Biological invasion by Maesopsis eminii in the East Usambara forests, Tanzania

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Following the introduction of the tree *Maesopsis eminii* to the East Usambara mountain range (Tanzania) early this century and large scale planting in the 1960s and 1970s, the species is invading gaps in the endemic-rich natural forests.
Maesopsis alters the forest ecosystem. Its impacts include: reduced regeneration of primary forest trees, increased frequency of introduced species of plants, thinner leaf litter, increased soil erosion, decreased organic matter in the topsoil and reduced diversity in the soil microfauna.
The susceptibility of the East Usambara forests to biological invasions, which contrasts with that of other continental moist tropical forests, may result from their long isolation and small size, as is the case with forests on tropical oceanic islands.
There is evidence of a local climatic change towards greater warmth and less reliable rainfall which may affect the rate of spread of *Maesopsis*.
Maesopsis is considered a threat to the survival of endemic species and degrades catchment quality. The need to control *Maesopsis*, including the replacement of *Maesopsis* plantations by sustained-yield forestry of native species, has been accepted by those concerned with forest management on the range, but selection of suitable strategies to implement this policy have yet to be agreed.

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The East Usambara range and forests

The eastern flank of the East Usambara range of low mountains (highest peak 1506 m) in north-eastern Tanzania is only 40 km from the Indian Ocean. The range consists of Precambrian gneisses, with some granulites. There is a main block and three isolated mountains to the east. The main block rises abruptly from the lowlands at 150–300 m and is bound on all sides by steep escarpments, levelling off at about 900–1050 m onto a deeply dissected plateau, which is most extensive in the south. There are two rainy seasons, March-May and October-December, with higher rainfall towards the south-east (max. 2000 mm yr^{-1}). The mountains form a major catchment, including for water supply to the coastal town of Tanga. The temperature/altitude relationship is abnormally steep for East Africa, due to abnormally low maximum temperatures at higher altitudes, where mist can be persistent (probably especially before about 20 years ago). The soils are deep, reddish clay-loams, with nutrients concentrated in a topsoil less than 20 cm deep. Forest topsoils above 850–900 m are markedly acidic (pH 3.5–5.5, compared with lowland soils – pH 6–7), and exceptionally strongly leached.

Forest vegetation forms an altitudinal continuum. The most frequently occurring species in each of four forest types recognized by a TWINSPAN classification of 65 plots placed along three altitudinal transects are shown on Tab. 1. For common descriptive purposes it is, however, convenient to recognize two forest types, lowland and submontane; the (arbitrary) altitudinal boundaries between them can be taken as lying at ca. 850 m. Lowland forests are semi-deciduous and typically have three tree layers at 35 m (emergents), 15–25 m and <15 m. Trees in the submontane forests are evergreen, they often have long straight trunks and are sometimes very tall (maximum measured 65 m): there are typically four ill-defined layers of woody plants at 40–60 m (emergents), 20–30 m, 10–20 m and <10 m.

The East Usambara range is one of a chain of mountains in eastern Tanzania and south-eastern Kenya known as the Eastern Arc Mountains, which are famous for the high levels of regional and local endemism in their forest flora and fauna (Rodgers & Homewood 1982; Hamilton & Bensted-Smith 1989; Iversen 1990). The lowland forests of the East Usambaras can also be seen as constituting a relatively sizable remnant of a highly fragmented belt of lowland forest running close to the East African

Tab. 1. Most frequent tree species in four forest types in the East Usambara range, according to a TWINSPAN analysis. Species are in order of declining frequency. Source and further information in Hamilton & Bensted-Smith (1989).

Forest type	Altitudinal range (m)	Species composition
1	290– 600	*Albizia glaberrima, Celtis* spp., *Antiaris toxicaria, Milicia excelsa, Terminalia sambesiaca, Zanha golungensis, Grewia goetzeana, Bequaertiodendron natalense, Ricinodendron heudelotii.*
2	280– 870	*Pachystela msolo, Trilepsium madagascariense, Leptonychia usambarensis, Funtumia africana, Antiaris toxicaria, Ficus* spp., *Milicia excelsa, Ricinodendron heudelotii, Tabernaemontana* spp., *Macaranga capensis.*
3	670–1040	*Myrianthus holstii, Allanblackia stuhlmannii, Trilepsium madagascariense, Odyendea zimmermannii, Pachystela msolo, Antidesma membranaceum, Leptonychia usambarensis, Trichilia dregeana, Afrosersalisia cerasifera, Strombosia scheffleri.*
4	900–1220	*Isoberlinia scheffleri, Allanblackia stuhlmannii, Cynometra* spp., *Sorindeia madagascariensis, Newtonia buchananii, Cola* spp., *Strombosia scheffleri, Beilschmiedia kweo, Maesopsis eminii, Odyendea zimmermannii, Syzygium guineense.*

