of the Zaire river basin and on the Zaire/Angolan coast. Representative voucher specimens and localities are listed in Table 1. However, Hepper (1979), draws attention to the lack of floristic information from parts of the centre of the Zaire Basin. In that area, *Maesopsis* may be better represented than available information suggests, although so much of the terrain is swampy that this is unlikely.

2. ECOLOGY OF *MAESOPSIS* IN EAST AND EQUATORIAL AFRICA

2.1 Distribution

Reports of *Maesopsis* are mainly from three areas: the Cabinda enclave and adjacent parts of Zaire in Bas-Katanga and in the Lake Victoria basin. In addition, outlying occurrences are reported in southern Sudan (Friis, 1992), at Kigoma in Tanzania (Johnston, 1972) and near Kawambwa in Zambia (Lawton, 1969) and in scattered localities have been indicated (Evrard, 1960) in the centre and in the north of the Zaire basin.

2.2 Broad relations with geology, soils, elevation and climate

2.2.1 Cabinda enclave and adjacent Zaire (occurrences west of 16° E)

In this area *Maesopsis* grows at low elevation - up to about 500 m - and is subject to relatively high mean annual temperatures (over 23 °C) and a well defined dry season (4-6 months with mean rainfall <50 mm). This, however, is offset by year-round high humidity (>60%). Mean annual rainfall is low: 800-1500 mm. Soils (FAO-Unesco, 1977) are mixed but fair (orthic ferralsols) to good (ferric cambisols, ferric luvisols, eutric nitosols) in agricultural terms. The parent materials are mainly precambrian crystalline rocks or sediments but younger (cretaceous) sediments in the south of the area.

2.2.2 Bas-Katanga (occurrences in latitudes 5-9° S and longitudes 22-26° E)

This is an area of moderate elevation (approximately 600-1100 m) and mean annual temperatures varying from 21.5-24.5 °C. The dry season is well defined but short (2-4 months) and usually no month is completely rainless. The dry season is, however, more severe at the southern edge of the area. Mean annual rainfall exceeds 1300 mm and may approach 1800 mm. Soils are agriculturally rather poor (xanthic ferralsols) in the wettest parts of the area where the parent rocks are tertiary or younger sediments but further south better soils (orthic ferralsols) occur on basement complex materials, much originating from in-situ weathering.

2.2.3 The Lake Victoria basin (occurrences between latitudes 2° N and 3° S and longitudes 29-35° E)

This is the area where *Maesopsis* occurs generally at around 1100 m but extends up to approximately 1500 m, the upper limit for the species in wild populations. Mean annual temperatures are from approximately 20-23 °C. Most reported occurrences close to the equator are in this area and therefore associated with an aseasonal climate, with no completely dry months. Only south of 2 °C are there more than 2 months with <50 mm mean rainfall. Mean annual rainfall is from about 1000 mm to as much as 2000 mm. The area generally has been subject to a complex and eventful geological history and particularly at the higher elevations of the edges of the basin soils may vary markedly over short distances. Orthic ferralsols, weathered from precambrian rocks, nevertheless predominate where *Maesopsis* has been reported. At the upper limits of the elevation range, more productive humic nitosols are sometimes present. At the other extreme, Ukerewe Island in Lake Victoria is mapped (FAO-Unesco, 1977) as an area of poor soils, ferric acrisols. To the southwest of the lake *Maesopsis* has been reported from areas with ferric luvisols, good soils.

2.2.4 Other localities

The remaining localities are at moderate elevation, except for Kapweshi (Zambia) which is higher (1300 m). Mostly climatic conditions are similar to those applying to the wetter parts of the Bas-Katanga area. In localities with an extended (5-6 months) dry season, better soils are sometimes present: rhodic ferralsols (Lukisi, Zaire) ; eutric nitosols/ferric luvisols (Uvinza, Tanzania). Eutric nitosols are also present at Talanga (Sudan) although the dry season lasts only three months.

2.2.5 Climate and soils at Amani

Conditions similar to those in the Amani area of the East Usambaras are well represented in the natural range of *Maesopsis eminii*, readily explaining its success as an introduced plantation hardwood. Where the climate is concerned, it is particularly the Lake Victoria basin conditions which are comparable (Table 2) although it is apparent that the Amani climate is rather more uniform than any of the other examples. Despite appreciably lower elevation, Amani does not enjoy higher temperatures because of anomalies which lower temperatures on the Tanzanian coast (Lundgren, 1978) and raise temperatures near Lake Victoria (Jameson, 1970)

There are conflicting classifications of the soils at Amani. FAO-Unesco (1977) map these as eutric nitosols. This implies they would offer an improved substrate for provenances adapted to ferralsols and could contribute to the impressive growth achieved in the plantations. However, IUCN (1985) report the soils as chromic luvisols. The most recent report (Hamilton, 1989) describes two sub-montane forest soil samples as orthic ferralsols and two more as xanthic ferralsols.

2.3 Maesopsis *autecology*

Given broadly suitable climate and soil conditions, areas where *Maesopsis eminii* has good potential to become established can be identified. For ensuring good performance or identifying control options, however, information is needed on the site conditions facilitating germination and fast growth thereafter. To manage populations on a sustainable basis and to develop strategies to limit spread or eliminate the species an understanding of the dynamics of populations and of individuals is needed.

2.3.1. Successional processes

Maesopsis has been recognised for upwards of 50 years as a colonizing species (Eggeling & Harris, 1939). More detailed investigation of *Maesopsis* dominated communities by Eggeling (1940, 1947) has clarified the colonization process at Budongo, Uganda. Casual observations at other localities indicate that elsewhere in the Lake Victoria basin broadly similar sequences of events take place (Thomas, 1941; Jackson & Gartlan, 1965). The inability of *Maesopsis* to directly invade ground arises from a combination of fire-sensitivity and sensitivity to competition, particularly for light. Opportunities for colonization arise in forest gaps and where a shrub-dominated transition zone separates relatively fire-sensitive forest from grassland. *Maesopsis* does not become established in a dense grass community. However, if fires are prevented or are infrequent and light, typical transition zone shrubs (especially *Acanthus arboreus* where Eggeling worked) gradually suppress associated grasses. As the woody thicket develops, conditions at ground level are modified and the ground cover becomes less even, probably mainly because of shading effects. Where the grass layer is less dense, but shade is light to moderate, tree and shrub seeds germinate. *Maesopsis*, which is fire-sensitive becomes established at this stage. Where there is little or no shade overhead vigorous early growth ensures it escapes suppression by other trees and shrubs which germinate at the same time.

