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Is the alien tree species *Maesopsis eminii* Engl. (Rhamnaceae) a threat to tropical forest conservation in the East Usambaras, Tanzania?

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Summary

The East Usambara mountains are globally important for biodiversity conservation. The work reported here aimed to clarify whether plantations of *Maesopsis eminii*, an introduced pioneer tree, are a source of alien tree invasion or a temporary element in a protected conservation forest ecosystem in these mountains. The natural regeneration dynamics of *M. eminii* and indigenous primary tree species were assessed in *M. eminii* plantations which were up to 35 years old, using clustered systematic sampling. A total of 103 and 95 woody species were observed in the sapling and lower canopy layers, respectively. Both layers showed an abundance of *Cephalosphaera usambarensis*, a local species also used in plantations. *M. eminii* was virtually absent in the sapling layer, and its frequency decreased in the lower canopy with time. Abundant spontaneous regeneration of native primary forest species occurred under *M. eminii*. The sapling density of *Allanblackia stuhlmannii, Beilschmiedia kweo* and *Greenwayodendron suaveolens* increased, and that of *Newtonia buchananii* decreased, with time. In the lower canopy, the density of *G. suaveolens, Parinari excelsa* and *Strombosia scheffleri* increased in relation to plantation age. Therefore, no active, risky eradication of *Maesopsis* is needed in the conservation area, but a priority management task should be to avoid canopy gaps.

Keywords: species invasion, natural regeneration, conservation, tropical submontane forest

Introduction

There is increasing concern about the threat of invasion from alien organisms in natural or semi-natural ecosystems. Deliberate or unintentional introduction of exotic species into natural ecosystems tends to alter the population dynamics and decrease genetic and species diversity (Williamson 1996). Trees and other woody species feature prominently as invaders, often as a result of horticultural practices (Richardson *et al*. 1992; Hughes 1994).

Plant invasions mostly take place in habitats disturbed naturally or by humans (Whitmore 1991; Rejmanek & Richardson 1996). Closed tropical forests are in general rather resistant to invasion by alien plants, but natural or man-made disturbance increases the risk of invasion (Whitmore 1991). However, *Maesopsis eminii* has been referred to as an exception to the rule that closed tropical forests are resistant to invasion (Cronk & Fuller 1995).

A general framework for studies on the ecology of alien tree species is provided by Williamson (1996), who discusses the distinctions and overlaps between 'invasion', 'colonisation' and 'weediness'. To be classified as invasive, an introduced species must be capable of establishing self-sustaining populations in areas of natural or semi-natural vegetation (Macdonald *et al.* 1989) and to produce a significant change in terms of composition, structure or ecosystem process (Hughes 1994; Cronk & Fuller 1995).

The East Usambara submontane rainforests in Tanzania are one of the most valuable conservation areas in Africa and constitute one of the great centres of plant diversity of the world (Sayer *et al.* 1992). They are known for their exceptionally high levels of regional and local endemism; at least 100 species of plants are strictly endemic to the Usambaras, and the forests are noteworthy for several rare and near-endemic species of birds and reptiles (Rodgers & Homewood 1982; Sayer *et al*. 1992). These forests also protect the water supply for 200 000 people in the nearby town of Tanga, and local people in the mountains depend on the forests for many of their daily needs.

M. eminii Engl. is a fast growing, gregarious pioneer tree species, which was initially introduced to the East Usambaras around 1913 (Binggeli 1989). The origin of the seed is unknown, but the species occurs naturally in low and moderate elevations in East and equatorial Africa (e.g. Hall 1995). Large-scale spread started in the 1970s, following industrial logging and subsequent planting of *M. eminii* to restock the logged sites, and its use as a nurse tree for the main timber species, *Cephalosphaera usambarensis* (Warb.) Warb. The two species were also planted in mixtures from the late 1960s. These plantations provided a massive seed source of *M. eminii*, while logging and private pit-sawing created suitable sites for colonization. Commercial harvesting was banned in 1986, and pit-sawing has also now been effectively regulated in the area (Hall 1995). The establishment of *M. eminii* plantations was discontinued in 1981 (Anon. 1988).