coast, from Kenya to Mozambique. These lowland forests also show high levels of regional and local endemism (Dale 1939; Hawthorne 1984).

The remaining forests of the East Usambaras are small in size (ca. 23000 ha) and are seriously threatened by forest destruction and degradation consequent to the spread of agriculture, logging and other activities. Achievement of good management of these forests is one of the most pressing conservation issues in Africa today. Unfortunately the integrity of the natural forest ecosystems is additionally threatened by invasion by exotic species (Tab. 2). One of the most serious of these is *Maesopsis eminii* Engl. The research on *Maesopsis* and on the invaded forests has been reported in detail in Hamilton & Bensted-Smith (1989).

Maesopsis eminii (Rhamnaceae) is a large African rain forest tree which can reach 43 m in height and a trunk diameter of 1.26 m (Eggeling 1947). It occurs naturally throughout west and central Africa, from Liberia to western Kenya (Kakamega Forest). It is commonly considered a lowland tree, but does occur in submontane forest (e.g. *Parinari*-rich forest) in central Africa. It is a fast-growing, light-demanding tree and generally considered a pioneer (Eggeling 1947; Taylor 1960). It is favoured in Uganda for planting for forest enrichment following intensive extraction of timber and fuelwood (Earl 1968). The wood is firm but strong and is regarded useful for internal building purposes and everyday furniture; it is not resistant to termites, but is permeable to preservatives.

Maesopsis eminii, along with some of the other invasive plant species, was introduced to the East Usambara by the Germans, who established a major biological and agricultural research station on the range in 1902. About 900 species of, mainly, trees and shrubs were planted, essentially to identify potentially useful plants for the colonial economy. A plantation of *Maesopsis* of ca. 1 ha was established at Amani (900 m altitude) in 1913 (Wood 1966) and there was also a plot at Longuza (160 m altitude). *Maesopsis* was found to grow well at both sites. Later, during the 1960s and 1970s, *Maesopsis* became widely planted after logging in Kwamkoro Forest Reserve on the southern plateau of the main range (altitude ca. 900–1000 m) as a nursery tree for the Eastern Arc endemic timber species *Cephalosphaera usambarensis*. Today, plantations and self-sown areas of *Maesopsis* at Kwamkoro have a similar appearance, with virtual mono-dominance of evenly-sized *Maesopsis* trees, and are difficult to distinguish.

Biology and mechanism of spread

Maesopsis flowers when young. In forestry, *Maesopsis* has been noted to flower under favourable conditions only 4–6 years after planting, although trees arising from natural regeneration were first seen to bear fruits at the age of 10 years (Karani 1968). The fruits of *Maesopsis* are quite large, 2–3 cm long, weigh 2 g, have a soft fleshy exocarp around a hard mesocarp and contain only one seed. The seeds are 1.2 × 0.6 cm in size and weigh 0.2 g. The peak of fruiting in the East Usambaras is about August, a time when hornbills, which are believed to be the main dispersers, occur in great abundance (Moreau 1935, 1937; Moreau & Moreau 1941). There are two species of hornbills in the East Usambara forests, the trumpeter *Bycanistes bucinator* and the silvery-cheeked *B. brevis*, the former mainly in lowland forest and the latter only in submontane forest (Rodgers & Homewood 1982; Stuart 1983). Just 15 years after the introduction of *Maesopsis*, P.J. Greenway stated on a herbarium sheet that it was "being spread by hornbills in all forest clearings around Amani" (Båtvik pers. comm.). Moreau (1935) made the observation that *B. brevis* swallow the fruit of *Maesopsis* and the tree "is being disseminated over a radius of several miles from Amani by the birds. Actually although the plantation is a small one [it was ca. 1 ha] it apparently provides the staple food for about fifty of the great hornbills for six weeks in the year." Two other potential dispersers of *Maesopsis* are the bird *Tauraco fischeri* and the fruit bat *Eidolon helvum*, which is very common, at least seasonally. Monkeys also eat the fruits and drop them locally. In Uganda Dawkins (pers. comm.) observed that at least a dozen animals, including bats, monkeys and many bird species, disperse the fruits.