2.3.2 Site requirements

Even in areas with abundant *Maesopsis* certain conditions are more favourable than others for establishment and persistence. Eggeling (1947) attached significance to soil quality noting that *Maesopsis* alone of several pioneer and early successional species was not an important constituent of colonizing forest on steep gradients and shallow soils. Other reports indicate reliance on a continuous moisture supply. Évrard (1968) identifies *Maesopsis* as a hygrophyte. This implies that soils prone to drought stress because they are shallow, or if gradient or texture leads to excessively free drainage, are unfavourable. Mugasha's (1981) reports that as a plantation species the best growth is on deep, well drained soils are consistent with this. Mugasha notes also that planted stands on some steep gradients have grown well, indicating that steep gradient alone does not necessarily make a site unsuitable.

2.3.3 Gap niches

Binggeli (1989) has assembled information on the ability of *Maesopsis* to become established in a range of gap and soil surface conditions. He concludes that suitable gaps are more likely to arise when the falling/felled tree is large (>60 cm diameter at breast height). This creates a complex gap within which areas where soil surface conditions are suitable for *Maesopsis* establishment are well represented. Binggeli recognizes four gap niches: crown debris, the bole itself (once decay is advanced), bare mineral soil, bare humus soil. It is on the bare humus soil that large numbers of *Maesopsis* become established. For the species to persist an area of soil must be well illuminated and remain unshaded until the *Maesopsis* which becomes established reaches canopy height. The gap therefore must be too large for closure simply from lateral crown extension simply from adjacent large trees and should not contain resilient trees able to regenerate shoots growing faster than the *Maesopsis* seedlings. It would appear that successful establishment requires close contact between the seed and a substrate enriched with decayed litter. Bare mineral soil, as is exposed on the root plate of a fallen tree, or where logging scores the soil surface, is unsuitable. This is presumably because of lower nutrient availability, or more intermittently lower moisture content as rainless periods are experienced, or both. The unsuitability of the crown debris zone can be attributed to the layer of loose debris denying incoming seeds access to the soil surface but preventing the germination of seed beneath it. Large gaps arising in forest with an open understorey and where litter turnover rates are so high that little undecomposed litter accumulates on the ground evidently favour *Maesopsis* establishment.

2.4 Natural history of Maesopsis

2.4.1 Ecological group

Maesopsis, because of its high light requirement is largely restricted to the dynamic situation of forest gaps and edges. From before the pleistocene epoch there have been geological and climatic events which have influenced forest extent and where the ecotones with savanna are located. In the last 50 000 years man has come to influence events at forest boundaries. This process has intensified in the last 12 000 years and has accelerated dramatically with rising human population pressure over the last 100 years. Forest fragmentation has increased the length of boundary in relation to forest area and the evolution of land management skills has introduced instability at most forest edges. Originally, however, forest gaps were probably more important than edges because of the rapid changes within them.

Maesopsis has evolved as a gap invading species - a gregarious pioneer which is not dependent on specific pollination and dispersal agents. Formal phenological studies are needed but already there have been a number of casual comments and an in-depth although short-term study of several aspects of the reproductive biology in the East Usambaras (Binggeli, 1989). Some of the information is inconsistent, suggesting wide variability within the species, or variation with the locality.

2.4.2 Reproductive biology

Mugasha (1981) reports flowering and fruiting at 4-6 years, but under natural or invasion conditions an age of about 10 years for the onset of flowering is more likely. At this age fast-growing individuals would be around 20 cm diameter at breast height and the crown would be high in the forest canopy. Observations that flowering is a rainy season event (Mugasha, 1981) are based on the Lushoto (West Usambara) climate. Binggeli considers the flowering period at

Amani the dry season. It is unclear if there are normally two separate flowering periods each year (Mugasha, 1981) or a single long period as described by Binggeli (1989). No pollination agents have been identified, although Mugasha (1981) speculates that entomophily is probable.

Fruits take three or four months to develop after pollination and because they are more conspicuous have been reported more frequently than flowers. Under the continually equable climate of the East Usambaras it seems doubtful if there are strictly regular flowering and fruiting periods and fruits have been noted in every month from June to January, although not necessarily in the same year. Eggeling & Dale (1951) describe *Maesopsis* as deciduous and so does Binggeli where there is a severe dry season. At Amani, Binggeli associates leaf shedding only with the fruit setting process. This suggests that in more constantly humid climates there is no regular leafless period: even during fruiting leaves remain at the tips of branches where fruits have not yet set.

Fruits contribute to the diet of silver-cheeked hornbills (*Bycanistes brevis*), monkeys and chimpanzees, all of which are dispersal agents. At Amani, hornbills have been noted for this for at least 60 years (Moreau, 1935) and recent observations (Binggeli, 1989) identify one species of dispersing monkey as the blue monkey, *Cercopithecus mitis*. Both these important dispersers are strictly arboreal ensuring dispersal is to places beside existing trees and not into open grassland or fallow.

Seeds are dispersed over long periods each year because of the extended fruiting period. At Amani, a concentration of hornbills, the major dispersers, was even reputed to rely on *Maesopsis* fruits for six weeks of the year (Moreau, 1935). Often seeds will be voided into forest with an intact canopy as the hornbills move to different canopy and emergent trees but beneath such trees at the forest edges and beside newly created gaps, establishment may result.

2.4.3 Seed biology

There is no convincing evidence that *Maesopsis* can be incorporated in a soil seed bank in the long-term sense usually understood because in contrast with many other pioneer trees the seeds apparently do not remain viable for very long. Ten months after collection no seed germinated (Anon., 1964) and in storage conditions of 4-8°C the proportion of viable seeds fell rapidly after 3 months (Yap & Wong, 1983). A maximum storage period of 5 months was urged by Watkins (1960) because of the decline in viability. Recent suggestions of a rather longer period of viability (N. Geddes, pers. comm.) await confirmation. There is no indication that the seeds of *Maesopsis* which germinated in the East Usambara seed bank study (Binggeli et al., 1989) were more than a few months old.

