ASSESSMENT OF FACTORS FOR DECLINING REGENERATION AND DEATH OF EAST AFRICAN CAMPHOR IN MOIST MOUNTANOUS FOREST OF TANZANIA

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RICHARD J, MADOFFE SS & MALIONDO SMS. 2014. Assessment of factors for declining regeneration and death of East African camphor in moist mountanous forest of Tanzania. The East African camphor (*Ocotea*), a canopy tree species and an important component of Chome Nature Reserve is seriously declining in density. Although the species is still illegally logged for timber, the main concern of ecologists is the declining regeneration and death of individuals in all age classes. In this study, we examined the influence of disturbance and heart rot on the regeneration and death of *Ocotea*. Forest disturbance and the status of *Ocotea* were assessed in 62 strips of 10 m wide and 100 m long. The results of this study indicate that disturbance was a more important determinant of *Ocotea* death than heart rot, and regeneration of *Ocotea* was much influenced by elevation. There was no evidence for the influence of disturbance on regeneration. These results suggest that the distribution of *Ocotea* in Chome Nature Reserve was shifting towards higher elevation. This was due to degradation of habitats suitable for growth of *Ocotea* in lower accessible areas. Therefore, protection by restricting anthropogenic activities in the nature reserve is important for restoring and maintaining camphor forests.

Keywords: *Ocotea*, Chome, elevation, illegal logging, habitat

INTRODUCTION

Anthropogenic disturbances including extraction of timber, uncontrolled fires, clearance for subsistence agriculture and charcoal making have been cited as major causes of habitat change resulting in reduction of plant species diversity in most tropical forests (MEA 2005). One example of such habitats is the Eastern Arc Mountains of Tanzania, one of the hot spot biodiversity areas in the world, which by the year 2000, had lost nearly 80% of its paleoecological forest habitat (Hall et al. 2009). Several studies in the Eastern Arc Mountains have reported decline in regeneration and density of important tree species which is associated with disturbance and overexploitation (Hamilton 1989, Mrema & Nummelin 1998, Frontier Tanzania 2001, 2005, Mwang'ingo et al. 2004). One of the species declining seriously in the Eastern Arc Mountains is the East African camphorwood, *Ocotea usambarensis* (referred to as *Ocotea* from here on). Although *Ocotea* is still illegally logged for timber, the declining regeneration and death of the species have been attributed to heart rot (Nsolomo & Venn 1994).

Ocotea whose native range in Tanzania is confined to the Eastern Arc Mountains and Mount Kilimanjaro (Mbuya et al. 1994), is also known to occur in mountain rain forests of Kenya, Uganda, Malawi and Zambia (Renvall & Niemela 1993). *Ocotea* used to be the dominant tree species in Chome and Magamba Nature Reserves (both in the Eastern Arc Mountains, Table 1) and on the southern slopes of Kilimanjaro, but its stands have been logged extensively, a practice started before the 1930s (Kimariyo 1972, Hamilton & Mwasha 1989). *Ocotea* regenerates mainly from suckers and coppices and in its favourite habitats can grow to a height of 40 m and diameter up to 3 m (Mbuya et al. 1994). Although germination of sown seeds of *Ocotea* is fairly good (Msanga 1998), natural regeneration from seed is uncommon due to predation by squirrels or damage by larvae before ripening (Bussmann 2004). It is for this reason that early research on *Ocotea* concentrated on finding alternative ways to regenerate the species and regeneration from root suckers proved to be the best (Kimariyo 1971, Mugasha 1996).

Table 1 Stand characteristics and density of *Ocotea usambarensis* (dbh > 10 cm) in the Eastern Arc Mountain forests as recorded from each of the four nature reserves, namely, Chome (CNR), Magamba (MNR), Uluguru (UNR) and Amani (ANR) Nature Reserves

Nature reserve	Elevation (m asl)	Average tree density (stems ha^{-1})	*Ocotea* density (stems ha^{-1})	% of canopy occupied by *Ocotea*	Current regeneration status	References
CNR	1250–2463	342	36	Dominant tree with over 42% of the canopy	Regenerating above 1500 m asl	Malimbwi & Mugasha (2001)
MNR	1650–2300	405	113	Dominant tree with over 57% of the canopy in some areas	Regenerating above 1500 m asl	Maliondo et al. (1998)
UNR	600–2638	364	17	Occupy over 3.7% of the canopy	Regenerating above 1700 m asl	Frontier Tanzania (2005)
ANR	300–1128	472	0.12	Occupy only 0.03% of the canopy	No regeneration	Hamilton (1989), Frontier Tanzania (2001)