Tab. 2. Some invasive plant species in the East Usambara forest. (Source Hamilton & Bensted-Smith 1989).

Species	Family	Status
Trees:		
Albizia chinensis	Mimosaceae	submontane forest, infrequent
Cedrela odorata	Meliaceae	lowland and submontane forest infrequent
Ficus altissima	Moraceae	lowland forest, not common
Hevea brasiliensis	Euphorbiaceae	lowland forest, infrequent
Hura crepitans	Euphorbiaceae	lowland forest
Hovenia dulcis	Rhamnaceae	submontane forest, local (near Amani)
Maesopsis eminii	Rhamnaceae	lowland and submontane forest. Locally very common in submontane forest; less common in lowland forest
Melia azedarach	Meliaceae	lowland forest, locally very common (Kwamsambia)
Millettia dura	Papilionaceae	submontane forest, locally common
Spathodea campanulata	Bignoniaceae	submontane forest occasional
Shrubs:		
Clidemia hirta	Melastomataceae	mainly submontane forest, very common
Lantana camara	Verbenaceae	lowland and submontane forest
Rubus niveus	Rosaceae	
Rubus rosifolius	Rosaceae	submontane forest, locally common

Our observations show that great quantities of fruits fall close to parent trees, but additionally suggest that fruits are dispersed rather efficiently and evenly throughout the natural forest, as indicated by the common occurrence of isolated seedlings far from potential parents in the natural forest of Amani-Sigi. Taylor (1960) made similar observations of dispersal in Ghana.

Maesopsis requires tree fall-gaps for establishment in the natural forest and is extremely competitive in this context in comparison with other gap species in the East Usambara forests. Growth rates of young plants can be very high under full light and when water is plentiful. Experimental work elsewhere shows that seeds do not have long-term dormancy, only 10% of seeds in one trial, for instance, remaining viable after 6 months (Yap & Wong 1983). Light is not required for germination and indeed germination can be enhanced by burial in the soil, presumably because of greater moistness. We compared germination of seeds laid out on the soil surface and buried at a depth of 3 cm; 5% of the former had germinated within one month, compared with 52% of the latter (no. of seeds in each trial = 120; both treatments irregularly watered at the same times). Seedlings (less than one year old, judging by lack of lignification) up to ca. 20 cm tall can be found even under dense forest. We counted a very high density of 805 individuals per square meter at one moderately shaded site in Amani West Forest Reserve. However, saplings (over ca. 0.5 m tall) are confined to gaps and occur at much lower densities. We recorded the survival of self-sown seedlings at three sites (open, partial shade, shade) with paired plots at each (watered, unwatered). Measurements extended from February 1 to May 20 1987, a period which was dry until April, when the rains started. Overall, mortality was higher in unwatered plots. Seedling survival was higher in the shaded plots during the dry period (90–95%) compared to unshaded plots (80–85%), but thereafter declined much more sharply in the shade (25–35% by May 20) than in the open (75–85%). Seedlings in the open started to grow appreciably when it rained, but those in the shade remained at ca. 18 cm, the height which presumably can be supported by the food supply in the seed. Partially shaded plots gave generally intermediate results. We conclude that both water and light are required for *Maesopsis* to grow beyond the seedling stage and that the thickening of the canopy in the rainy season creates additional shade which kills off *Maesopsis* seedlings.

We studied *Maesopsis* in gaps (both natural and the sites of pit-sawing operations) of different ages. The origin of natural gaps in a sample examined was: trunk breakage (51%), uprooting (35%), branch fall (7%), death while standing (7%) (n = 98). The date of younger gap formation was determined by records of pitsawing or examining tree rings, which we showed to be approximately annual in *Maesopsis* and some other species up to an age of ca. 15 years (older rings in *Maesopsis* are hidden by apparent deposition of secondary material). The presence of gaps over ca. 15 years was determined by a combination of indicators, such as the presence of long ridges of organic matter (along the lines of old logs), the presence of the shrub *Dracaena steudneri* (which becomes established in gaps and thereafter can persist under shade), the presence of lines of big *Maesopsis* trees (established along the line of fallen trunks) and the presence of stilt roots (the great majority of which, in these forests, are formed by the establishment of tree seedlings on logs of fallen trees, with roots descending to the ground (Binggeli in prep.)).