The long period each year over which fruits ripen compensates for the early loss of viability in terms of population maintenance. Gaps arising over several months of the year can still receive fresh seed. Further compensation comes from the wide seed-to-seed variation in time to germination: 90-200 days (Yap & Wong, 1983; Mugasha & Msanga, 1987; Binggeli, 1989). In and close to concentrations of mature *Maesopsis* typical of forest edges and old gaps seed rain is heavy. Binggeli (1989) reports density >800 seedlings m^{-2}. Germination does not depend on exposure - with suitable soil surface conditions it will take place in the shade. The creation of a gap will release some of the established seedlings and more seedlings should develop from seed already dispersed but subject to delayed germination. If the fruiting season is continuing, further seedlings may originate from seed rain received after gap formation. Tests in the field (Binggeli, 1989) have shown that germination prospects are higher when there is good contact with a constantly moist substrate. By burying seeds to 3 cm depth Binggeli achieved >50% germination in 4-5 weeks from a batch of 120 seeds. Only 5% of the same number laid on the soil surface germinated in the same period.

Although germination will take place in shade, survival is dependent on early exposure to high light intensity. *Maesopsis* appears to be unable to recover from suppression and no seedling bank develops. Of the large number of small seedlings he recorded, Binggeli concluded that almost all died in less than one year.

2.4.4 Population structure

There is general agreement that *Maesopsis* is gregarious but little information on the character of *Maesopsis* populations (Table 3). The gregariousness arises from its distinctive appearance as a pure stand of even-aged individuals in gaps and its prominence at many forest margins. Most inventory data are unsatisfactory for characterising populations. With appraisal of potential commercial value as the primary objective inventories have been directed at relatively intact natural forests with gaps accounting for a trivial proportion (no more than 1-2%) of the area, or secondary forest where succession has progressed beyond the stage where *Maesopsis* is a major component. The figures from Talanga and Bugoma in Table 3 show this. In Eggeling's (1947) ecological study, however, *Maesopsis* forest has been identified as a distinctive type and representative plots have been assessed in detail.

The figures for Sample Plots 2 - 4 represent an age sequence. In vegetation 30 - 40 years old, (SP 2), most *Maesopsis* is 30 - 50 cm dbh. In older vegetation (50 - 60 years - SP 3) most *Maesopsis* is >50 cm dbh and individuals <20 cm dbh are absent. By an age of 60 - 150 years (SP 4) Maesopsis is of much less importance, although the surviving trees are mainly >60 cm dbh. From these observations Eggeling (1947) reached the conclusion that *Maesopsis* persists for only a single generation. The early decline, ending a phase of canopy dominant lasting less than 100 years has led to the view that *Maesopsis* is short-lived (Eggeling, 1951). Dawkins (1965), however accepts the possibility of much greater age ("at least two centuries") citing *Maesopsis* as a persistent-seral species. The solitary large Zambian tree described by Lawton (1969) illustrates this: Lawton speculates it could have become established in abandoned cultivation 100 -150 years before it was reported. There is no doubt, nevertheless, that most individuals do not reach a great age. Both Eggeling (1947) and Binggeli (1989) note that later recruits into groups of *Maesopsis* and the less vigorous of the initial colonists are eventually suppressed. At the scale of a typical gap there is only space for one or two full sized *Maesopsis*. This process is believed to explain the presence of scattered and isolated *Maesopsis* in the upper canopy of mature forest. Regeneration beneath these scattered trees is not normal but effective dispersal of seed to sites which are open for colonization is still possible as hornbills regularly fly over distances of several kilometres.

Eggeling's stand table for the swamp plot (SP 11) implies only sparse occurrence and perhaps restriction to the drier parts. Silvicultural experience indicates retarded growth and higher disease incidence if the substrate is waterlogged (Mugasha 1981). Subject to these effects it is unlikely that *Maesopsis* grows well enough to withstand competition from species well-adapted to conditions of poor drainage.

3 *MAESOPSIS* IN THE EAST USAMBARAS

3.1 Overview

There is uncertainty about the amount of *Maesopsis* planting which has taken place in the East Usambaras. Only the original stand, below the Amani Rest House and the plantings carried out at Kwamkoro in the 1960's are well known as points of introduction. Other areas where *Maesopsis* has been planted at higher elevation are in the Mtai forest (where the species was used for enrichment near the Mamba enclave) and as an agroforestry trial species at the top of the botanic garden (more recent planting, after use of the species stopped elsewhere). There have also been lowland plantings - in Longuza forest reserve and at Manga. Trees from all these plantings are now old enough to fruit, although this has been reported only for Amani, Kwamkoro and Longuza. Second generation *Maesopsis* are also fruiting around Kwamkoro and Amani and many mature trees are now present on the public land bordering the forest reserves.

The situation in the East Usambaras became a matter of concern in the 1980's and establishment of *Maesopsis* as a plantation tree was discontinued in 1981 (AFIMP, 1988a). By this time, spontaneous spread, usually attributed to hornbills had affected most areas of forest above the escarpment and south of Bulwa. Maps based on 1986/7 inventory returns for individuals >20 cm dbh reflect this (Hamilton, 1989). By 1988 it had been decided that efforts be made to eradicate *Maesopsis* from the area where it had been planted at Kwamkoro. Binggeli's (1989) review of the *Maesopsis* situation presented a scenario which highlighted postulated future trends and has greatly increased the drive for management action to reduce the impact of the invader. Binggeli's reconnaissance of the *Maesopsis* situation took place in 1987 and revealed extremely active invasion of forest areas by the species. Logging had been suspended in 1986 but the consequences of operational standards described by Hamilton & Mwasha (1989) as "very poor" during the preceding few years were inescapable. Many gaps were large, high densities of gaps had been created in concession areas, restrictions on activities where gradients were steeper than 60% had often been disregarded and areas within 50 m of watercourses were not left unlogged. Binggeli was able to see many gaps in the early stages of regeneration and the most constant feature was the abundance of *Maesopsis* in them. More recently, pit-sawing has also been effectively regulated and its impact on the forest above the escarpment is currently negligible.

In 1994 areas of forest above the escarpment from Derema to Kwamsambia were visited. Brief visits were also made to the lowland reserves at Longuza and Manga and to the top of the escarpment beyond the 1986 logging area of Kwamkoro Forest Reserve. In the lowland areas there was no evidence of explosive spread of *Maesopsis*. At Manga all trees seen were those originally planted and none appeared to have fruited. At Longuza regeneration was noted within the plantation area but *Maesopsis* was not a major component of the canopy. At the top of the escarpment no *Maesopsis* was seen although there were recent natural tree falls and other open areas. Gaps which were too small, an unsuitable gradient, well developed undergrowth and more rapid colonization by other species, especially another invader (*Clidemia)*, explain its absence. Several tree fall gaps in forest on more level ground in unlogged forest above the escarpment were examined. *Maesopsis* (3 saplings) had only invaded the largest, a multiple fall. Throughout the logged forest *Maesopsis* was present, although only as established trees, mostly 10 - 20 cm dbh. Numbers were higher near the plantation area.

