The invasive potential of tea: naturalisation and spread of *Camellia sinensis* in natural and logged forests of the Amani Nature Reserve

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Abstract

Exotic species are one of the most important issues in conservation biology. In our study we focus on the naturalisation and spread of *Camellia sinensis* in the Amani Nature Reserve (ANR), in the East Usambara Mountains of Tanzania. The area studied was a small plot of abandoned tea plants. We found that the tea has spread both into an undisturbed, natural forest and a logged forest adjacent to the site. However, this spread is occurring at a relatively slow rate. More pronounced is the effect within the plot, where the tea is regenerating at very high densities, suppressing all other species.

INTRODUCTION

The threat posed by the spread of exotic species to global biodiversity has become a prime conservation issue (Arim et al 2006). Traditionally seen as a problem facing temperate and island ecosystems, the negative impacts of exotic plants in tropical regions have recently been highlighted (Binggeli 1998). Furthermore, there is a common association between invasive plant species and plant characteristics such as high growth rate, fecundity and dispersal (Bellingham et al 2004). A third concept usually associated with invasive species is the colonisation of disturbed areas, rather than climax tropical communities, which are seen as resistant (Whitmore 1991).

The Amani Nature Reserve (ANR), located in the East Usambara Mountains of North-Eastern Tanzania, has been the focus of much research on invasives, due to the many species imported to the Amani Botanical Gardens. It is also an area with a large number of endemic species (23% of mountain plant species, 3% of birds, 6% of mammals and 20 species of African violet are endemic (Rodgers 1982)). The reserve was gazetted in 1997 from the Amani Botanical Gardens and surrounding forest reserves. The area surrounding the reserve is currently used for tea plantations, agriculture, forestry and human habitation. The reserve is highly fragmented and consists of some areas of undisturbed natural forest and large areas of secondary forest, with a high proportion of exotic species. Of the approximately 1,000 species introduced to the botanical gardens, 1% has become invasive (Groves 1986). The main focus of research on invasives in the ANR has been on *Maesopsis eminii*, *Clidemia hirta* and *Lantana camara*.

This study aims to examine the invasive potential of tea (*Camellia sinensis* O. Kuntze). The species has only rarely been reported as naturalised in East Africa (Verdcourt 1962). The area being studied is a small abandoned tea plantation (possibly a trial plot) that forms part of the nature reserve. This area is an exceptional opportunity for the study of invasion as it is bordered by both disturbed and undisturbed habitat and the introduction effort is precisely known.

MATERIALS AND METHODS

The study was carried out during July 2006 in the Amani Nature Reserve (ANR).

Study site

The study site was located approximately 1km West of the village of Amani. It was owned by the Karimgee Monga tea estate up until 1997 when it was incorporated into the Amani Nature Reserve. The site consists of three rows of planted tea running along the top of a ridge, approximately 950m a.s.l. The ridge runs down from Mbomole hill in an NW direction. The tea plantation is bordered by undisturbed natural forest on the E slope and previously selectively logged forest on the W slope (AFIMPP, 1988). It is clear from observations that the plantation has been abandoned for some time as the tea has grown into sub-canopy trees. The only evidence of previous management is single coppicing of 31% of the studied planted trees, usually at the base, suggesting that the plantation was abandoned soon after planting. The date of planting is not known but is believed to have been between 50 and 80 years ago (Mdolwa pers. comm., 2006). The rows of planted tea extend for over 190m, by 8m wide, but the study site ended at 184m, where the ridge rises steeply up to Mbomole hill. This was due to the difficulty of the terrain and the change in habitat type. The area being studied shows only a slight slope in the NE direction, while on both the W and E sides the slope gradually increased to between 15^{o} and 30^{o}.

Mapping of planted trees

The first step in the study was to produce a map of the planted area detailing the position of all planted tea trees (i.e. the seed source) and all other tree species taller than 5m. For the purpose of mapping the study site the rows of planted tea were labelled Central (C), East (E) and West (W) based on their orientation. The Northern-most tree of the C row was defined as the starting point. From that point the bearing and length of the C row were measured and the position and DBH (diameter at breast height, 1.4m) of each tree along it was recorded. For the E and W row trees the perpendicular distance to the C row, the distance along the C row and the DBH were recorded.