Our results showed that *Maesopsis* is spreading into gaps even in forest apparently undisturbed by man. For example, *Maesopsis* is present at all altitudes in Amani-Sigi Forest Reserve, which has not been logged and seems to be little disturbed in other respects. Seed germination occur on bare humus soil and seedlings can sur-

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Our results showed that *Maesopsis* is spreading into gaps even in forest apparently undisturbed by man. For example, *Maesopsis* is present at all altitudes in Amani-Sigi Forest Reserve, which has not been logged and seems to be little disturbed in other respects. Seed germination occur on bare humus soil and seedlings can survive for a few months regardless of light conditions, but they will only grow on to become saplings and young trees where there is full light. Saplings and trees of *Maesopsis* tend to occur around the sites where fallen trunks once stood and along the lines of the fallen trunks, and to be absent from areas of crown debris. Saplings can grow up to 3 m per year and therefore outcompete all native species in tree-fall gaps. There has been an intensification of the rate of colonisation with time. In one region we determined that 40–62.5% of younger (< ca. 15 years old) gaps contain *Maesopsis*, compared with 2–8% of older gaps. *Maesopsis* is not a short-lived pioneer, Eggeling's (1947) data suggest that *Maesopsis* can reach an age of at least 150 years. We estimate that some trees in the East Usambara forest are more than 60 years old and since we have never recorded a large dying or dead *Maesopsis*, most large trees are likely to grow older.

Transformation of the submontane forest ecosystem

Maesopsis cannot be regarded as a short-lived colonizing species which has only a transitory influence on the forest ecosystem. Scattered isolated trees may have little effect, but existing extensive stands of *Maesopsis* already cause major ecological modifications. The whole forest will be transformed in character if *Maesopsis* increases in abundance in those places where it already exists and if it spreads to new areas. At present *Maesopsis* is most abundant in submontane forest but this is probably a historical accident and it also seems to grow well in lowland forest.

The following evidence indicates that *Maesopsis* causes major changes to the submontane forest ecosystem on the East Usambaras.

(1) There is little regeneration of primary forest trees beneath a *Maesopsis* canopy. Those other species of trees found in older *Maesopsis* stands are principally light-demanders, which are able to grow because of the thin canopy and light shade cast by *Maesopsis*. For example, one 12 year old stand of *Maesopsis* examined in Kwamkoro Forest Reserve showed a monospecific canopy of *Maesopsis* (15–20 m tall) and an understorey (up to 10 m tall) containing the following light-requiring species: *Albizia gummifera, Anthocleista grandiflora, Harungana madagascariensis* (very common), *Macaranga capensis, Myrianthus holstii* and *Polyscias fulva*. The only two shade-tolerant species noted in the understorey were *Allanblackia stuhlmannii* and *Sorindeia madagascariensis*, and there were indications that both were survivors from the natural forest, before logging. At one time *Cephalosphaera usambarensis* was planted beneath nursery trees of *Maesopsis* at Kwamkoro (Mugasha 1982). In some compartments, where a few mature *Cephalosphaera* were retained during logging and no underplanting was carried out, there is evidence that natural regeneration of *Cephalosphaera* has taken place, including on the bare soil of former logging tracks, but such regeneration of *Cephalosphaera* is not the general pattern. The lack of regeneration of primary forest trees under *Maesopsis* in the East Usambaras contrasts strongly with the observations of Dawkins (pers. comm.) in Uganda where species of *Guarea, Khaya* and *Lovoa* become widely established below *Maesopsis*.

(2) Introduced species of plants are much more abundant in *Maesopsis*-rich forest than in natural forest. Three common shrubby species found are *Clidemia hirta, Lantana camara* and *Rubus rosifolius*.