On the public lands passed on the way to the forest reserves, and visited as far north as Maravera, saplings are encountered much more often - especially at the margins of cultivated land and beside recently widened roads. During limited time spent, mostly in transit, on the tea estates, *Maesopsis* was often seen as large groups of well-grown trees, but no areas of new invasion were noted.

3.2 Critical Maesopsis *areas*

Critical areas are seed source areas and invasible areas.

Concentrations of reproductively mature *Maesopsis* are potential sources of seed which could be dispersed over a radius of several kilometres. Most reference to such concentration in the past has concerned the 1913 plantation in the Amani West reserve and the Kwamkoro plantations. Near the 1913 plantings other dense concentrations have had time to develop spontaneously and have been utilized for research purposes not only short-term by Binggeli (1989 - his Site D) but longer term by TAFORI (Experimental Plot 385 - Mugasha, 1980). Areas where spread across the boundary of the Kwamkoro plantation has produced a similar situation are being investigated by N. Geddes. Further potential seed sources are the concentrations of mature *Maesopsis* on estate lands but the extent and location of there has not yet been determined.

With the cessation of logging activities, invasible areas now rarely develop in the forest reserves. Agricultural activity constantly creates invasible sites on the public lands, however. This represents a long term threat in the sense that trees established on public land which reach reproductive maturity will become additional seed sources. If disturbance within the forest increases as a consequence of future management changes, a new phase of active colonization would be probable. In the sense that no part of the Amani Nature Reserve is more than 4 - 5 km from the nearest areas where small-scale agriculture is practised, the whole area is potentially at risk as long as there is no progress in eliminating *Maesopsis* from the public and estate lands as well as the forests.

3.3 Options for plantations and other critical areas

Most discussion of *Maesopsis* eradication has been concerned with Kwamkoro Plantation, apparently mainly because of the publicity attracted by the reversal of planting policy there. The threat to the natural forest of invasion by *Maesopsis* has ceased with the cessation of logging since invasible sites are created much less frequently and on a smaller scale. Nevertheless, there is now an enormous seed source which would ensure explosive spread if disturbance levels rose again within the forest. During the present period of much lessened interference in the forest, the opportunity to reduce the size of the seed source should be taken.

Because the seed source is shared between the forest estate, tea estates and public lands action should be undertaken in all three. TAFORI will need to be persuaded to close Experiments 285 and 385.

3.3.1 Forest and plantation areas

Binggeli (1989) favours mechanized logging for the plantation area and ring-barking of the large individuals which have appeared in natural forest. For the plantation area Seymour (1993) has explored the option of manual harvesting and suggested pit-sawing with three trees processed per pit and about 25 pits per hectare. Both suggestions for this plantation involve high levels of disturbance, even though Seymour's recommendation to use each pit for all trees harvested within 20 m (rather than the usual single tree) was made to reduce site damage.

On the tea estates, Geddes (pers. comm.) has looked at the potential for killing *Maesopsis* with arboricides and by girdling and recorded some success.

There are disadvantages and advantages associated with all the possibilities considered - the logging methods would invite a new pulse of invasion but would generate income. Arboricide and girdling treatments would not create new sites for invasion because the trees treated die and disintegrate gradually - as can be seen at the present time in the treatment areas - but would yield no revenue. It is generally undesirable for chemical treatments to be used in natural communities and the less effective girdling is to be preferred if trees are not harvested.

Based on the views of Binggeli and Seymour three options are therefore available if intervention is carried out:

Option 1 financial investment in labour to treat individual trees

Option 2 mechanized logging or pit-sawing timed to take place when there is little or no fruiting (i.e. April-May) with manual uprooting of regenerating saplings six months later

Option 3 mechanized logging or pit-sawing with provision to re-seed the disturbed areas with indigenous pioneer species.

A further option, mentioned in passing by Seymour (1993) also merits consideration.

Option 4 use of draught animals to extract logs from both plantation and spontaneously developed stands.

The first option is the only one which arises for isolated seed sources well inside the forest. In general there is presently so little successful colonization that the retention or removal of scattered trees will not affect the forest. It may nevertheless be thought appropriate in policy terms to remove all detected *Maesopsis* from the core of the nature reserve. Ring barking would be effective on such trees - as Binggeli (1989) has noted, within well-developed forest light intensity below the girdling point will be low and while epicormic shoots may be produced their persistence is unlikely. The ability of large, old *Maesopsis* to produce epicormic shoots may in any case be very limited although Geddes (1993) found his largest treated individual (47 cm dbh) did produce them.

The remaining options assume trees will be harvested for timber and the hope would be to generate sufficient revenue to pay for the operation. Since *Maesopsis* is of timber value these options ensure an existing resource is not wasted. For both Option 2 and Option 3 a decision is needed between mechanized or manual logging. Mechanized logging has appeal mainly in the plantation at Kwamkoro which is extensive (over 500 ha - Seymour, 1993) and on terrain where there are roads that could be re-opened. The older plantation at Amani could also be harvested by mechanized logging: a short extraction route would be needed but could be put through pasture so no forest disturbance would be involved. The old spontaneous population at the Forest House can be accessed by existing roads. At present these are probably the only areas with sufficient density of stems >35 cm to be attractive to saw mills carrying out their own logging. For the area generally *Maesopsis* is mostly still small (AFIMP 1988b). At Kwamkoro rapid early growth in response to tending has produced stands of large trees (Seymour's figures suggest >100 trees ha^{-1} >35 cm dbh), even though from the late 1970's attention declined and eventually ceased. The Amani populations are of large individuals because they are much older. Despite falling current annual increment after a size of *ca* 20 cm dbh is reached (Mugasha 1980), enough time has passed for these trees to have reached large sizes. Considerable disturbance is inevitable with mechanized logging. Pit-sawing is generally regarded as less damaging because activities can more easily be carried out at single tree level and thinly dispersed. There is nevertheless considerable point damage because of soil disturbance, particularly if a pit rather than a ramp is used. Rolling logs to where they are processed causes additional damage. Seymour (1993) eliminated this by having logs carried but 4 m logs greater than 35 cm mid diameter tend to be too heavy for this. Seymour was also concerned about site damage as pits and suggests rolling up to 20 m to reduce pit numbers. Rolling damage affects established regeneration since a clear path at least 4 m wide has to be made to the pit and 12 - 15 logs could be rolled (not all over the same ground) to a pit processing three trees.