Naturalisation and spread of tea

The aim was to characterise the area under the tea plantation and the spread from it. Belt transects were used to measure the vegetation gradient from the planted area to the forests on either side of the ridge, in order to estimate the extent *C. sinensis* had spread from the plantation. Six transects of 30 m by 2 m were laid out on either side at regular intervals of 30 m. Starting from the W row and E row, for the logged and natural forests respectively, the transects extended at a perpendicular angle away from the plantation. The transects were divided into sections of 1 m by 2 m and all woody plants, excluding vines, were identified as either *Camellia sinensis* or non tea species and measured to within size classes of 20 cm, up to 5 m. The gradient of the slope along the transects was also measured.

Longer transects were then run to establish the extent of spread from the plantation. The transects again extended at a perpendicular angle to the rows of planted tea but were begun 30 m away from the outer row (E or W). The transects extended for 200 m, by 6 m wide. Only *Camellia sinensis* plants were recorded and measured to size classes of <1 m, 1-3 m and >3 m. Three transects were laid out on either side, beginning at 30, 90 and 150m along the C row for the E side and at 30, 90 and 120m for the W side. It was not possible to start a transect at 150m on the W side as it would extend past the forest boundary.

In order to estimate the natural regeneration of tea from the planted trees the density and size class distribution of the vegetation in the plantation was measured using 14 randomly selected quadrats of 1 m^2. All woody plants, excluding vines, were measured from 20 cm up to 5 m, in size classes of 20 cm.

Due to time constraints, quadrats for the natural and logged forests were conducted along 200m transects. The first 200 m transects on each side were used to judge the minimum distance from the plantation needed to avoid high densities of tea. This was set at 50 m and quadrats of 4 m^2 were then laid at regular intervals of 30 m up to the end of the transects, for a total of 10 transects for each forest type.

Observations

Two other factors relating to the regeneration and spread of tea were investigated by observation alone, during the study. These were the extent of mortality of the regenerating tea and any evidence of dispersal mechanisms other than gravity.

Height-DBH

To quantify the relationship between height and DBH for *C. sinensis* a randomly selected subset of trees, of all sizes, were measured in the plantation. For trees below 1.4m the diameter half way up the stem was measured. For trees that were too high to measure a clinometer was used. The equation obtained from the regression analysis (Figure 1) was: DBH = 0.0497561 + 0.421103 Height + 0.0408562 Height^2 (R^2=99.6%, P<0.001, n = 49).

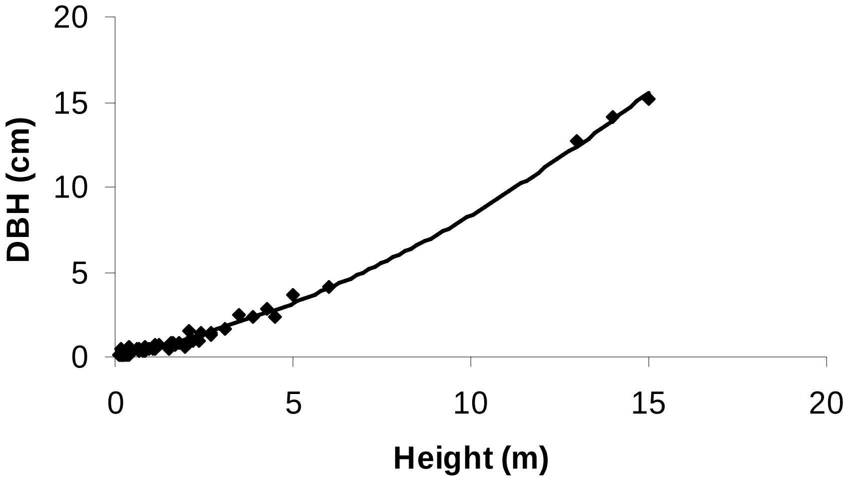

Figure 1. Second order polynomial regression analysis between height and BH for *C. sinensis* (R^2=99.6%, P<0.001, n = 49)