(3) The rooting system has a different structure under a *Maesopsis* stand, compared with the natural forest. Observations by a colleague, David Taylor, showed that all the species of trees which he examined (*Allanblackia stuhlmannii, Cephalosphaera usambarensis, Harungana madagascariensis, Maesopsis eminii* and *Newtonia buchananii* and others) possessed deep roots penetrating 2 m or more into the soil. There is however, a marked difference between natural forest and *Maesopsis* forest in that the former typically shows a dense mat of interwoven roots within 10 cm of the soil surface; this layer is essentially absent from *Maesopsis* forest. Rootlets have a different morphology in the upper layers of the two forest types, those in natural forest being chubby and mycorrhizal, while those in *Maesopsis* forest are thin and fibrous.

(4) The biology and physical properties of the near-surface soil are substantially different in *Maesopsis* forest, compared with natural forest. [These observations have been made by the following scientists, in addition to ourselves: David Taylor (roots, pH, earthworms); Amyan Macfadyen (litter, soil fauna); S. Mahunka (arthropods).]

(i) Leaf litter is notably deeper in natural forest (often 5 cm or more) than in *Maesopsis* forest (0–3 cm); much of the relatively little litter in *Maesopsis* forest consists of *Maesopsis* twigs and small branches (*Maesopsis* is a self-pruner).

(ii) A topsoil layer (5–10 cm thick) is typically present under the litter in natural forest, with a well-defined boundary with the subsoil. This topsoil is darker coloured, moist, crumbly and rich in roots. There is no equivalent in *Maesopsis* forest, in which the upper 10 cm of soil is typically the same reddish colour as soil below 10 cm; it tends to be dry and compacted.

(iii) During storms, it was noted that there is a much more direct penetration of rain onto the forest floor in *Maesopsis* forest than in natural forest, related to the thinner canopy, and also much more surface run-off. Unlike in natural forest, soil erosion can readily be observed and it is clear that the red colour of the upper soil is because it actually is exposed and eroding subsoil.

(iv) The acidity of the upper soil (0–5 cm, below the litter) is notably lower in natural forest than in *Maesopsis* forest. In one set of 30 measurements distributed equally between neighbouring patches of natural forest and *Maesopsis* forest, the mean pH in natural forest was found to be 6.2 (range 5.8–6.8) and in *Maesopsis* forest 4.2 (3.4–5.4).

(v) Earthworms are less abundant in natural forest than in *Maesopsis* forest and there is a difference in the relative abundance of different species. An introduced American species is very common in the *Maesopsis* forest, but not in natural forest (Zicsi pers. comm.).

(vi) The soil faunas of natural and *Maesopsis* forest contain similar numbers of arthropod individuals, but the faunas are very different in terms of species composition and diversity. *Maesopsis* soils have a rather uniform fauna, while the fauna changes greatly from place to place within natural forest. For instance, Mahunka (1990) found that, of the 200 or so species of Oribatid soil mites (of which about 150 are endemic) recorded in the natural forest, only 57.5% of them were found in *Maesopsis* stands. Arthropod species richness was significantly lower under *Maesopsis*, particularly in the litter.

(vii) There is some evidence from litter bag experiments that leaves of *Maesopsis* are relatively quickly decomposed, compared with leaves of typical trees of natural forest. Feeding experiments show that *Maesopsis* leaves are relatively palatable to diplopods, which are major members of the soil macrofauna of these forests.

(5) There is evidence that the number of hornbills has increased during the fruiting season of *Maesopsis*, judging by the number of hornbills noted by Moreau (1935) and accounts by local people in 1987. This increase is likely to be due to increased food supply with rapid growth of the *Maesopsis* population.

The East Usambara forests: unusually susceptible to biological invasions?

Further evidence for the invasive potential of *Maesopsis* has been reported from elsewhere. In the mainly logged coastal Ngezi Forest of Pemba Island (Tanzania), Beentje (1990) found *Maesopsis* regenerating in 21 of the 85 investigated plots. It has also been found to be regenerating in forest plantations in Fiji (Marten 1980). In Rwanda *Maesopsis* has been reported as spreading in savanna (Troupin & Girardin 1975). These reports of natural regeneration and invasion in various habitats and under various climatic conditions suggest that *Maesopsis* is rather unspecialized in its ecological requirements, apart from those needed for successful seedling establishment.