Option 2 anticipates harvesting with disturbance accepted but applying measures to prevent the re-occupation of the site by *Maesopsis*. If undertaken as a commercial operation mechanized logging would be expected to cut all trees >35 cm and pit-sawing all trees >30 cm. If the two were sequenced with initial mechanized logging removing the larger trees, pits for manual processing could be positioned in areas already disturbed. The number of trees to be pit sawn would be moderate, overcoming the problem foreseen by Seymour of finding sufficient pit-sawing expertise. Trees smaller than 30 cm dbh would have to be cut or girdled by the management authority.

Under this option the timing of intervention is important. Logging during April and May is recommended although these are months of heavy rainfall. Information available suggests this is the period when the trees are least likely to be fruiting so there should be no immediate influx of *Maesopsis* seed to the disturbed area. Seed rain from other species should contribute to early restoration of vegetation cover. A follow up operation is needed. This would be six months after exploitation and involve uprooting saplings developed from previously dispersed seed or released by canopy removal. At the same time any coppice shoots from stumps or girdled trees should be cut. If care is taken to minimize damage to other species these should be able to suppress any residual *Maesopsis*.

Option 3 is based on the same harvesting rationale. In this case a stand of one or more alternative and indigenous pioneer species would be created by sowing on sites disturbed in the logging process. These pioneers would occupy the sites before a new generation of *Maesopsis* could appear. This has the advantage over Option 2 of being feasible at drier times of year more suitable for logging. There are disadvantages, however, due to lack of available basic biological information. It is unclear whether there is an important seed bank of woody species in the forest soils of the Amani area. The investigation of Binggeli et al. (1989) found little evidence. It could not detect ability for a seed to remain viable for periods in excess of one year because only four months passed between soil sampling and the conclusion of the study. There is no tradition of forestry seed stores holding stocks of the seeds of pioneer species because they have little or no timber importance and little information on their phenology has been gathered. It is likely that observations made in areas with more strongly seasonal climates do not apply at Amani and that year-to-year variation is quite marked, as it seems to be in the flowering and fruiting of *Maesopsis*. Times and methods for seed collection have to be determined. However, pioneers are all species which produce seed frequently and copiously. Once a programme of phenological observation is initiated the problem of seed supply should be quickly solved, probably within one year. Binggeli has already drawn attention to the potential of indigenous pioneer species as nurse trees, naming eleven. Three he lists (*Harungana*, *Macaranga* and *Polyscias*) are appropriate as species to sow to accelerate site recovery. *Albizia gummifera* , *Bersama* and *Zanthoxylum gilletii* are additional possibilities.

Option 4 is an idea tentatively put forward by Seymour (1993) but not developed because it would be innovative in the Amani area. It is attractive for removing large trees which have become established singly in the natural forest at Amani and Kwamkoro. Individual trees can be extracted in more heterogeneous terrain than by mechanized logging and no pits or ramps need to be made. The effect would involve more damage than the girdling recommended by Binggeli but still would be at an intensity sufficiently low for early site recovery and minimal site impact. Revenue would accrue from the extracted logs. There is experience of logging with draught animals at Sokoine University of Agriculture (Department of Forest Engineering) and they have been used in the University Forest on Mount Meru. Using draught animals for logging is a procedure clearly acceptable in areas of high biodiversity value.

3.3.2 Tea estate and public land

Removal of *Maesopsis* from public and tea estate land will concern trees mostly too small to interest pit-sawyers or sawmills. The tea estates are already examining the problem, having provided the population used for arboricide tests and having used *Maesopsis* as a fuelwood. Studies aimed at identifying an economically acceptable control strategy are in progress with the encouragement of the tea estates and it would be inappropriate to make independent suggestions. What is more important is that measures on the tea estates and elsewhere in the area be synchronized. There should be continuing liaison between the Catchment Project and the tea estates on progress in halting and reversing the spread of *Maesopsis*.

The public lands are the main area where spread is currently active, an inevitable consequence of the soil and vegetation disturbance when fields are prepared for crops in areas receiving *Maesopsis* seed rain. Most trees are young but unless they are considered obstructions they will be left to grow to reproductive maturity. This is because not being natural to the area no use-value has been given to them by the local community. In fact, while *Maesopsis* is viewed in forestry circles as a good utility timber, in the Amani area people are more familiar with higher quality indigenous woods, and continue to seek these. It is unlikely that the local community will take any action specifically to control *Maesopsis* in the foreseeable future. The effort of cutting a tree is only justifiable if it provides material that can be used. There is clearly an opportunity for a Project initiative here in the form of extension work. The local community has shown environmental consciousness in several respects already and there is no reason to doubt their ability to understand the significance of the *Maesopsis* problem if it is described to them. The wood can be used and the promotion of carpentry producing household furniture and other items is a possibility. This should be reinforced by some demonstration activities organized by the Project - perhaps setting up a workshop for the purpose. The Malaysian success in creating a timber industry based on rubber wood, when new clones replaced old in the 1980's, illustrates what can be achieved with an unfamiliar material given suitable promotion.

3.4 Natural spread

The spread of *Maesopsis* has been a process recognized at Amani for many years and was probably first reported by Moreau. The size class distribution for the species given in AFIMP (1988b) indicates most trees are still small and young. The AFIMP map shows considerable spread beyond the areas initially planted. It seems likely that this has largely followed the Kwamkoro plantings. The Kwamkoro planting was on a large scale. Invasion has particularly affected the areas logged since the early 1970s which would have been when planted trees at Kwamkoro began to fruit.

Disturbance within the forest is the principal factor leading to spread. Initial spread at Amani was over a fairly short distance to forest close to the research station, where some disturbance can be assumed. Binggeli (1989) notes that more favourable sites for *Maesopsis* establishment arise where there is human activity and *Maesopsis* spread continues on the public land. Within the forest reserves there is little evidence of rapid proliferation because large logging gaps exposing suitable bare humus soil are not arising. Multiple tree falls occur where there is some invasion occur, but are rare.