RESULTS

Planted trees and natural regeneration

The study site contains 123 planted *C. sinensis* trees with a mean DBH of 13 cm (1 S.E. = ±0.3) and a mean height of 13 m (1 S.E. = ±0.5) and 34 other tree species with DBH between 3.8 cm and 161 cm (see map, Appendix A). The middle (C) row of tea trees has a total length of 184 m with trees planted approximately 3.8 m apart. The E and W row of tea trees are planted approximately 3.8 m away from the C row in a straight line. There are an estimated 15 gaps where planted tea trees would be expected. The non-tea trees in the site are almost entirely mature native and *Maesopsis eminii* trees that together form the canopy.

The planted tea trees have produced a very dense undergrowth of seedlings and saplings (mean naturally regenerated *C. sinensis* stems per m^2 = 85, 1 S.E. = ±8; estimated total stems = 190,000). The majority of stems are very small (<20 cm = 55%) and small (20 – 40 cm = 28%) seedlings. However, the undergrowth is quite evenly distributed, when seen in terms of basal area (Figure 2).

The estimated total basal area of naturally regenerating *C. sinensis* in the plantation is 8.8 cm^2/m^2 (1 S.E. = ±1.4), while the basal area of the planted trees is 10.6 cm^2/m^2.

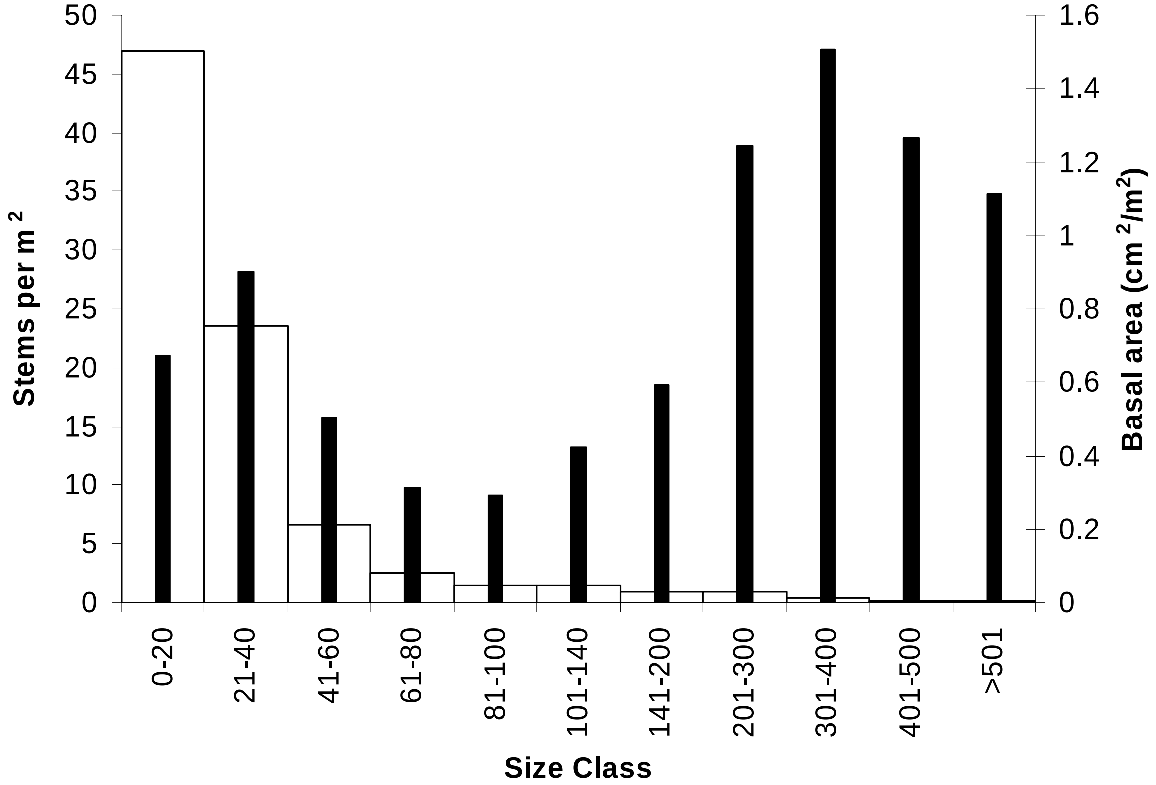

Figure 2. Mean abundance of naturally regenerating Camellia sinensis stems per size class per m2 (□, left axis) and mean total basal area per size class per m2 (■, right axis)

The basal area is derived from the average height and abundance per size class using the regression equation for the height-DBH relationship (Figure 1).

There is a significantly lower total abundance of non-tea woody species in quadrat samples from the tea plantation compared to controls in the natural and logged forests (ANOVA, F=21.58, d.f. = 31, $P<0.001$; Fisher's pairwise $P<0.05$). There are also significantly lower abundances as per size class (Fisher's pairwise $P<0.05$), except between non-tea plants under 1m in the logged forest and the plantation (Figure 3).

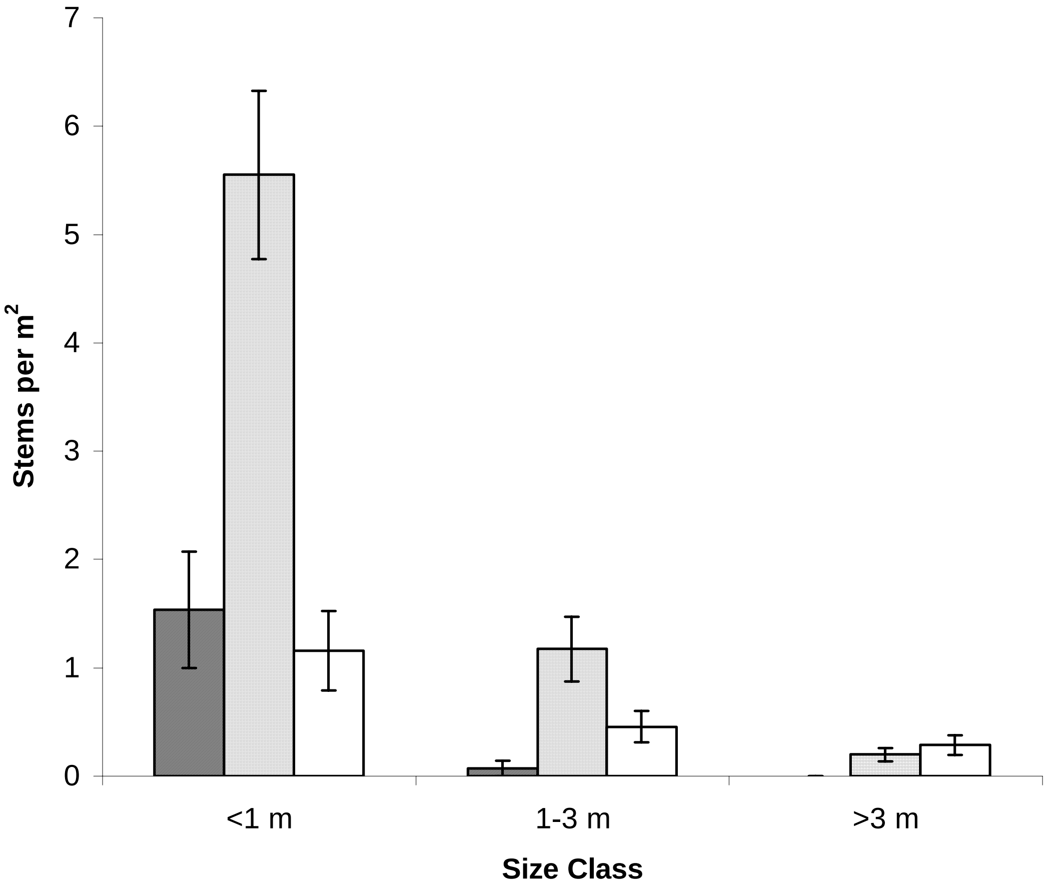

Figure 3. The mean (±1 S.E.) abundance of woody species, other than *C. sinensis*, in three size classes found in the tea plantation (▨), the natural forest (⚃) and the logged forest (☐)

