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SHORT COMMUNICATION

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Maesopsis eminii Engl. mortality in relation to tree size and the density of indigenous tree species at the Amani Nature Reserve, Tanzania

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1 | INTRODUCTION

Maesopsis eminii Engl. is a lowland rain forest tree species in the family Rhamnaceae. The species is native to Africa, but has been introduced in Australia, Latin America and Asia continents. In Tanzania, the species natural range is limited to the rain forest of Bukoba and Geita in the lake zone of Tanzania (Binggeli, 1989; Epila et al., 2017; Geddes, 1998; Hall, 1995).

Maesopsis eminii (from now on Maesopsis) was introduced by Germans in 1913 as a small plot in the Amani Botanical Garden, which is now part of the Amani Nature Reserve (ANR). Due to poor records, the origin of the planted materials is not known but it is thought to come from the lowland forests of Bukoba or Geita (Hall, 1995). Soon after its introduction, Maesopsis started to spread into the adjacent natural forests of ANR (Binggeli, 1989; Cordeiro, Patrick, Munisi, & Gupta, 2004). The most recent data show that the species accounts for more than 15% of large trees in the submontane part of the reserve (Frontier Tanzania, 2001; Geddes, 1998; Kilenga, 2007) and comprised 50% of trees in agroforestry systems (Hall, Gillespie, & Mwangoka, 2011). The tree species is now found in other nearby forests such as Mlinga and Nilo Nature Reserves (Cordeiro et al., 2004), but it is not known if this population is related to the one in ANR.

There had been concerns from scientists, that the increasing population of Maesopsis in ANR would threaten species diversity, hence the ecosystem of Usambara mountain forests. In 1980s, there was a call to eliminate Maesopsis from the forests (Binggeli, 1989; Hamilton & Bensted-Smith, 1989), but this was not performed due to cost implications and largely due to the claim that Maesopsis would die of old age and slowly be overtaken by indigenous species regenerating under the canopy after one generation (Hall, 1995). Now that more than a century has elapsed since its first introduction, the validity of this claim needs to be verified.

In order to contribute knowledge on the dynamics of Maesopsis in East Usambara, we provide an assessment of Maesopsis mortality at two sites where the species was planted in the 1910s and 1980s. We hypothesized that mortality of Maesopsis increase with increase in tree diameter size (proxy to age) and increase in the density of indigenous species (proxy to competition).

2 | MATERIALS AND METHODS

This study was conducted in March 2013 in the Amani Botanic Garden and Kwamkoro Forest blocks in the ANR (Figure 1). The ANR is described in detail by Hamilton and Bensted-Smith (1989). The origin of the stand at the base of Mbomole Hill near the ANR main office is unclear. It was most probably logged in the 1960-70s and Maesopsis was either planted or naturally regenerated. It is likely that some trees had already established soon after the establishment of the nearby original German plantation and have since died. At Kwamkoro, Maesopsis was planted between 1963 and 1977 for the purpose of providing shade and shelter to the heavily exploited endemic tree *Cephalosphaera usambarensis* (Geddes, 1998; Hall, 1995; Viisteensaari, Johansson, Kaarakka, & Luukanen, 2002). Most of the Maesopsis trees planted at this site are still present (Cordeiro et al., 2004; Viisteensaari et al., 2002).

The study employed a systematic sampling design where plots and transects were established at fixed distances. At each study site, the starting point of the first transect was selected randomly but keeping a 50-m buffer from the forest edge or stream. The transect

