THE IMPACTS OF ANTHROPOGENIC ACTIVITIES ON THE VEGETATION COMMUNITIES AND STRUCTURE IN THE WESTERN PART OF RUNGWE FOREST RESERVE, TANZANIA

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ABSTRACT

Rungwe Forest Reserve is among the degraded southern Tanzania tropical montane forests. It was investigated the effects of illegal anthropogenic activities on the plant community structure on the western part of Rungwe mountain forest reserve. The study area was classified into three levels of disturbance (least disturbed, moderately disturbed and highly disturbed) and transect method was used to collect data. Two clusters (clusters A and B) of plant communities based on Two Way Indicator Species Analysis (TWINSPAN) were found. Cluster A included communities from the least and moderate disturbed sites and cluster B had plant communities from the highly disturbed site. The least, moderately and highly disturbed sites had many individuals within the DBH range of 19-57 cm, 10-47 cm and 11-14 cm, respectively. The observed variation in size class structure among the sites was caused by the intensity of anthropogenic disturbance. The inverted J shaped patterns of diameter size class distribution were indicative of regeneration and active recruitment from lower tree growth sizes. It was concluded that the existing plant community structure was shaped by the impacts of anthropogenic activities. Thus, conservation management interventions are necessary for protection of the forest.

Keywords: Plant communities, disturbance, montane forest, population size structure, Rungwe

INTRODUCTION

Rungwe Forest Reserve is among the tropical rift montane forests in the south western part of Tanzania. It is composed of several structurally and compositionally distinct plant communities compared with other ecoregions as its most dominant vegetation being the mountain grassland (White 1983). Within the forest, there are varieties of habitats characterized with thickets, scrublands and bush vegetation that accommodate high plant biodiversity (White 1983). Regardless of high plant biodiversity, a number of illegal anthropogenic activities have continued over the years that may be the causes of its degraded conditions. The degradation of Rungwe Mountain Forest is associated with the loss of primary habitats suitable for performance of indigenous plant biodiversity. The increase in anthropogenic activities has been caused by the readily available market of wood resources at Katumba and Mwakaleli Tea Factories that are within Rungwe District. For example, between 2009 and 2010; 24, 071 m^3 and 23,043 m^3 of firewood were supplied in Katumba and Mwakaleli Tea Factories, respectively (George 2012). However, 22, 000 m^3 of fuel wood on average is required for tea processing in Katumba and Mwakaleli Tea Factories per year such that 62% of the fuel wood illegally comes from Rungwe Mountain Forest Reserve (George 2012). The growing demand for fuel wood resources by the aforementioned factories has accelerated the degradation of natural habitats and the plant communities in the Forest Reserve. The

increase in human population among wards (Kiwira, Isongole and Kyimo) that are in close proximity with Rungwe Mountain Forest Reserve (Tanzania Bureau of Statistics 2002, 2012) has concomitantly increased the forest resource needs that has generated an extreme pressure on plant communities and threatened existing montane forest biodiversity (TBS 2002, 2012). The locals encroach the reserves to obtain wood fuel, charcoal making including other forest products (Bakarr *et al.* 2001, Poorter *et al*. 2004) that makes trees and shrubs heavily exploited. There is evidence that the local populace communities have encroached natural forest reserves to obtain forest products (Bakarr *et al.* 2001, Poorter *et al*. 2004) of which trees and shrubs in the study forest are of no exception. The existing anthropogenic activities included fuel wood collection, pole cutting, charcoal making, and clearance for food crop cultivation may have affected the montane plant population structure and loss of species among plant communities within the study forest. It was investigated effects of anthropogenic activities under the assumption that the existing plant communities and population structure has been shaped by the generated impacts of anthropogenic disturbance within the western Rungwe Mountain Forest reserve.