Spread of tea

The extent of spread of tea along the 30 m transects showed no significant correlation to the gradient of the slope (P<0.419). Furthermore, comparing the coefficients of the regressions, there is no significant difference between the change in the abundance of tea plants along the transects into the natural and logged forests (natural forest regression coefficient = 167, 1 S.E. = ±21, P<0.001, n=6; logged forest regression coefficient = 128, 1 S.E. = ±21, P<0.001, n=6). On this basis the data from transects on both sides were treated as one dataset to produce a mean of the vegetation gradient on both sides of the plantation. Figure 4 illustrates the sharp change in the composition of the vegetation from the plantations to the forests. Also visible is the existence of clusters of tea plants away from the plantation some of which include large (3 – 7 m), seeding trees. Figure 5 illustrates the change in stem density between the tea plantation and the forests.

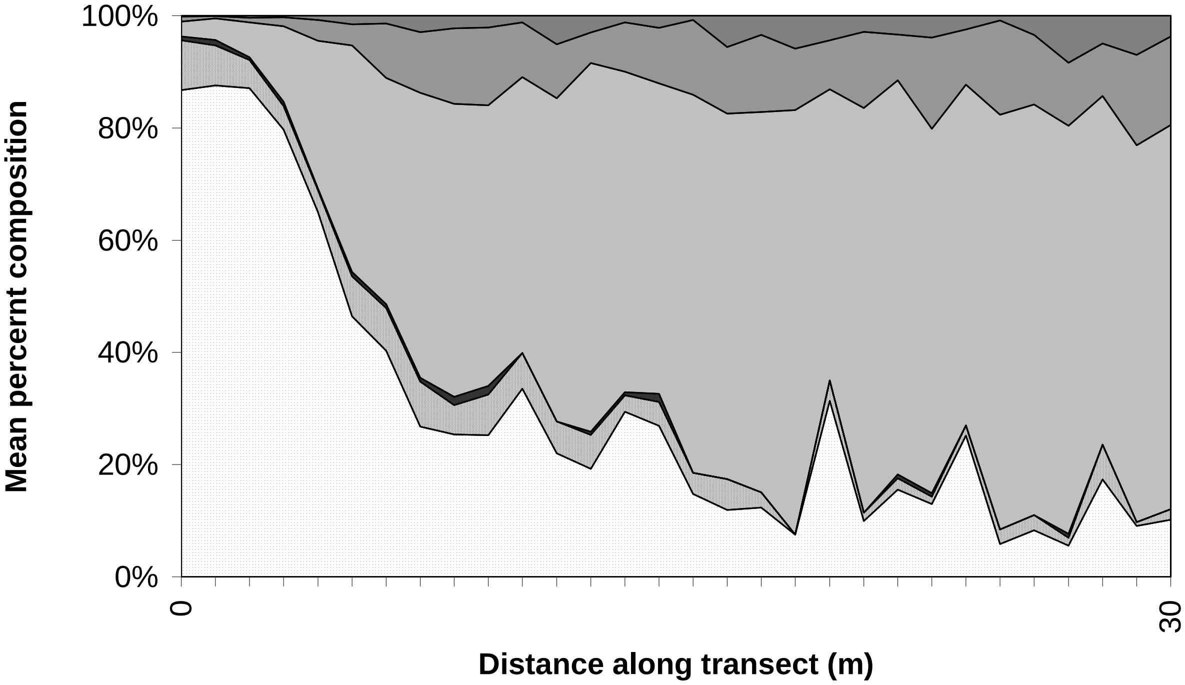

Figure 4. Mean percent plant composition for *Camellia sinensis* in size classes of <1m (□), 1-3m (▩), >3m (■) and other woody plant species, excluding vines, in size classes of <1m (□), 1-3m (□), >3m(□) along the 30 m transects