Old trees in an advanced state of senescence or standing but dead are of acknowledged conservation significance. However, where they are numerous and many fall because of a severe storm event or within a short time interval there may be extensive gap creation. A feature of parts of the unlogged forest is a relatively high density of unusually large (>1 m dbh) *Ocotea usambarensis* in this state. These are likely to be survivors of *Ocotea* stands that occupied cleared land over 200 years ago. They are large enough to produce gaps vulnerable to *Maesopsis* invasion if they fall naturally. A proportion might be felled piecemeal to minimize damage to the associated vegetation cover and control the timing of loss from the canopy. Enough could be left to meet conservation needs. Decisions about possible action should be based on a formal survey of their distribution.

N. Geddes (pers. comm.) has been assessing outward spread of *Maesopsis* from the Kwamkoro plantations. Preliminary results show spread of *Maesopsis* in quantity to points approximately 1200 m away but much less to points 1800 m away. At present there is no information on the interval between these points. This spread is estimated to have been achieved in 15-20 years and spontaneous trees throughout the invaded area are now large enough to fruit. Over the whole range examined (4000 m) there are large trees, suggesting dispersal has come from the plantation in a single phase. Most successful establishment is close to the plantation, presumably because more seeds were deposited here and few seeds were carried beyond 2000 m. There is no clear evidence of large numbers of *Maesopsis* being actively recruited to pole size. Geddes offers a preliminary interpretation that the population was established when freshly disturbed sites were present and is no longer expanding. In the smaller size classes (<2 cm dbh and >1.3 m in height) *Cephalosphaera* and *Allanblackia* were more numerous. However, this may be because these species are slower growing and have accumulated over a much longer period. Their rates of recruitment to this size class may be lower than that of *Maesopsis*. Geddes' research also includes observations on pole-sized (5-10 cm dbh) individuals and he expresses concern that there is heavy pole-cutting pressure. *Maesopsis* is disregarded while *Cephalosphaera* and *Allanblackia* are preferentially taken. In this size class, *Maesopsis* is presently more numerous than the others named. Even with control over *Maesopsis*, the impact of pole-cutting on the other species is a matter of management concern. The cutting pressure should be reduced by creation of alternative pole sources or measures making *Maesopsis* poles more acceptable by preservative treatment or charring of the basal 50 cm to make them more durable in contact with the ground.

3.5 Tree regeneration in invaded areas

Binggeli (1989) lists a number of species he thinks could be displaced by *Maesopsis* and, assuming primary forest species would not regenerate under *Maesopsis*, predicts a "worst case scenario" of a 50% *Maesopsis* canopy over the East Usambaras in 200 years. It does not appear that this process is underway. There is abundant regeneration of indigenous pioneers, especially *Polyscias* and *Macaranga* with the *Maesopsis* that has become established in gaps. Determining the relationship of *Maesopsis* with the regeneration of primary forest species is more difficult. Even in the least disturbed forest the overall density of saplings is low and primary forest species are not normally gregarious. Extensive data sets are needed to allow a proper evaluation. There is need to monitor stand development to decide longer-term trends. Already, however, Geddes has confirmed that considerable numbers of non-pioneers, including *Cephalosphaera* and *Allanblackia*, are present beneath the *Maesopsis*. There is no doubt that some are of recent establishment and not simply part of a long-standing seedling bank. Observations suggest healthy growth of non-pioneer species within *Maesopsis* plantations but little or no representation of *Maesopsis* saplings. At present there is no evidence that *Maesopsis* retains sites. The general pattern of succession is broadly consistent with the single generation process described by Eggeling (1947) for Budongo. There is no evidence to support the contention (Binggeli & Hamilton, 1990) that the soil changes, which take place as *Maesopsis* stands develop, inhibit the regeneration of primary forest tree species.

4 FURTHER INVESTIGATIONS

The suggestions of further studies are divided into three categories: monitoring, information needs and experimental research.

4.1 Monitoring

4.1.1 Identification of areas needing monitoring

It is apparent that there has so far been no attempt to unify information on areas in and around the East Usambaras where *Maesopsis* has been deliberately planted. It is suggested this be done through a simple questionnaire presented to forestry staff asking them to list localities where they know planting was carried out. They should be asked what the plants were used for - plantation, enrichment, tea estates, to private land owners, for agroforestry, for trials, for research plots - and when the plants were supplied. It is preferable that this information be collected on a face-to-face interview basis and not by mail. Nursery staff should be asked if the nurseries where they now work, or worked previously, raised any *Maesopsis*. If *Maesopsis* was raised they should be asked when and where the seedlings were taken for planting.

4.1.2 Extent of major *Maesopsis* stands

There are several sets of air photo cover for the East Usambaras and the images cover public and estate land as well as the forest reserves. One set is very recent. The recent set should be interpreted specifically in terms of *Maesopsis* stands and a map of these made as a baseline for deciding priority areas if a removal policy is adopted. When areas now occupied by *Maesopsis* have been identified, older photo cover should be consulted to clarify the history of those stands.

4.1.3 Field-based monitoring

There should be continuing monitoring of tree species populations in planted and invaded areas. In Kwamkoro it is suggested that a set of replicate permanent sample plots be established in the plantation and another set in the invaded forest. Three 1 ha plots in the 1966 planting area should be established within the plantation, one incorporating Seymour's research site so that some idea of long-term response to the pit-sawing activity can be gained. Four 1 ha plots outside the plantation, two at a distance of 1000 m and two at 2000 m should be established. The Geddes transect area would be suitable for these. In monitoring, emphasis should be on small trees and recording of reasonable numbers of saplings of indicator species should be attempted. On the first assessment all trees >5 cm dbh should be mapped and labelled and smaller ones recorded in the vicinity of each of 16 points at intersections of a 20 m x 20 m grid imposed on the plot (disregarding points at the boundary). At each point the nearest 10 individuals in each size class (>50 cm <1 m tall; >1 m tall < 2 cm dbh; >2 cm dbh <5 cm dbh) should be labelled and the identity and size recorded. Size will be expressed as a height for the first size class, and dbh for the third. Both parameters should be recorded for the intermediate class. Assessments after the first will record the persistence and, it still alive, size of trees labelled previously and extend labelling and recording to new recruits. Some will move to higher size classes. New recruits in the small size classes will be any appearing among those previously labelled. To keep a minimum sample size of 10 at each point plants further from the sample centre than the original group may need to be included.