For several years, declining regeneration and death of *Ocotea* stands, which account for almost 50% of some forests in the Eastern Arc Mountains, have drawn attention of many scientists. Occurrences of *Ocotea* stand mortality for example in Chome Nature Reserve has increased since it was first noticed (L Nshubemuki, personal communication). Usually deaths of *Ocotea* take the form of dieback of branches which finally leave the dead trees branchless. The declining regeneration and mortality have been attributed to heart rot which is thought to be transmitted from mother trees to regenerants through roots and causes death (Nsolomo & Venn 1994, 1998). Recently, however, we observed that deaths of *Ocotea* are more frequent in highly disturbed areas. In less disturbed areas, several *Ocotea* trees which had hollow trunks due to heart rot were still having green crowns and had recruited several surviving regenerants in their vicinity. In the 1930s, heart rot was already a common problem in mature *Ocotea* trees. The decay limited the use of the species for peeler logs. However, at that time, deaths in all age classes which are seen nowadays were not observed (Willan 1965). The performance of *Ocotea* which is a climax tree species but also has characteristics of pioneer species may be altered by disturbance (Bussmann 2001). Paucity of quantitative evidence of the influence of disturbances and heart rot poses significant gap in our understanding of the ecology of *Ocotea* and management of the problem. Therefore, in this study we surveyed Chome Nature Reserve which is a moist forest of differentially disturbed areas (based on past licensed logging activities) to determine the importance of disturbance on dieback and regeneration of *Ocotea*.

MATERIALS AND METHODS

Study area

Chome Nature Reserve, which covers 14,283 ha of land is located between 4° 10'–4° 24' S and 37° 53'–38° 00' E. The altitude of Chome Nature Reserve ranges between 1250 and 2463 m above sea level. Rainfall is estimated at 3000 mm on the wetter eastern side of the reserve, while the dryer western slopes receive an estimated 1500–2000 mm. Temperature ranges between a minimum of 15 °C in July and a maximum of 20 °C in February (Lovett 1993). Main vegetation types are submontane, montane and upper montane forests. The montane forest occurs between 1500 and 2300 m above sea level which, before extensive logging, was dominated by *Ocotea*. Unlike many other forests in the Eastern Arc Mountains, huge *Ocotea* trees reaching 45 m in height and 2 m diameter are common in the Chome Nature Reserve (URT 2010). Much of the disturbances after the logging ban in 1986 are due to illegal logging of *Ocotea*, *Podocarpus* spp. and *Newtonia buchananii*. In addition, *Parinari excelsa*, a common tree species in the submontane forest, is cut for fuelwood, whereby big trees are debarked to hasten their death and later felled for fuelwood.

Data collection

In determining the intensity of tree cutting and other past human disturbances in the forest, the study adopted techniques that were used by Frontier Tanzania (2005). Eight transects ranging from 2 to 3 km in length were established from the boundary to the interior of the forest towards Shengena peak. The forest was accessed from eight villages (Vushanje, Mtii, Mvaa, Changuluwe, Gonjanza, Suji, Tae and Chome) which border the forest. The villagers practise illegal pit-sawing in the reserve. Data were collected along each transect in a 10 m wide (i.e. 5 m on either side of the transect line) and 100 m long strip with an interval of 200 m between strips. This gave a total of 62 strips in all the eight transects, equivalent to 0.05% of the sampled area of Chome Nature Reserve. Heath land (1458 ha) which is dominated by *Philipia* spp. was not sampled in this study.

Along the strip, each woody plant (i.e. not lianas or creepers) with diameter at breast height (dbh) > 5 cm was measured, identified and recorded as live, cut or naturally dead. All young *Ocotea* trees with dbh ≤ 5 cm within the strips were counted and those with dbh > 5 cm were assessed in terms of their health status (live, dying back or dead) and their site elevation recorded. Assessment of heart rot intensity on both live and dead *Ocotea* was done in order to predict the cause of their health status. The heart rot intensity indices were scored on a scale of 1 to 3, where 1 = trees with severe heart rot signified by holes in the trunks, 2 = trees with clear symptoms of decay (i.e. fungal fructification and epicormic branches) and 3 = trees which had none of the above defects (Nsolomo & Venn 2000). In assessing the influence of heart rot on the regeneration, only mature *Ocotea* trees with dbh > 30 cm within the strip were considered. The index with highest frequency (mode) in the strip was regarded as the score for heart rot intensity of the strip.