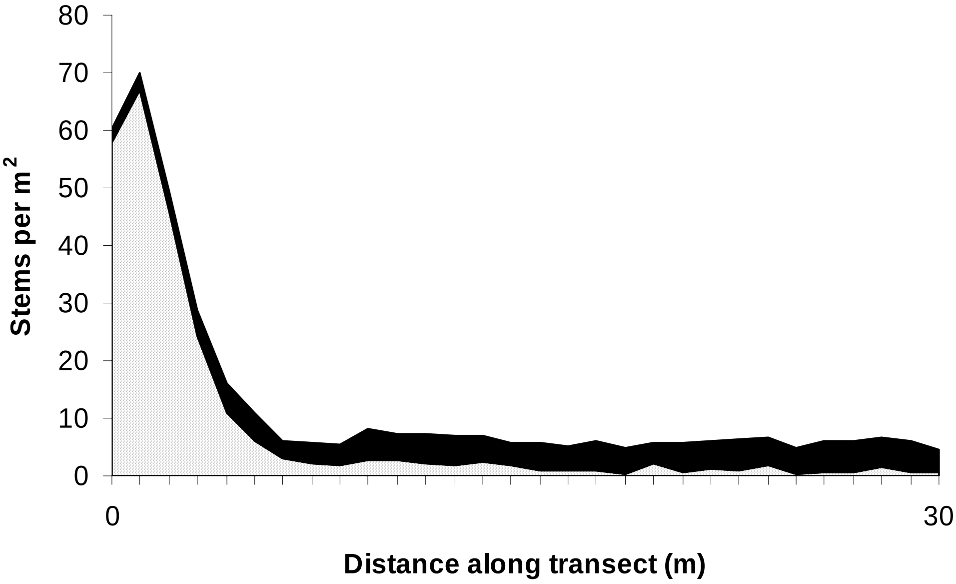

Figure 5. Mean stems per m^2 of *Camellia sinensis* (□) and other woody plant species (■), excluding vines, along the 30 m transects

The 200 m transects show a very similar long-range dispersal of *C. sinensis* into both forests (Figure 6) (natural forest regression coefficient = -0.423, 1 S.E. = ±0.05189, P<0.001, n=3; logged forest regression coefficient = -0.417, 1 S.E. = ±0.0723, P<0.001, n=3). For that reason, the datasets of the 200 m transect were again combined to give a mean dispersal distance (Figure 7).

Figure 7 shows that *C. sinensis* has spread a considerable distance from the seed source, although it is still found at very low densities in the forests. The figure also confirms observations of clusters, usually around seeding trees, that have established in both forests.