Major invasions of introduced trees in continental tropical forests appear to be unusual (Binggeli 1990), and it is believed that tropical rain forests are resistant to invasions (Whitmore 1991). Other cases of invasions in Africa are the spread of the South American *Cecropia* from Limbe (Cameroon) and Eala (Zaire) botanic gardens. *Cecropia peltata* was probably introduced early this century (Berg et al. 1985) by the Germans to a colonial station established to identify economic plants. Léonard (1951) reported that seeds of *Cecropia leucocoma* imported from the Estacion Agronomica de Puerto Bertani (Paraguay) were then grown in the Jardin Colonial de Laeken (Belgium) and the saplings were introduced to the Jardin Botanique d'Eala (Zaire) in 1911. By 1933 the species was recorded about 20 km away from Eala. Both species are short-lived pioneers and are replacing *Musanga cecropioides*, an ecological equivalent (Léonard 1951; McKey 1988). *C. peltata* is also spreading on lava flows on Mount Cameroon (I. Edwards pers. comm.). In contrast to continental tropical forests, those found on long-isolated oceanic islands are well-known to be susceptible to plant invaders (e.g. Brockie et al. 1988).

Several explanations may be advanced for the present seriousness of plant invasion in forests on tropical islands compared with continents. One is that all tropical forests are, in fact, prone to invasion, but that oceanic islands got off to an early start, being sites of early European arrival and attempts to establish plantations. Another is that species on oceanic islands have broad ecological amplitude related to their relatively poor floras, and that this leaves opportunities for introduced species with specialist requirements. A third is that there is a disharmony in species composition on islands and this allows some plants with life forms which are naturally absent to become established. A fourth is that island plants are generally uncompetitive, not having been subject to the greater selection pressures affecting continental plants.

The merits of the above explanations are difficult to assess, mainly because of our limited knowledge of biological invasions. The first explanation finds support in Uganda where *Broussonetia papyrifera* was first planted in Budongo Forest around 1953 and is now naturalised in some logged and treated forest areas (Synnott 1985). The pattern of *Broussonetia* invasion in Budongo (where *Maesopsis* is native) appears to be similar to that of *Maesopsis* in the East Usambaras. It is possible that *Broussonetia* will invade tree-fall gaps in undisturbed forest.

The East Usambara forests are rich in species of plant and animals which either do not occur elsewhere or else are confined to forests near the East African coast and/or on the Eastern Arc Mountains. The degree of distinctiveness of the flora from that of the main African forest block in West and Central Africa indicates long isolation of the forests of eastern Tanzania from forests elsewhere. These forests, including those on the East Usambara, are small and to some extent isolated from one another and may perhaps be regarded as a continental analogy of an oceanic archipelago. Therefore, any special reasons for the high susceptibility of oceanic islands to invasions might also apply to the forests of eastern Tanzania.

Is climatic change aiding invasion?

In central and west Africa, *Maesopsis* is regarded as essentially a lowland forest tree, though it does occur in some lower altitude submontane forests (with *Parinari*, *Strombosia*, etc.), equivalent to those on the East Usambaras. There is evidence for climatic change since about 1970 towards a more lowland type of climate in the submontane zone of the East Usambaras, which may have accelerated the rates of spread and population increase of *Maesopsis*. Climatic change did not, however, initiate the *Maesopsis* invasion, which started before climatic change occurred (Moreau 1935; Willan 1965). The evidence for climatic change is as follows (details in Hamilton & Bensted-Smith 1989):

(1) At one site, examined in detail in the natural submontane forest, there has been an exceptionally high number of tree-falls during recent years. It is not known how widespread this phenomenon of large-scale tree mortality is on the East Usambara range. A high frequency of recent tree-falls has also been recorded from submontane forest on the nearby West Usambara range (Hall 1985).

(2) The montane forest tree *Ocotea usambarensis* is represented by large specimens on ridges in the submontane forest, but there is no regeneration from seed. The species is here at the lower end of its altitudinal range and thus it is possible that the recent failure to regenerate is due to a rise in temperature.

(3) Meteorological measurements on the East Usambara range and its neighbourhood indicate that the climate has changed since about 1970 with: (a) slightly higher temperatures and (b) a tendency to greater extremes in annual rainfall, with many exceptionally dry years and some very wet years (measurements form a wider regional area show that the rainfall change is a regional phenomenon, not restricted to the mountains).

(4) Reports of climatic change by local residents tell of a greatly reduced incidence of mist in the submontane forest zone, generally reduced annual rainfall coming in more concentrated and more isolated episodes, and greater warmth.