The condition of each strip was assessed in terms of disturbance intensities due to past human activities. The intensities were ranked as mild, moderate or high disturbance. The criteria that were used by the survey team as a measure of disturbance intensities were presence of foot paths, presence of sawing pits, number of logs and tree stumps, absence of climbers and the general forest physiognomy. Canopy density, mostly used to determine regeneration in tropical forests, was assessed in each strip and this also assisted as additional measure of disturbance. Percentage of the canopy density was measured using concave spherical densitometer (Lemmon 1957). Three readings of the canopy density were taken over each strip (one at the middle and one each at both ends) and the average calculated.

Data analysis

Data were analysed using SAS 9.1.3 (2009). One-way ANOVA was used to explain basic trends in forest and *Ocotea* status in relation to the three disturbance categories. Before running the ANOVA, all variables that did not pass normality test were log (x + 1) transformed with the exception of canopy cover (arcsine transformed) as well as elevation and density of live trees (both were normally distributed). Multiple regression analysis (using backward elimination) was used to determine the influence of elevation, disturbance, canopy cover and heart rot intensity on regeneration and health status of *Ocotea* trees. Models were re-run excluding the elevation in the explanatory variables to determine effects of disturbance, heart rot intensity and canopy cover on regeneration and health status of *Ocotea*. Before running the regression analysis, correlation between explanatory variables were computed and co-linearity was diagnosed using variance inflation factor.

RESULTS

Density of stumps and live trees

Generally, the entire nature reserve was disturbed with the exception of small patches at high altitude (> 2200 m above sea level) which were covered with tree species such as *Myrica salisfolia, Memecylon deminutum*, *Myrsine pulchura* and *Schefflera myriantha*. These spesies were less preferred by the surrounding communities. The most common and frequently registered form of existing disturbance in the nature reserve was tree cutting. Of the 62 strips surveyed, 16 were highly disturbed, 22 moderately and 24 were in semi natural forest where disturbance was mild (Table 2). There was no evidence

Table 2 Stand characteristics, elevation and canopy cover recorded (mean ± SE) in strips with different disturbance intensities in Chome Nature Reserve, Tanzania

Variable	Disturbance intensity		
	High	Moderate	Mild
Number of strips	16	22	24
Average dbh of *Ocotea* (cm)	37.6 ± 5.7	54.9 ± 24.3	94 ± 47.1
Density of *Ocotea* (stumps ha^{-1})	57 ± 19	29 ± 11	7 ± 3
Density of *P. excelsa* (stumps ha^{-1})	126 ± 44	34 ± 32	0
Density of live trees ha^{-1}	354 ± 42	531 ± 34	504 ± 41
Density of stumps ha^{-1}	399 ± 44	189 ± 21	73 ± 10
Elevation (m)	1450 ± 34	1712 ± 65	1953 ± 56
Canopy cover (%)	74.6 ± 4.5	82.4 ± 1	89.9 ± 0.7

dbh = diameter at breast height

of past illegal logging (such as saw pits or old stumps of *Ocotea*) at high altitude as more than 60% of the stumps were from recent cuts. Density of stumps varied significantly in the three disturbance categories ($F_{2,59}$ = 42.7, p < 0.0001, Table 2). In highly disturbed areas, an average of 399 trees ha^{-1} were cut. In this case, the density of stumps in highly disturbed areas was almost six times higher than in mildly disturbed areas. *Ocotea* and *P. excelsa* were the most cut tree species with average of 57 and 126 stumps ha^{-1} respectively (Table 2). Almost all cut *Ocotea* were big trees with dbh > 30 cm while cut *P. excelsa* were both small and big trees. Unlike in other Eastern Arc Mountain forests, big *Ocotea* trees with dbh > 100 cm still exist in mildly disturbed areas.

On average, density of live trees was significantly higher in intermediate disturbance ($F_{2, 59}$ = 4.9, p < 0.01, Table 2) than highly disturbed areas. Elevation varied significantly across disturbance categories ($F_{2, 59}$ = 17.8, p < 0.001, Table 2), with areas in low altitude being more disturbed than in high altitude. Canopy cover also exhibited significant difference ($F_{2, 59}$ = 12.3, p < 0.001, Table 2) between disturbance categories.