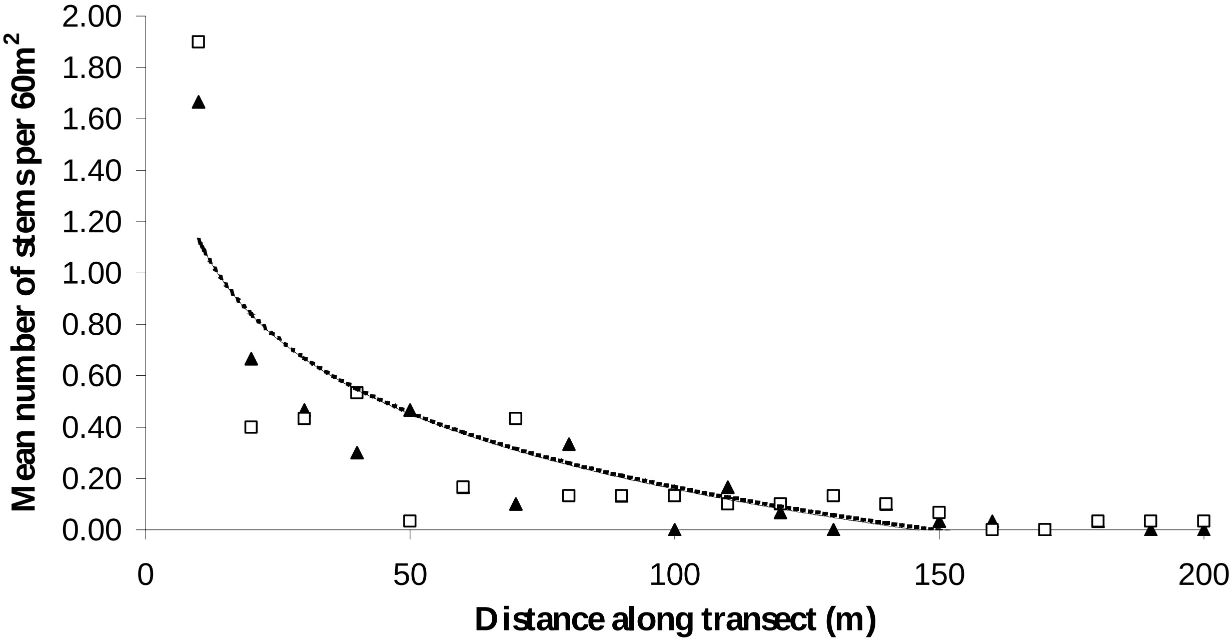

Figure 6. Mean number of *C. sinensis* stems per 60m^2 along the 200 m transects for natural (▲) and logged (□) forests, showing best-fit lines (—— natural and - - - - logged)

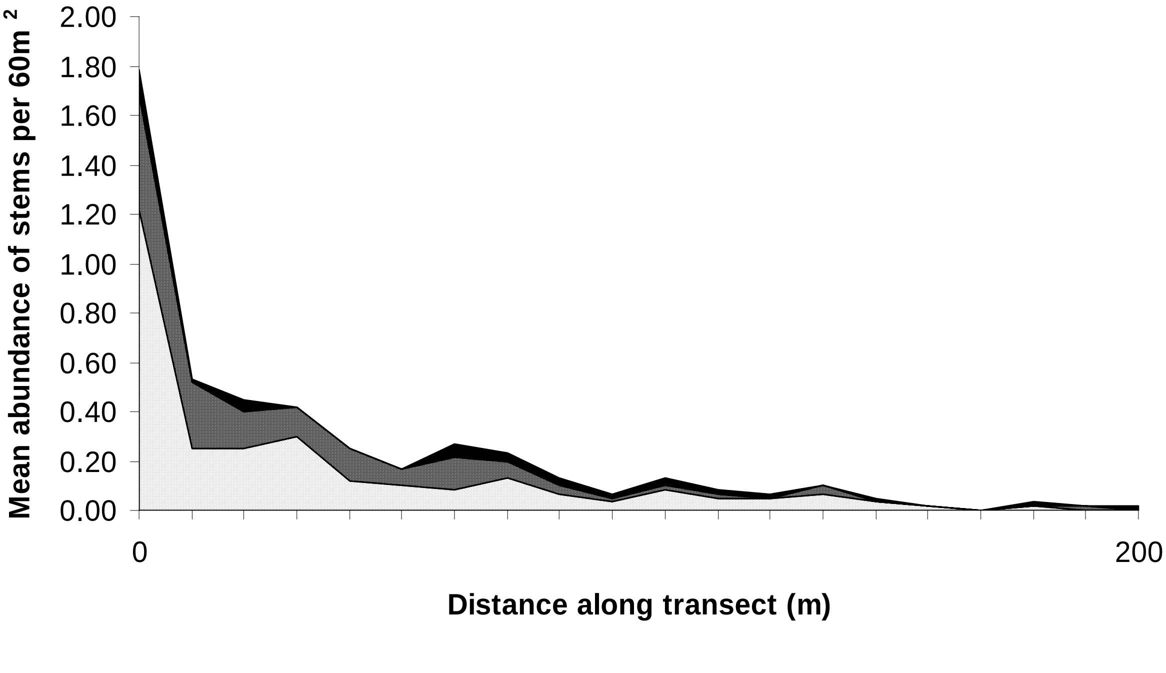

Figure 7. Mean abundance of *C. sinensis* stems per 60 m^2 for size classes of <1m (□), 1-3m(□) and >3m(■) along the 200 m transects