(5) A greater reduction in the luxuriance of an epiphytic fern in the submontane forest has been noted by Prof. T. Pocs. "I was shocked [in 1987] to witness the disappearance of the great specimens of the epiphytic fern *Vittaria zosterifolia*, which used to be found in the Amani area. *Vittaria zosterifolia* is an interesting fern, capable of almost indefinite growth during the rainy seasons. During dry seasons, the greater part of the ribbon-like fronds die back, so that the leaves seem to be a good indicator of average wetness in rainforest habitats. In 1970 I could observe many specimens on trees in the Amani Botanical Gardens and in the neighbouring primary rainforests with leaves longer than 2 m. Nowadays, these individuals, if they can be found at all, bear leaves only 20–30 cm long, with bigger specimens (but still only 50–60 cm long) only on trees bending over the cataracts of Sigi River."

(6) Before about 1970, the submontane zone of the East Usambara was considered malaria-free, but the disease is now widespread. Higher temperatures favour malaria (Bruce-Chwatt 1985).

(7) Since 1970, several lowland crops such as coconut and mango can now be successfully grown in the submontane zone. This was formerly impossible.

Control of Maesopsis

It is now generally accepted that *Maesopsis* poses a serious threat to the maintenance of the biodiversity and catchment values of the East Usambara forests and must be controlled (Kalaghe et al. 1988). The issue has even received front page coverage in Tanzania in the Daily News (Mwalubandu 1989). Control of *Maesopsis* is incorporated as an objective in a new management plan for the East Usambara forests lying within government forest reserves (Määttä 1988a,b).

Since 1988, some efforts have been made to implement management policies relating to *Maesopsis*. For example, IUCN, which has a conservation and development project on the range, has attempted to encourage greater use of large diameter *Maesopsis* for timber, as well as develop markets for *Maesopsis* poles (Wardell & Mwasha 1989). Although *Maesopsis* is an important timber in Central Africa, little use of the wood has been made in the East Usambaras where locally better-known hardwoods are still available. In the East Usambaras the wood is not favoured for fuelwood, though it has been used to make furniture (Seymour 1991). The market for *Maesopsis* is still very limited. Successful commercialisation of the wood will be necessary if harvesting of *Maesopsis* is to be economically viable.

Maesopsis in the Kwamkoro plantation produces a very large quantity of seeds which are easily dispersed into the adjacent natural forest. The successful control of *Maesopsis* necessitates the harvesting of the *Maesopsis* plantation at Kwamkoro and its replacement by native hardwood species. A tentative silvicultural programme has been advanced for *Maesopsis* at Kwamkoro, involving some degree of mechanisation in the form of winches to pull logs to the existing forest tracks (Binggeli & Hamilton 1990). The proposed scheme stressed the importance of exploiting the forests on a sustainable basis and limiting the impact of harvesting on soil erosion, an important factor on the steep slopes of the East Usambara range. More recently, Seymour (1991) carried out a pilot experiment to assess the suitability of pit-sawing and manual carrying for harvesting *Maesopsis* plantations. Ten canopy *Maesopsis* were cut and estimates made of the logging damage to trees and saplings, timber yields and costs. Seymour concluded that a combination of pit-sawing and manual carrying of *Maesopsis* is a suitable, but overly time consuming, method.

Independently, IUCN has set up a pilot project to remove *Maesopsis* outside Forest Reserves, which has proved to be controversial because the experiments involve the use of arboricide (Glyphosate), a substance potentially toxic to amphibians, of which there are several endemic species in the East Usambaras.

Nearly five years have elapsed since policies concerning *Maesopsis* were formulated, but little has been achieved on the ground, despite the continued involvement of IUCN and FINNIDA. A strategy to tackle the invasion of the natural forests by *Maesopsis*, the harvesting of *Maesopsis* in plantations and logged forests, and the commercialisation of the wood has yet to be devised. This requires the cooperation of all parties involved in the conservation, development and exploitation of the East Usambara forests. Also, further research is essential if the eradication, or at least the control, of *Maesopsis* is to be achieved. The forests of the East Usambaras are amongst the most biologically important in Africa but they are relatively small in size and are subject to heavy human pressure. Prompt action is needed to control the invasion of *Maesopsis* and ensure conservation of the forest ecosystems.

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