Conflicting reports about the threat of *M. eminii* to indigenous forests have been presented. For instance, according to Binggeli (1989), *M. eminii* would have the potential to invade up to 50% of the natural forest area in the

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East Usambaras within the next 200 years. When compared to intact forests, areas colonized by *M. eminii* were predicted to show poor regeneration of primary tree species, an abundance of introduced shrub species, and changes in soil properties and the bird fauna (Binggeli & Hamilton 1993). On the other hand, Hall (1995) concluded that the spreading rate of *M. eminii* had significantly declined after the discontinuation of logging in the East Usambaras in 1986. Geddes (1998) has recently suggested that the regeneration of *M. eminii* is more a reflection of past human intervention than a measure of its 'invasive' nature.

Different strategies have been proposed to contain, control or eliminate *M. eminii*. Reliable information to assess the validity of the proposed management options is required, and apart from the recent work by Geddes (1998), there is a general lack of quantitative data on the effect of *M. eminii* on the regeneration of the native tree species which this study aimed to rectify.

The objective of the present work was to ascertain which view is more correct, that *M. eminii* is an aggressively-invading alien requiring active management, or that this tree is a temporary element in the ecosystem which will gradually be replaced by native tree species through natural succession. This was assessed by investigating the regeneration dynamics of *M. eminii* and nine primary forest 'indicator' tree species in *M. eminii* plantations of different age. The ultimate purpose was to guide conservation management in the East Usambaras.

Methods

The East Usambara mountains form part of the isolated Eastern Arc mountains in eastern Africa. The study site at Kwamkoro falls within the Amani Nature Reserve, which was gazetted for forest conservation in 1997. The site is located on a plateau at 900–1000 m altitude (lat 5°02′S, long 38°45′E). Average annual rainfall at the Amani Research Station, located 10 km from the site, is 1904 mm (FAO 1984). The vegetation belongs to the Zanzibar-Inhambane submontane rainforest type and has floristic affinity particularly to the Guineo-Congolian flora of West and Central Africa (Lovett 1993). The soils are leached and rather acidic, and the mineral soil under the thin organic layer is poor in nutrients (Hamilton 1989).

Approximately 680 ha of primary submontane forest were logged between 1963 and 1981, but scattered emergent trees were left in the area, which was subsequently planted with *M. eminii*, partly in mixture with *C. usambarensis*. This area was selected for sampling, because it forms the largest concentration and seed source of *M. eminii* in the East Usambaras (Anon. 1988).

Eleven compartments planted in different years, namely 1963, 1968, 1969, 1970, 1971 (two compartments), 1973, 1974, 1975, 1976 and 1979, and covering a total area of 452 ha, were included in the fieldwork for the present study in January–April 1998. These compartments were considered to represent both the temporal and geographical variation of the entire planted area. The woody vegetation of the area was assessed using clustered, systematically-placed circular plots in a grid network. Clustered sampling was applied to allow for the large spatial variation known to occur in the regeneration and establishment of seedlings in tropical moist forests (e.g. Bruenig 1996, p. 56). The distance between gridlines was 50 m, and the clusters were placed along these lines 40 m apart. Based on the size of the compartments, 10–20 clusters were measured in each. In total, 152 clusters were assessed.

A cluster was formed by three plots; one with a radius of 10 m, inside of which there were two others with a radius of 2 m. In the former, all trees ($\geq$ 5 cm but $\leq$ 20 cm diameter breast height [dbh]) representing the lower canopy layer, and in the latter, all saplings ($\geq$ 1 m height but $<$ 5 cm dbh), were enumerated and identified by species. Species names and descriptions follow Beentje (1994) and Schulman *et al.* (1999).

The sapling and lower canopy layers were considered to represent regeneration that had occurred after planting in the compartments, the most recent of which was in 1979. Species composition was analysed by clusters (n = 152). Statistical analysis of individual species used the data pooled by planting compartments (n = 11).