Disturbance, elevation and canopy cover

In all regression models, elevation was the only consistent variable explaining the variation in density of *Ocotea* regenerants, dead and live trees (Table 3). Density of regenerants and live trees increased with increasing elevation while that of dead trees decreased. Although disturbance could not explain the variation in density of regenerants, it significantly explained the variation in density of dead *Ocotea*. As expected, density of live trees decreased with increasing disturbance. In the best-fit models, canopy cover also significantly (p < 0.001) determined variation in density of regenerants and dead trees. Heart rot did not account for any variation as it was not significant (p > 0.05) in all models. Co-linearity was not particularly a problem as all the variance inflation factors were lower than 2.5, thus, all the explanatory variables were used in explaining regeneration and health status of *Ocotea*. Elevation was significant correlated with disturbance (r = -0.61, p < 0.01, df = 62) and, as expected, canopy cover significantly correlated with disturbance (r = -0.54, p < 0.01, df = 62, Table 4).

In examining the influence of elevation on other explanatory variables, models were re-run excluding the elevation. All models for disturbance index were not affected by excluding elevation (Table 5). However, for canopy cover, significant positive value (p < 0.0001) was included for both regenerants and live tree densities and non-significant value, for dead trees model. Again, heart rot index is not significant in all models (p > 0.05). Therefore, without explicit information on elevation, results suggest that disturbance was more important in determining the health of *Ocotea* trees. *Ocotea* still regenerated in high altitude, particularly between 1600 and 2200 m above sea level. Most of the regenerants encountered were from root suckers, few were from recent cut stumps as coppices and very few as seedlings. Generally, it was observed that coppices and suckers emanating from the same parent tree differed in

Table 3 Results of multiple regressions showing the influence of elevation, disturbance, canopy density (arcsine transformed) and heart rot on regeneration and health status of *Ocotea* in Chome Nature Reserve, Tanzania

Variable	Regenerants	Health status	
		Dead/dying back	Live
Adjusted r^2	0.61	0.62	0.35
F	48.84	31.95	16.26
Elevation	0.0072****	-0.0015**	0.0016****
Disturbance index	-	0.7512****	-0.8256**
Canopy cover	-0.10236***	-0.0281**	-
Heart rot index	-	-	-

* = p < 0.05, ** = p < 0.01, *** = p < 0.001 and **** = p < 0.0001 '-' indicates values that were dropped out as they were non significant

Table 4 Results of Pearson's correlation coefficient between explanatory variables

Variables	Elevation	Disturbance index	Canopy cover	Heart rot index
Elevation	1.00	-0.613****	0.225	0.037
Disturbance index		1.00	-0.543****	-0.003
Canopy cover			1.00	0.073
Hear rot index				1.00

*p < 0.05, **p < 0.01, ***p < 0.001 and ***p < 0.0001

Table 5 Results of multiple regressions showing the influence of disturbance, canopy density (arcsine transformed) and heart rot after eliminating the effect of elevation on regeneration and health status of *Ocotea* in Chome Nature Reserve, Tanzania

Variable	Regenerant	Health status	
		Dead/dying back	Live
Adjusted r^2	0.43	0.54	0.34
F	45.8	72.4	15.4
Disturbance index	-	0.68****	-0.934**
Canopy cover	0.045****	-	0.0359****
Heart rot index	-	-	-

*p < 0.05, **p < 0.01, ***p < 0.001 and ****p < 0.0001; '-' indicates values that were dropped out as they were non significant

their vitality, whereby coppices were weaker and drying out while suckers were healthy and had thicker root collar diameter.

DISCUSSION

Despite the official logging ban in 1984 and the many steps that were taken to improve the forest condition by reducing anthropogenic activities in all the Eastern Arc Mountains, logging for timber and tree cutting for fuelwood are still a problem in Chome Nature Reserve. Control of illegal harvesting, in particular *Ocotea*, is virtually impossible unless surrounding communities are practically involved in forest management (Malimbwi & Mugasha 2001). The fact that at least 10 stumps of *Ocotea* per ha was from recent cuts still posed significant threat to *Ocotea*, which is already in decline due to dieback (URT 2010). The objective to conserve biodiversity and water catchments by upgrading most of the Eastern Arc Mountain forests to nature reserves may not be realised if conservation plans are not supplemented with identification and promotion of other alternative income-generating activities. Currently, illegal logging is still one of the primary income-generating activities for the communities around Chome Nature Reserve. Most of the efforts undertaken by forest guards to stop logging received risky and stiff objection from surrounding communities especially from the youths. Negative correlation between elevation and disturbance suggests that areas in low altitudes were more disturbed than in the high altitudes where access was difficult. This situation, which is very common to almost all the Eastern Arc Mountain forests, is threatening the existence of species with restricted range in low altitudes (Hall et al. 2009).