OBSERVATIONS

Only a very small number of dead *C. sinensis* stems were found during the study, suggesting very low mortality rates. In terms of dispersal, a number of dense clusters of 10 to 20 even-aged seedlings were found growing far from the plantation. These clusters are typical of rodents that feed on and store seeds in the ground. It was suggested that the pouched giant rat (*Cricetomys* spp.) is the species involved, though this would need to be investigated further.

A further observation made was a perceived higher incidence of disease, evident in leaf damage, on isolated plants away from the plantation. It is difficult to find a mechanism that would explain this observation, other than differences in microhabitat between the ridge and the forests.

Also, plentiful seeds were found on the ground under the planted trees, including many that were just germinating. The seeds are large (approx. 1.5 cm in diameter) and seed production is thus low compared to other invasives.

DISCUSSION

The results confirm the observation that the planted tea in the study site has naturalised (i.e. it is acting as a seed source for successful regeneration). The size class distribution (Figure 2) shows no stratification, but rather a continuous regeneration, combined with very little evidence of mortality. There is also a very high density amongst the regenerating tea (85 stems / m^2) indicating low intraspecific competition and a high shade tolerance under the dense canopy. This high density appears to be suppressing the regeneration of non-tea species, with a mean number of stems of only 1.6 / m^2 (1 S.E. = ±0.53) (Figure 3), essentially forming a monotypic stand of tea. The similar low frequency of stems <1 m measured in the logged forest (Figure 3) can be attributed to the reported regeneration suppression by *Maesopsis eminii* (Geddes 1998), that dominates the forest, and the higher abundance of herbaceous species observed in the logged forest, that were not present in the tea plantation.

The very high density underneath the planted tea drops rapidly a few meters away from it (Figure 4 and 5) demonstrating that the majority of seeds are not dispersed but germinate under the parent population. Therefore, despite a high propagule pressure, there appears to be insufficient dispersal for the rate and extent of invasion seen with other exotics. One mode of long-range dispersal appears to be by rodents and a number of founder populations were also observed up to the end of

the 200m transects (Figure 7). The existence of second generation, successfully seeding adults suggests that the population of *C. sinensis* will persist and continue to spread through the forest.
The similarity between the extent of spread between the logged and natural forests contradicts the common association of invasives with disturbed habitats and the resistance of tropical forests to invasion (Whitmore 1991) (Figure 6). *C. sinensis* seems to be equally able to colonise disturbed and undisturbed habitats, despite its slow growth rate. This may be due to its shade tolerance and its role as an understory species in its natural range.

CONCLUSIONS

Camellia sinensis is clearly able to naturalise and become a sub-canopy dominant in the Usambara Mountains, given sufficient introduction effort. The extent of this dominance in the study site and its effect on the natural forest dynamics, through regeneration suppression, has clear management implications regarding the incorporation of tea plantations into nature reserves. It is suggested that all *C. sinensis* plants should be eliminated from any such areas and native pioneers planted in their place. The lack of regeneration of non-tea tree species under the planted trees of the study site would suggest that tea could eventually form a low canopy forest, once the large canopy trees have died.

In terms of invasion, *C. sinensis* appears to spread at a slow rate compared to other invasive species found in the ANR. However, the presence of the species in many areas of the reserve and its ability to spread into undisturbed natural forest are of concern. Long time-lags have been observed with other invasives (Binggeli 1998) and thus the density and rate of spread of *C. sinensis* may increase once a sufficiently large population is achieved.

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