MATERIALS AND METHODS

Description and location of Rungwe Mountain Forest Reserve

Rungwe Mountain Forest Reserve is located within Rungwe District in Mbeya Region, Tanzania (Figure 1). It is found between latitudes 9°02' and 9°12'S and longitudes 33° 35' and 33°45' E. To the east, the forest is bordered with Bujingijila forest corridor and Mount Livingstone forest reserve (that has recently being included as part of Kitulo National Park). This cloaks the steep escarpment of the Lake Nyasa through overlooking Mwakaleli town (Davenport 2005). Some 10 km to the northwest is the Mporoto ridge forest reserve with the impressive crater of Lake Ngozi. To the south, the reserve is bordered by Tukuyu Town (Majule *et al.* 2008). The western part of Rungwe Mountain Forest Reserve is surrounded by six villages that include Ndaga, Ilolo, Rungwe, Syukula, Ikama and Katabe (Lovett 1993).

The climate of Rungwe District is generally tropical with marked seasonal and altitudinal temperature variations with sharply defined dry and wet seasons (Majule 2010). The general climatic conditions around Rungwe Forest Reserve are influenced by Lake Nyasa, from which winds carry moisture into the highlands (Lovett 1993). The temperature ranges between 16 ºC in the highlands and 25 ºC in the lowland areas (Majule 2010). The rain starts in October and ends in May followed by a dry and cold spell between June and September (Sakala 1998, Majule 1999). The south-eastern slopes of this mountain receive a maximum up to 3,000 mm of rainfall a year, which is the highest amount of rainfall in Tanzania (Majule 2010). The soil in Rungwe District is mainly volcanic in origin, such that in the upper and mid altitudes is covered with thick layers of volcanic and alkali basalt (Majule 2010).

Sampling procedures

A preliminary survey was first carried out in July 2013 in various parts of the Rungwe Forest Reserve to define the existing vegetation segments in terms of homogeneity and the levels of disturbance through anthropogenic activities. The western part of Rungwe Mountain Forest Reserve was more degraded than other parts at varying degrees (least, moderately and highly disturbed) and therefore selected for the purpose of this study. Two transects were laid out in each site making a total of six transects (of 500 meters long) established in the study area. The forest disturbance levels were located approximately in the same topographic positions to avoid its effect on plant communities as recommended by Addo-Fordjour *et al.* (2009). Six plots

(making a total of 18 plots) were randomly established along the transect line following the habitat heterogeneity. Trees were sampled in a 20 m x 50 m plot size where the number and stem diameter of trees at breast height were recorded. A plot size measuring 2 × 5 m nested in a bigger plot (of 25 × 20 m) (Stohlgren et al. 1995) was then used to measure shrubs and poles with diameter size class of 7 to 10 cm. The plots measuring 2 × 5 m were used to assess the density of lower size classes to include sapling and seedlings within the forest. Saplings were the young trees with diameter size class of 2 to 6 cm. The tree seedlings were those with diameter size class < 2 cm as recommended by Luoga (2004) and Lejju (2004) and each individual of the trees, shrubs (including poles sapling and seedlings) were enumerated. Plant species were identified to species level in the field when this was possible and for those which proved difficult to identify, specimens were collected, pressed and then identification was done by matching with preserved herbarium specimens that have been collected from various parts of Tanzania and East Africa.

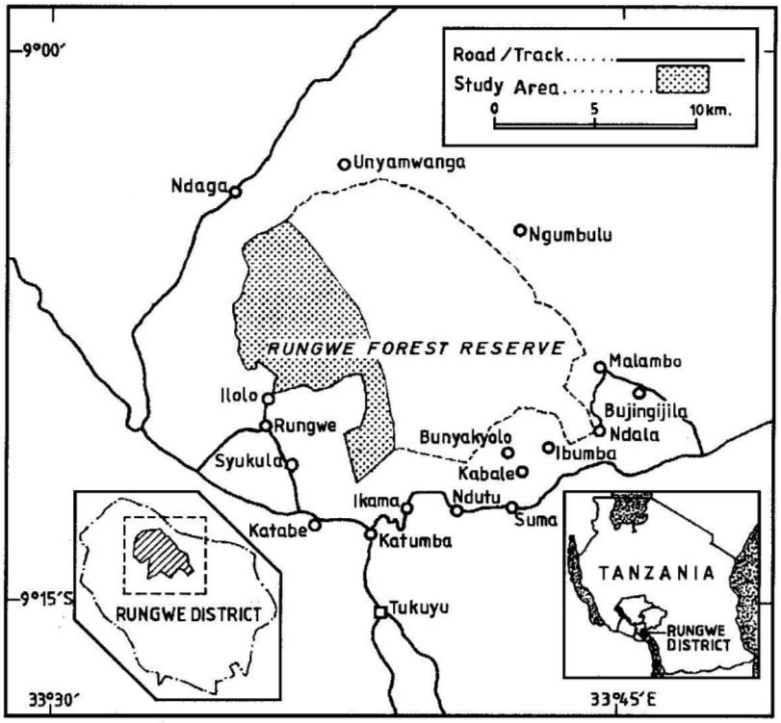


Figure 1: Map showing the location of Rungwe Mountain Forest Reserve including the study area in the western part and surrounding villages.