Although results from this study show that density of regenerants was primarily influenced by elevation, the role of heart rot on *Ocotea* regeneration cannot be underestimated. This is based on the fact that by assuming all encountered regenerants emanated only from mature trees within the strip we might have inadequately determined the influence of heart rot on the regeneration of *Ocotea*. Survey in the Uluguru show that sucker production is inversely related to the degree of heart rot in *Ocotea* stumps (Mwamba 1986). Nevertheless, such results cannot be used to conclusively infer the relationship between degree of heart rot in standing *Ocotea* trees and regeneration as it is obviously expected that severely rotted stump cannot support regenerants. Notwithstanding these limitations, the study has found no evidence of a relationship between disturbance and regeneration of *Ocotea*. Hence, regeneration of *Ocotea* was only influenced by elevation. *Ocotea* is light demanding at the early stage of its growth and this is one of the reasons why is considered as both a pioneer and a climax tree species (Kimariyo 1971, Mugasha 1978). Results from this study do not contradict with these findings as, in this study, most of the regenerants of *Ocotea* were also found in localised gaps at high altitudes but not in severely disturbed low altitudes where canopies were more open. In contrast, succession and regeneration studies in montane forest of Kenya reported failure of regeneration of *Ocotea* in open canopy after large-scale logging (Bussmann 2001, 2004).

The influence of altitude on regeneration of *Ocotea* in Chome Nature Reserve provides reasons for declining regeneration in lower parts of the Eastern Arc Mountains which used to have *Ocotea* as one of the dominant tree species. In Amani Nature Reserve *Ocotea* was abundant but restricted within 900 to 1100 m above sea level (Hamilton 1989). Although direct comparison between the four nature reserves is difficult, *Ocotea* would currently be considered a rare tree species in Amani Nature Reserve based on its proportion to other tree species (Table 1). Amani Nature Reserve is considered more restored in terms of tree density than the other four nature reserves, yet it is the only reserve in the Eastern Arc where *Ocotea* is no longer regenerating. The highest point in Amani Nature Reserve (1130 m) is lower than the lowest point in Chome Nature Reserve (1250 m). Amani Nature Reserve is unusually wetter, moist and cold due to the influence of the Indian Ocean and this allows growth of tree species which are found in relatively higher altitudes in other Eastern Arc Mountain forests (Hamilton 1989, Iversen 1991). Altitude is directly linked to a variety of ecological factors with significant impact on plant regeneration, e.g. temperature, humidity and soil (Iversen 1991), which were not considered in this survey. Changes in such climatic variables are considered as one of the possible causes hampering regeneration of *Ocotea* in Eastern Arc Mountains (Iversen 1991, Schulman et al. 1998).

As with regeneration, densities of dead and live *Ocotea* were also influenced by altitude. However, disturbance had stronger influence than elevation on the death of *Ocotea*. Severe illegal cutting of upper canopy and climax species in Chome Nature Reserve such as *P. excelsa*, *Ficalhoa laurifolia* and *Podocarpus* spp. may have contributed to the death of *Ocotea* as the species is not known to be an open canopy species (Bussmann 2004). The role of disturbance, particularly logging on forest condition has been widely studied. In most cases, disturbance is implicated as the factor that predisposes trees to insects and diseases which finally cause death of the trees (Hennon & DeMars 1997). This study represents a very different scenario, in which disturbance is implicated as the cause of tree death. When studying fungal decay in *Colophospermum mopane,* Smith and Shah-Smith (1999) found that the decay (heart rot) is not capable of causing death of the species. This was due to the fact that majority of the fungi isolated from *C. mopane* were saprophytes which attacked only dead heartwood and bark of the tree, without affecting the living cambium.

This study suggests that distribution of *Ocotea* in Chome Nature Reserve is shifting towards higher elevation due to changes in habitat quality. The previous moist and wetter habitats in Chome Nature Reserve might have shifted to high elevation due to persistent disturbance in the low elevation, resulting in adulterated plant distribution. Prevailing dieback of *Ocotea* stand and declining regeneration were possibly due to degradation of habitat suitable for the growth of *Ocotea*. However, the role of warmer microclimate than during previous period as reported by Hamilton (1989) and Hemp (2009) cannot be ruled out.

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