Apart from *M. eminii*, nine 'indicator' species (*Allanblackia stuhlmannii* (Engl.) Engl., *Beilschmiedia kweo* (Mildbr.) Robyns & Wilczek, *Greenwayodendron suaveolens* (Engl. & Diels) Verdc., *Isoberlinia scheffleri* (Harms.) Greenway, *Newtonia buchananii* (Baker) Gilb., *Odyendea zimmermannii* Engl., *Parinari excelsa* Sabine, *Sorindeia madagascariensis* DC., *Strombosia scheffleri* Engl.) were selected to describe the regeneration of the primary forest species and natural succession after logging and planting of *M. eminii*. These species are generally judged to be important constituents of the natural submontane forest in the East Usambaras (Anon. 1988; Hamilton 1988; Hamilton *et al.* 1989; Iversen 1991; Lovett 1993). Although *C. usambarensis* belongs to this group, it was analysed separately, because it is the most important commercial tree species in the area and is also planted in some of the sampled compartments. Non-linear regression analyses were used to assess the relationship between species density and plantation age.

Results

A total of 103 and 95 woody species were found in the sapling and lower canopy layers, respectively. The species composition was characterized in both layers by the abundance of *C. usambarensis* (Tables 1 & 2). *M. eminii* was rare in the sapling layer; only two saplings of this species were found in the entire sample.

A negative relationship was found between plantation age and the density of *M. eminii* in the lower canopy layer (R^2 = 0.81; $y = 3200e^{-0.151x}$; Fig. 1). Plantation age explained 81% of the variation in the density of *M. eminii*. In the sapling layer, significant increase in relation to plantation age was found in the density of *A. stuhlmannii* (R^2 = 0.52), *B. kweo*

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Table 1 Mean density of the ten most common and nine indicator woody plant species (*) in the sapling layer (≥ 1 m tall to < 5 cm dbh; n = 152).

Species	*Mean density*		*%*	*Description*
	ha^{-1}	*SD*	*of all species*	
Cephalosphaera usambarensis (Warb.) Warb.	1450.0	1710.6	21.6	Tall tree
Alchornea hirtella Benth.	934.2	1406.8	13.9	Shrub
Mesogyne insignis Engl.	418.4	694.1	6.2	Shrub or small tree
Sorindeia madagascariensis DC.*	368.4	537.9	5.5	Small tree
Leptaulus holstii (Engl.) Engl.	360.5	666.7	5.4	Shrub
Whitfieldea elongata (Beauv.) C.B.Cl.	313.2	831.1	4.7	Shrub
Newtonia buchananii (Baker) Gilb.*	160.5	299.3	2.4	Tall tree
Strombosia scheffleri Engl.*	139.8	345.3	2.1	Medium-sized to tall tree
Memecylon semseiii A.& R. Fernandes	136.9	417.1	2.0	Shrub
Rinorea angustifolia (Thou.) Baill. ssp. *albersii* (Engl.) Grey-Wilson	128.9	547.8	1.9	Shrub or small tree
Greenwayodendron suaveolens (Engl. & Diels) Verdc. ssp. *usambaricum* Verdc.*	47.4	145.1	0.7	Medium-sized tree
Allanblackia stuhlmannii (Engl.) Engl.*	44.7	126.5	0.7	Medium-sized to tall tree
Parinari excelsa Sabine*	39.5	128.2	0.6	Tall tree
Isoberlinia scheffleri (Harms.) Greenway*	28.9	122.7	0.4	Tall tree
Beilschmiedia kweo (Mildbr.) Robyns & Wilczek*	18.4	84.1	0.3	Medium-sized to tall tree
Odyendea zimmermannii Engl.*	10.5	64.2	0.2	Medium-sized to tall tree
Indicator species, total	858.1	836.8	12.8	
Other species listed above, total	3742.1	2386.0	32.0	
Grand total	6732.6	2934.7	100.0	

Table 2 Mean density of the ten most common and nine indicator woody plant species (*) in the lower canopy layer (5 cm ≤ dbh ≤ 20 cm; n = 152).