4.2 Information needs

4.2.1 Pioneer seeds

To make adoption of Intervention Option 3 (p. 15) realistic observations should be initiated on the phenology, particularly fruiting times, of the key pioneer species *Albizia gummifera*, *Bersama abyssinica*, *Harungana madagascariensis*, *Macaranga capensis*, *Polyscias fulva* and *Zanthoxylum gilletii*.. Individuals of similar size in the dbh classes 5 - 10 cm, 10 - 15 cm, 15 - 20 cm and 20 - 30 cm should be observed. As far as possible 5 individuals of each size class of each species should be monitored in a given landscape position. The landscape positions are ridges, slopes and valleys. Observation will thus be made on 15 individuals of each size class for species with a wide ecological amplitude found in all three landscape positions. The five individuals should be in separate locations. Observation should be made on a fortnightly basis. When fruiting is observed arrangements should be made to collect seed in quantity. Seed should be air-dried and stored in closed containers at ambient temperature. Viability should be checked at three month intervals for at least three years or until all seeds tested prove dead (whichever is earlier).

4.2.2 Phenological studies of *Maesopsis*

Following the pattern described in 4.2.1 above, comprehensive records of *Maesopsis* phenology should be assembled. There should also be tests of the viability of the seed after different periods of storage.

4.2.3 Confirming the origin of Amani *Maesopsis*

It would be advantageous to clarify where the original seed brought to Amani originated. This could be done by electrophoresis methods. It should be part of a study including material from *Maesopsis* introduced to other parts of Tanzania and indigenous trees from the Bukoba area. Material from other parts of the range would be needed - liaison with other national forest services would be required. Attempts should be made to include material from at least two locations in each of the three main areas of concentration (see 2.2.1 - 2.2.3 above) and as many of the isolated and outlying populations as possible.

4.3 Seed and seedling population dynamics

A series of seed bank/seed rain/seedling population study plots should be set up. Preferably these would be in association with the *Maesopsis* permanent sample plots but even if no *Maesopsis* permanent sample plots are established it is important that seed/seedling dynamics are investigated in the field. The soil seed bank should be investigated by blocking or continually removing seed input to replicated small sample plots. Sets of replicates should be blocked for different time periods over 2 years (12 at 2 months intervals or 8 at 3 months intervals). Seed rain should be collected and assessed (all species) throughout the period and seedlings (all species) present at the start should be labelled and their persistence and growth recorded. As new seedlings appear these should also be labelled and monitored in the same way. This will show if there is a seed or a seedling bank and indicate any marked differences between the species in this respect. Depending on the expertise and funding available to carry out such a study the design could be extended to include a gap creation event so that any contrast in the dynamics of seeds and seedlings in gaps and under a canopy can be determined.

4.4 Field survey

4.4.1 Old trees

A survey of trees >1 m dbh should be carried out in the Kwamsambia/Kwamkoro reserve area. There would be a 100% enumeration and mapping of trees of this size. An extensive area, at least 20 ha, would be covered. This would be a block including 20 m of the slope at the top of a 400 m length of the escarpment and extending back through the unlogged forest on the plateau. Each tree enumerated would be named and its diameter, height and condition recorded. Standing dead trees would be included. The enumeration returns should be compared with those for other tropical forest areas to check if the numbers of large trees are unusually high.

4.4.2 Intensifying the *Maesopsis* transect work

Information has already been collected from a broad belt of forest extending from the Kwamkoro plantation boundary towards the northwest. Sixteen sampled strips in groups of 2 to 5 cross this belt. Within the groups an interval of 150 m separates strips. Wider intervals, 450 m, separate the groups. The data, collected by N. Geddes and still being processed, have proved very informative where the status of *Maesopsis* in invaded forest is concerned but need consolidation by extending sampling to the un-assessed 450 m gaps between the groups of strips, particularly at a distance of 1300 - 1800 m from the plantation where the prominence of *Maesopsis* has proved to change markedly over a short distance. The transect area is well characterized and will be useful for future monitoring. It might be a valuable indicator of any spread of *Maesopsis* from public land into the forest. If the full complement of 26 strips at 150 m intervals were enumerated, a robust monitoring plan for the area most suited for long-term *Maesopsis* study could be prepared.

5 CONCLUSIONS

1. *Maesopsis* is not spreading through the forests as actively as it was while logging operations were taking place in the area.
2. A large reservoir of *Maesopsis* is present on public and tea estate land.
3. There is uncertainty about where *Maesopsis* has been planted in the East Usambaras because no attempt has been made to unify the scattered and poorly documented records of plantings.
4. There is no clear evidence that *Maesopsis* will retain sites now occupied. Indications are that the succession will broadly be as in Uganda - a floristic change after one generation.
5. There are well represented populations of indigenous pioneer species in areas invaded by *Maesopsis*.
6. There is no clear evidence that regeneration of primary species is suppressed or prevented where there is a *Maesopsis* canopy.

6 RECOMMENDATIONS

1. Although the rate of spread of *Maesopsis* into the forest appears to have declined complacency is not advisable. A change in management policy could provoke renewed invasion and the seed source in nearby public land is increasing. Intervention to remove mature trees is desirable but should apply on public and estate land as well as to forest reserves.
2. There should be logging of *Maesopsis* at Amani and Kwamkoro. There is justification for using mechanized logging, pit sawing and extraction by draught animals depending on which stands and which sizes of trees are to be harvested.
3. A questionnaire survey should be used to clarify where *Maesopsis* has been planted.
4. Extension activity should be devised to encourage local people to cut *Maesopsis* on public lands and make use of it
5. An accurate map of the location of dense stands of *Maesopsis* should be prepared from the recent air-photo cover of the East Usambaras.
6. More permanent sample plots should be established in *Maesopsis* stands and in monitoring change within these emphasis should be on the dynamics of the regeneration of *Maesopsis* and other species.
7. The viability of *Maesopsis* seed should be determined by formal seed testing procedures.