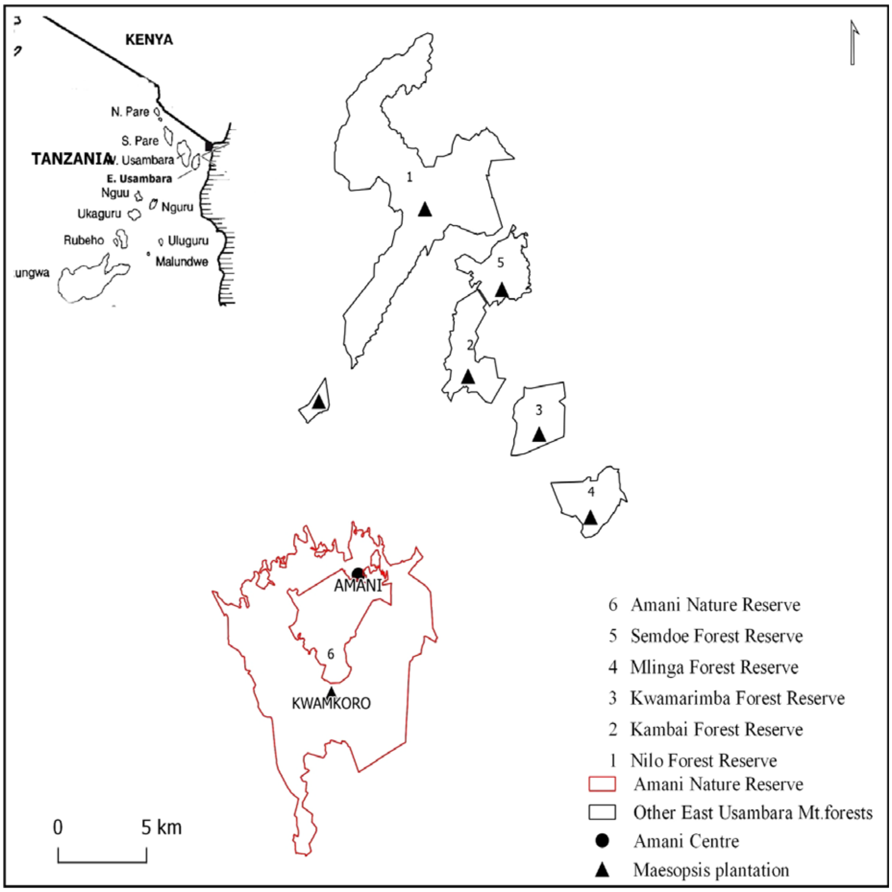

FIGURE 1 Map of East Usambara showing Amani Nature Reserve and the study sites [Colour figure can be viewed at wileyonlinelibrary.com]

length was 1 km long towards the West direction. Three additional transects were established parallel to the first one at an interval of 150 m. Along each transect, square sample plots measuring 10 × 10 m (0.01 ha), were sampled at an interval of 100 m, yielding 10 plots per transect and 40 plots per site. In each plot, all alive and dead Maesopsis trees with a diameter ≥10 cm at a height of 30 cm were measured. Stem diameters were taken at 30 cm above-ground level to allow measurements of trees broken below breast height diameter. For each dead Maesopsis, the mode of mortality was categorized as follows: trunk breakage, uprooting and die standing. In each plot, the indigenous tree species with diameter ≥10 cm were also measured (count). Due to limited funds, we did not determine the composition of indigenous tree species or perform diameter measurements for indigenous species.

We tested the hypothesis that mortality of Maesopsis increases with increase in tree diameter size and the density of indigenous species. Nominal logistic regression analysis was used to assess the effect of size on mortality of Maesopsis. The dependent variable (y) was coded as either dead or alive Maesopsis (y = 0, 1, with 0, set as a reference) and independent variable (x) was the diameter of corresponding alive or dead Maesopsis. Simple linear regression (standard least square model) was used to assess the effect of stocking on mortality. In this model, the dependent variable was the number of dead Maesopsis in a plot and the independent variable was the number of indigenous tree species in a plot. Twelve plots did not have dead or alive Maesopsis, thus excluded from the analysis. All analyses were performed in SAS JMP, version 12.

3 | RESULTS AND DISCUSSION

The number of dead Maesopsis accounted for 38% of all Maesopsis individuals in Amani and 23% in Kwamkoro. The mode of tree death was through trunk breakage, died standing and uprooting (Table 1). In two encounters, we found a group of dead Maesopsis stems originating from the same base stem (Figure 2).

TABLE 1 Alive indigenous species, Alive and dead Maesopsis and the mode of mortality

Site	Transect length (km)	Plots (#)	Total no. of all alive trees	Number of alive indigenous trees	Number of alive Maesopsis	Number of dead Maesopsis	Total no. of alive and dead Maesopsis	% of dead Maesopsis of total Maesopsis	Modes of mortality		
									Trunk breakage	Uprooting	Died standing
Kwamkoro	4000	40	434	354 (82%)	80 (18%)	48	128	38	35 (73%)	6 (13%)	7 (14%)
Amani	4000	40	305	207 (68%)	98 (32%)	29	127	23	16 (55%)	10 (35%)	3 (10%)

There was no evidence that mortality increases with an increase in diameter size (Figure 3). Nominal logistic regression analysis revealed that Maesopsis mortality diminishes with an increase in diameter size (χ^2 = 16, $P < 0.01$, R^2 = 0.1). For every 1 cm increase in diameter, mortality decreased by 5%. The findings suggest that the stability of Maesopsis increases as it increases in diameter growth probably fostered by the development of effective lateral and deep tap root that improve its ability to anchorage and access to soil nutrients (Taylor, 1989). Furthermore, as the tree matures, it occupies the subcanopy or canopy and thus suffers less from light competition than while it is part of the understory (Mugasha, 1981). The mortality of small Maesopsis trees observed in the present study could be caused by competition for resources arising from regenerating indigenous trees even though weak linear relationship was found between mortality of Maesopsis and stem density of indigenous species (R^2 = 0.04, $P < 0.05$; Fig. 4). Competition weakens the tree species to the extent that when exposed to secondary factors such as wind the species get killed (Antos, Parish, & Nigh, 2008).