Species	*Mean density*		*%*	*Description*
	ha^{-1}	*SD*	*of all species*	
Cephalosphaera usambarensis (Warb.) Warb.	84.2	131.1	17.1	Tall tree
Maesopsis eminii Engl.	75.0	87.3	15.2	Medium-sized to tall tree
Alchornea hirtella Benth.	72.0	145.1	14.6	Shrub
Macaranga capensis (Baill.) Sim.	41.0	60.3	8.3	Small to medium-sized tree
Sorindeia madagascariensis DC.*	19.1	33.2	3.9	Small tree
Myrianthus holstii Engl.	18.8	39.9	3.8	Small to medium-sized tree
Tabernaemontana ssp. L.	18.4	30.0	3.7	Shrub or small tree
Allanblackia stuhlmannii (Engl.) Engl.*	12.6	26.2	2.6	Medium-sized to tall tree
Polyscias fulva (Hiern) Harms	11.7	29.9	2.4	Medium-sized to tall tree
Anthocleista grandiflora Gilg	8.4	24.8	1.7	Medium-sized to tall tree
Greenwayodendron suaveolens (Engl. & Diels) Verdc. ssp. *usambaricum* Verdc.*	8.0	22.4	1.6	Medium-sized tree
Newtonia buchananii (Baker) Gilb.*	6.3	15.1	1.3	Tall forest tree
Odyendea zimmermannii Engl.*	5.9	15.3	1.2	Medium-sized to tall tree
Strombosia scheffleri Engl.*	4.8	14.5	1.0	Medium-sized to tall tree
Parinari excelsa Sabine*	2.9	11.2	0.6	Tall tree
Isoberlinia scheffleri (Harms.) Greenway *	0.8	5.1	0.2	Tall tree
Beilschmiedia kweo (Mildbr.) Robyns & Wilczek *	0.4	3.6	0.1	Medium-sized to tall tree
Indicator species total	60.7	70.3	12.3	
Other species listed above, total	329.6	247.4	32.0	
Grand total	492.7	266.4	100.0	

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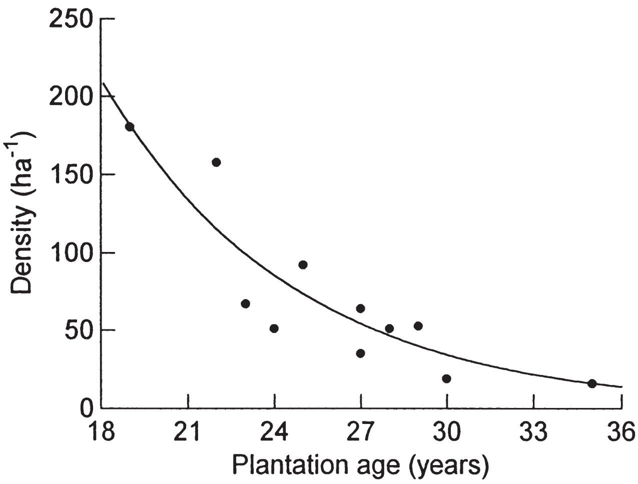

Figure 1 Density of *Maesopsis eminii* in the lower canopy layer as a function of plantation age.

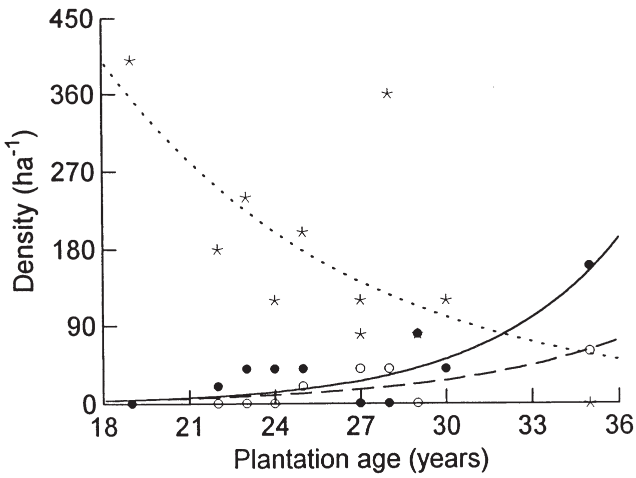

Figure 2 Density of *Beilschmiedia kweo* (dashed line with open circles), *Greenwayodendron suaveolens* (solid line with filled circles) and *Newtonia buchananii* (dotted line with stars) in the sapling layer as a function of plantation age.