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TABLES

Table 1. Representative localities for Maesopsis eminii *by country*

Locality	Co-ordinates	Voucher specimen	Reference
Angola			
Buco Zau	4°45'S, 12°32'E	Gossweiler 6526	Exell & Mendonça (1954)
Pango Munga	5°03'S, 12°30'E	Gossweiler 6465	Exell & Mendonça (1954)
Sumba, Peco	6°15'S, 12°30'E	Gossweiler 8645	Exell & Mendonça (1954)
Kenya			
Kakamega	0°15'N, 34°52'E	Machin 864	Johnston (1972)
Sudan			
Talanga	4°02'N, 32°45'E	-	Jenkin et al. (1977)
Tanzania			
Minziro	1°00'S, 31°50'E	-	Eggeling & Harris (1939)
Kikuru	1°04'S, 31°38'E	-	Eggeling & Harris (1939)
Ukerewe	2°03'S, 33°00'E	Conrads 5313	Johnston (1972)
Ussui	2°25'S, 31°15'E	Braun, Hb. Amani 5537	Johnston (1972)
Urinza	5°10'S, 30°20'E	Procter 303	Johnston (1972)
Uganda			
Budongo	1°47'N, 31°35'E	Dawe 783	Eggeling & Harris (1939)
Bugoma	1°20'N, 31°05'E	-	Howard (1989)
Itwara	0°48'N, 30°28'E	-	Howard (1989)
Mabira	0°30'N, 32°57'E	-	Howard (1989)
Najembe	0°24'N, 33°01'E	Dawkins 569	Johnston (1972)
Lolui Island	0°07'S, 33°42'E	Jackson 1144	Johnston (1972)
Kasyoha -Kitomi	0°15'S, 30°15'E	-	Howard (1989)
Kalinzu-Maramagambo	0°30'S, 30°00'E	-	Howard (1989)

Sango Bay	0°51'S, 31°42'E	-	Eggeling & Harris (1939)
Bwindi	1°05'S, 29°35'E	-	Howard (1989)
Zaire			
Tukpwo	4°26'N, 25°51'E	Gérard 404	Évrard (1960)
Boketa	3°10'N, 19°48'E	Evrard 1174	Évrard (1960)
Yangambi	0°46'N 24°27'E	Louis 7193	Évrard (1960)
Rutshuru	1°11'S, 17°40'E	Ghesquière 6666	Évrard (1960)
Nioki	2°43'S, 29°35'E	Flamigni 7090	Évrard (1960)
Kiaka	5°26'S, 14°59'E	Devred 1044	Évrard (1960)
Mvuazi	5°27'S, 14°54'E	Devred 125	Évrard (1960)
Luki	5°38'S, 13°04'E	Toussaint 89	Évrard (1960)
Kiobo	5°38'S, 13°07'E	Donis 365	Évrard (1960)
Musangana	5°48'S, 22°56'E	Collier 282	Évrard (1960)
Gandajika	6°45'S, 23°57'E	Chalon 737	Évrard (1960)
Kaniama	7°31'S, 24°11'E	Mullenders 1816	Évrard (1960)
Kamina	8°44'S, 25°00'E	Risopoulis 384	Évrard (1960)
Likasi	10°59'S, 26°44'E	Hoffman 283	Évrard (1960)
Zambia			
Kapweshi	10°00'S, 28°50'E	Lawton 1332	Lawton (1969)

Table 2. Rainfall and temperature regimes associated with ferric orthosols at Amani and in the Lake Victoria basin

Rainfall

	J	F	M	A	M	J	J	A	S	O	N	D	Year (total)
Amani	80	77	171	347	322	111	100	99	105	161	163	168	1904
Bukoba	149	157	246	363	316	85	51	81	108	134	161	189	2040
Fort Portal	44	79	144	196	145	81	63	122	182	215	167	92	1530
Hoima	30	69	119	170	147	87	103	151	181	179	134	65	1435
Jinja	79	54	120	191	122	49	65	90	92	179	150	81	1272
Kisumu	57	60	160	195	177	101	68	96	79	64	106	105	1278
Masindi	40	56	118	153	146	96	115	137	138	137	113	59	1308

Source: FAO (1984)

Mean temperature (°C)

	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year (mean)**
Amani (911)*	22.7	23.1	22.9	21.7	20.4	19.1	18.2	18.1	18.7	19.9	21.5	22.2	20.7
Bukoba (1137)	21.3	21.5	21.5	21.4	21.3	21.1	20.5	20.5	20.9	21.3	21.3	21.3	21.2
Fort Portal (1539)	19.0	19.5	19.5	19.7	19.3	18.7	18.3	18.7	18.6	18.7	19.0	19.0	19.0
Hoima (1158)	23.6	24.2	24.0	23.0	22.5	22.0	22.0	21.5	21.7	22.0	22.5	22.6	22.6
Jinja (1173)	22.5	22.7	23.2	22.7	22.1	21.5	21.0	21.5	22.0	22.5	22.5	22.3	22.2
Kisumu (1146)	23.8	24.2	24.1	23.3	22.7	22.2	21.8	22.0	22.2	23.7	23.8	23.6	23.1
Masindi (1147)	23.8	24.1	23.5	23.5	22.7	22.5	21.5	21.5	21.8	22.7	22.7	23.0	22.8

***elevation (m)**

Source: FAO (1984)

Table 3. Individuals ha^{-1} of Maesopsis eminii*, exceeding the diameter at breast height (dbh) indicated in East and Equatorial Africa*

dbh	1*	2	3	4	5	6
> 10	0.3	_	45.1	_	_	2.8
> 20	0.1	_	44.4	59.2	_	2.1
> 30	0.1	0.6	38.1	56.4	_	2.1
> 40	0.1	0.4	24.0	52.2	19.0	1.4
> 50	0.1	0.3	4.9	36.0	16.9	0.7
> 60	0.1	0.3	1.4	18.3	14.1	0
> 70	0.1	0.1	_	_	_	0
> 80	0.1	0.1	_	_	_	0
> 90	<0.1	<0.1	_	_	_	0
>100	_	<0.1	_	_	_	0
Individuals Observed	58	15	64	84	27	4
Reference	Anon 1960	Jenkin et al. (1977)	Eggeling (1947)	Eggeling (1947)	Eggeling (1947)	Eggeling (1947)

*1, Bugoma Central Forest, Uganda (conventional inventory)

2, Talanga, Sudan (convetional inventory)

3, Budongo Sample Plot 2 (colonizing forest, 30 - 40 years);

4, Budongo Sample Plot 3 (colonizing forest, 50 - 60 years);

5, Budongo Sample Plot 4 (colonizing/mixed forest ecotone, 60 - 150 years);

6, Budongo Sample Plot 11 (swamp forest)