FIGURE 2 A group of three *Maesopsis eminii* trees (centre) died standing at Amani Nature Reserve [Colour figure can be viewed at wileyonlinelibrary.com]

Alive Maesopsis accounted for 18% in Amani and 32% in Kwamkoro of all alive trees (Table 1). The number of alive Maesopsis in both sites was lowest at diameter class ≥ 20-30 and highest at a diameter class >30- 40 cm, making an inverted "N" shape (Figure 3). The size class distribution indicates that the recruitment of Maesopsis is low. An actively recruiting tree species is expected to show high abundance of smaller than large sized tree (Chidumayo, 2016). Large number of indigenous trees in Maesopsis stands suggests that succession is occurring whereby the latter is being replaced by indigenous species, which is consistent with findings from other studies (Hall, 1995; Viisteensaari et al., 2002). Poor recruitment of Maesopsis is probably due to lack of large-scale disturbance that can create adequate gap size for growth and development. Recent natural tree falls create small disturbances that can only be colonized by indigenous tree species. In our survey, an uprooted Maesopsis with DBH 45 cm created approximately 100 m^2 gaps at the base of the tree and 180 m^2 at the crown. According to Binggeli (1989), a minimum gap size of 300 m^2 is required for successful invasion by Maesopsis.

To sum up, the results of this study showed substantial mortality and retrogressive recruitment of Maesopsis in its original area of introduction. Mortality of small Maesopsis trees was higher than that of large ones, and the sample area shows high densities of regenerating indigenous trees. We argue that poor recruitment of Maesopsis found in this study was caused by the absence of big gaps necessary for Maesopsis establishment. The study findings support a natural

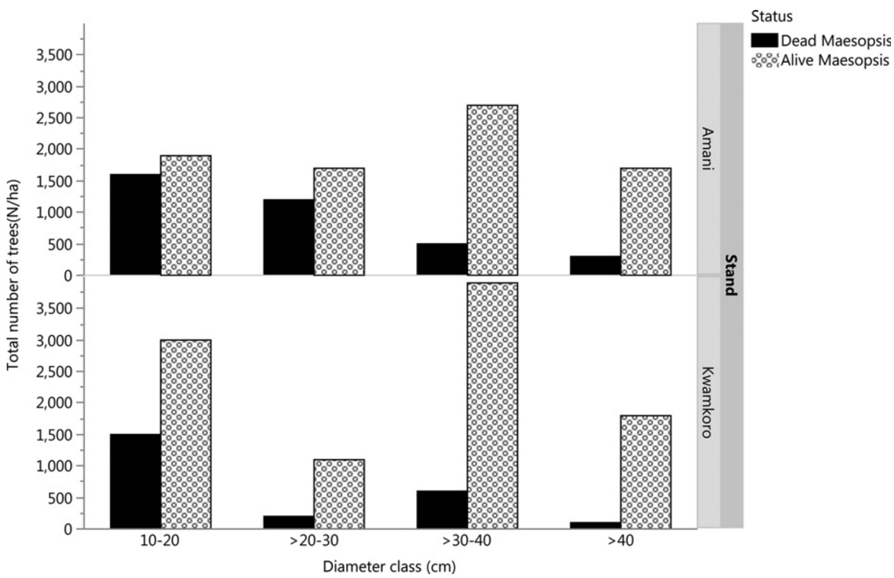

FIGURE 3 The diameter size distribution of dead and alive Maesopsis at Amani and Kwamkoro stands

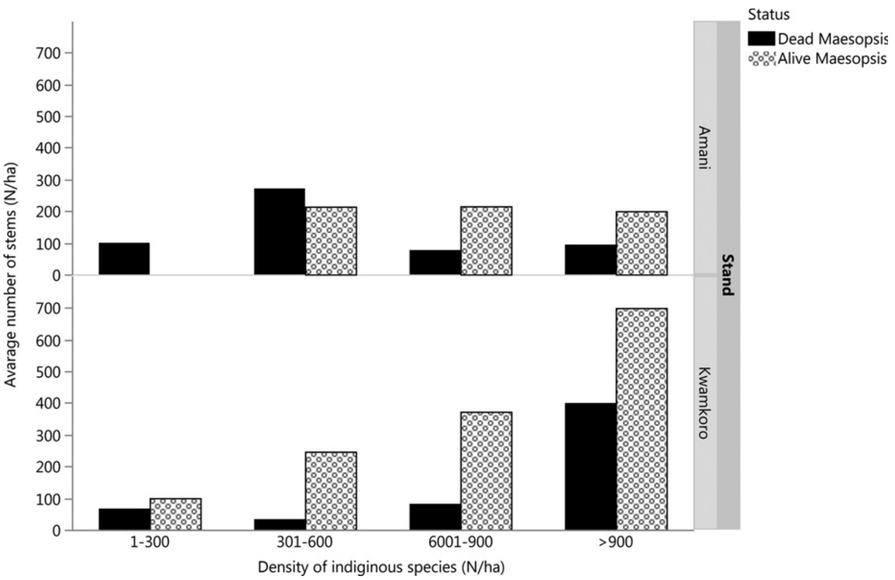

FIGURE 4 The density class for indigenous species in relation to distribution of dead and alive Maesopsis at Amani and Kwamkoro stands

replacement by indigenous species in the formerly planted Maesopsis stands.

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