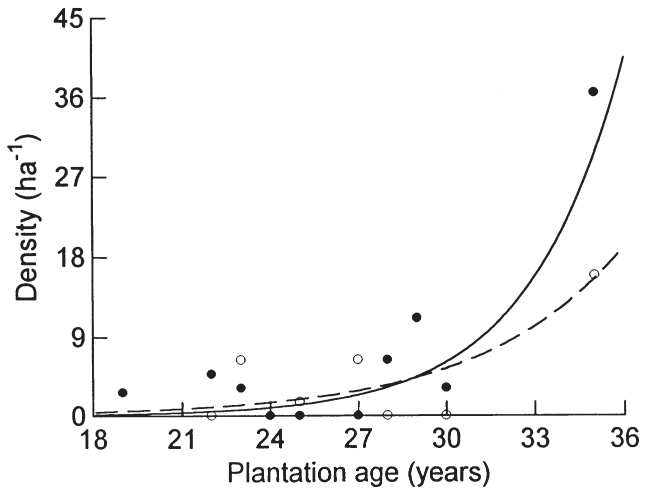

Figure 3 Density of *Greenwayodendron suaveolens* (solid line with filled circles) and *Strombosia sheffleri* (dashed line with open circles) in the lower canopy layer as a function of plantation age.

($R^2 = 0.56$; $y = 0.199e^{0.164x}$) and *G. suaveolens* ($R^2 = 0.72$; $y = 0.07e^{0.22x}$), whereas that of *N. buchananii* decreased with time ($R^2 = 0.47$; $y = 3166e^{-0.115x}$; Fig. 2). The remaining indicator species did not exhibit significant trends in our data. In the lower canopy layer, a positive relationship was observed between density and plantation age in *P. excelsa* ($R^2 = 0.37$), *G. suaveolens* ($R^2 = 0.91$; $y = 0.0005e^{0.314x}$), and *S. scheffleri* ($R^2 = 0.51$; $y = 0.01e^{0.219x}$; Fig. 3). The rest of the indicator species did not vary significantly with plantation age.

Discussion

Regeneration of *M. eminii* beneath its own canopy was strongly associated with the age of the plantations. Observations of seed dispersal (Moreau 1935; Binggeli 1989) strongly suggest that the initial regeneration is derived from seed dispersed by birds (especially hornbills) and monkeys from mature trees located outside the planted areas, at least until the planted trees start producing seed at 4–10 years of age (Hall 1995). Canopy closure, however, effectively reduces seedling establishment, as indicated by Eggeling (1947) and Binggeli (1989).

Our results demonstrate that in older plantations (>30 yr) virtually no seedlings of *M. eminii* are recruited to the sapling layer, despite the presence of a large number of small, ephemeral seedlings (J. Viisteensaari, personal observation March 1998). As a consequence, *M. eminii* will gradually decline in the lower canopy layer 45–50 years after planting, as observed in Uganda by Eggeling and Dale (1951). Our results

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strongly support Eggeling's (1947) view that the successional development of *M. eminii* follows a single-generation or cohort pattern. Furthermore, as *M. eminii* may not be able to maintain the sites it has occupied, indigenous canopy species will gradually take over these sites through natural succession.

The invasion of *M. eminii* in the East Usambaras has been facilitated by logging and other disturbance (Hall 1995; Geddes 1998). The risk of further spread of *M. eminii* into the forest has already been reduced, as logging was discontinued in 1986 and pit-sawing has been effectively regulated (Hall 1995). Our findings, based on plantations only, are in agreement with the results obtained by Geddes (1998) in the natural forest outside the plantations and suggest that at present *M. eminii* does not pose a serious threat to undisturbed natural forests of the East Usambaras. Binggeli's (1989) conclusion that the species could quickly colonize a substantial proportion of these forests is therefore not sustained. However, as Hall (1995) pointed out, colonization could start, if future management leads to increased forest disturbance.

The regeneration of the indigenous species under the canopy of *M. eminii* appears to have been greatly underestimated in the past. Binggeli (1989) and Binggeli and Hamilton (1993) concluded that *M. eminii* suppresses regeneration of native primary tree species, although later authors no longer found evidence of this (Hall 1995; Geddes 1998). Our observations confirm that non-pioneer species or representatives of the late successional or climax stage in the natural submontane forest are able to regenerate and establish under *M. eminii*, as demonstrated by their presence in the sapling and lower canopy layers.

Our data do not allow us to define the exact time of establishment of the individual trees. We assume, however, that many of the new indicator recruits in the sapling layer were established after planting of *M. eminii*, since some of them (e.g. *A. stuhlmannii, B. kweo* and *G. suaveolens*) increased in density in relation to plantation age as saplings, as did also *G. suaveolens* and *S. scheffleri* in the lower canopy. We cannot support the view of Binggeli and Hamilton (1993) that the regeneration of the shade-tolerant species results from the pre-logging phase. While the indicator species comprised only around 12% of all the species in both layers, this could not be directly associated to their decline, since non-pioneers or species of the late successional stages are typically not gregarious. The decreasing proportion of *N. buchananii* as a function of plantation age suggests that, although it is a typical climax species of the mature submontane forest in the area (Anon. 1988; Hamilton *et al.* 1989; Iversen 1991; Lovett 1993), it may be a light-demander at least at the juvenile stage.

The previous somewhat-contradictory conclusions on the persistence of *M. eminii* (cf. Binggeli 1989; Binggeli & Hamilton 1993; Hall 1995; Geddes 1998) may be due to the fact that some studies were conducted earlier, when the effects of previous disturbance caused by logging were more apparent, than our study in 1998. Different sampling procedures may also have affected the results: for instance, an earlier assessment of the regeneration of the primary forest species (Binggeli 1989; Binggeli & Hamilton 1993) was based on data from a limited number of sites and was thus unrepresentative either of the entire study location, or of the East Usambaras as a whole.

Because of the lack of reliable information on the occurrence of planted *C. usambarensis* trees in the study area, the natural regeneration dynamics of this species could not be accurately quantified. Regeneration was, however, observed in areas where the species had obviously not been planted. While it is conceivable that a few individuals of *C. usambarensis* in the lower canopy have originated from the pre-planting period, the high mean density of saplings (1450 ha^{-1}), and the fact that it was the most frequent species in the sapling and lower canopy layers, strongly suggest that ample, post-plantation natural regeneration of this species has occurred. Recent studies by Geddes (1998) also indicate that regeneration of *C. usambarensis* is favoured by a *M. eminii* canopy.

Different strategies have been proposed to manage *M. eminii* in the East Usambaras. Binggeli (1989) and Binggeli and Hamilton (1993) recommended the harvesting of the *M. eminii* plantations and the replacement of this species by native species. Hall (1995) proposed selective removal of mature trees on public and estate land as well as forest reserves. Geddes (1998), in contrast, associated the spreading of *M. eminii* with logging and other disturbance in the past, and did not foresee a need for intervention.

Considering the present low level of man-made disturbance in the East Usambaras, large-scale elimination of *M. eminii* is not feasible. Removals of the species by clear-cutting would result in increased soil erosion and renewed spread (Hall 1995). Dense populations of ephemeral seedlings combined with prolific seed production from adjacent stands would inevitably make it possible for the species to retain such sites.

From a management perspective, it is very difficult to contain the spread of *M. eminii* in the non-protected forest areas where agriculture and forest clearing provide continuous sites for colonization. At present the most appropriate management strategy is to control disturbance in the conservation area.

Utilization of *M. eminii* by local people should be allowed in the forest reserves. For instance, limited pole cutting, which involves the removal of small or medium-sized trees, would not increase spread, nor decrease the regeneration of the indigenous species beneath the canopy. Such activities should, however, be carefully controlled and accompanied by efficient extension and close supervision.

Resources available for biodiversity conservation are always limited. Conservation expenditure should thus be targeted at sites and measures that will produce the greatest value for the investment (e.g. Sayer 1995). In the case of *M. eminii* in the East Usambaras, this would imply that a modest investment to reduce future disturbance in areas prone to *M.*

eminii invasion may yield greater benefits than the inevitably larger inputs required for its thorough eradication.

Interventions promoting regeneration, or increasing the proportion of the local species, may be justified for conservation or biodiversity purposes in areas of high species richness. Experiences of such techniques as enrichment planting have also been contradictory and do not offer immediate solutions for biodiversity conservation in the East Usambaras.

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