Vegetation data analysis

The plant communities were generated based on Two Way Indicator Species Analysis (TWINSPAN) (Hill *et al.* 1979) which is incorporated within the Community Analysis Package (CAP) version 1.5 (Henderson and Seaby 1999). The species assemblages were differentiated into vegetation communities based on indicator species. The vegetation data was processed through Microsoft excel spread sheet based on anthropogenic disturbance where a data matrix was generated using a pivot table and the converted into a compatible format (CSV-

comma delimited) with the (CAP) software. The plants population structure was assessed based on the number of individuals (density) at different diameter size classes.

RESULTS

Population size structure of trees and shrubs in Rungwe forest

Variations in population size structures of trees and shrubs existed among study sites where trees in least disturbed site had DBH sizes between 10 and 109 cm and the moderately disturbed site had a DBH sizes in a range between 10 and 79 cm. The highly disturbed site had trees with DBH sizes in a range between 10 and 39 cm (Figure 2). Among the studied sites, it was observed large number of trees with diameter sizes greater than 100 cm in the least disturbed site than it was in moderate and the highly disturbed sites. The DBH size class distributions were considerably skewed displaying an inverted J-distribution pattern with large number of individuals clustered in small diameter sizes that decreased in density with increasing diameter sizes at breast height (Figure 2).

Similar pattern was observed on the stem density of shrubs among the study sites (Figure 3), where high density was observed at 1-6 cm diameter sizes with an inverted J-shaped distribution pattern in all study sites where many individuals were in low size class that gradually decreased with the increased in stem diameter sizes. However, the density of shrubs was the highest in the moderately disturbed site followed by that in highly disturbed site and the least disturbed site (Figure 3).

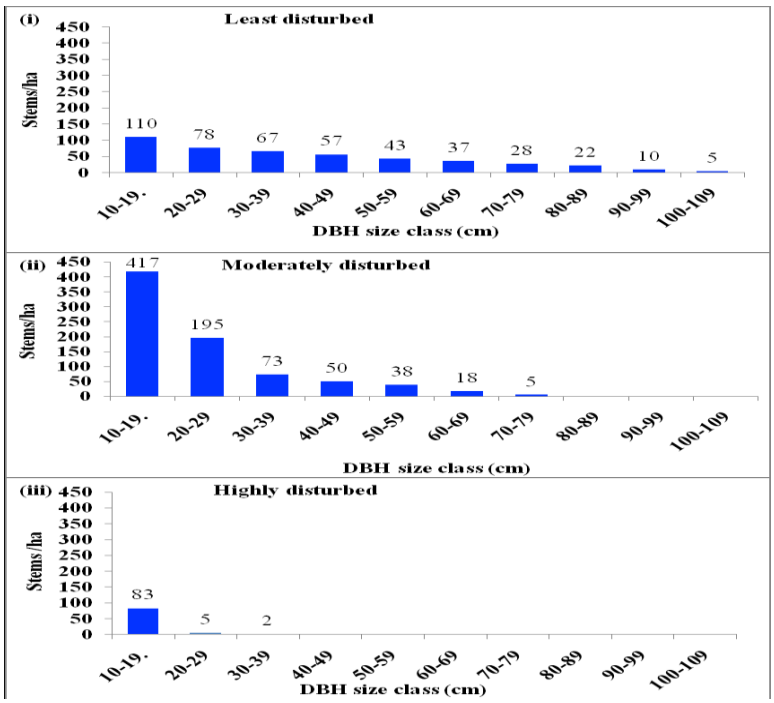


Figure 2: The DBH size class distribution of trees among sampling sites in Rungwe forest.

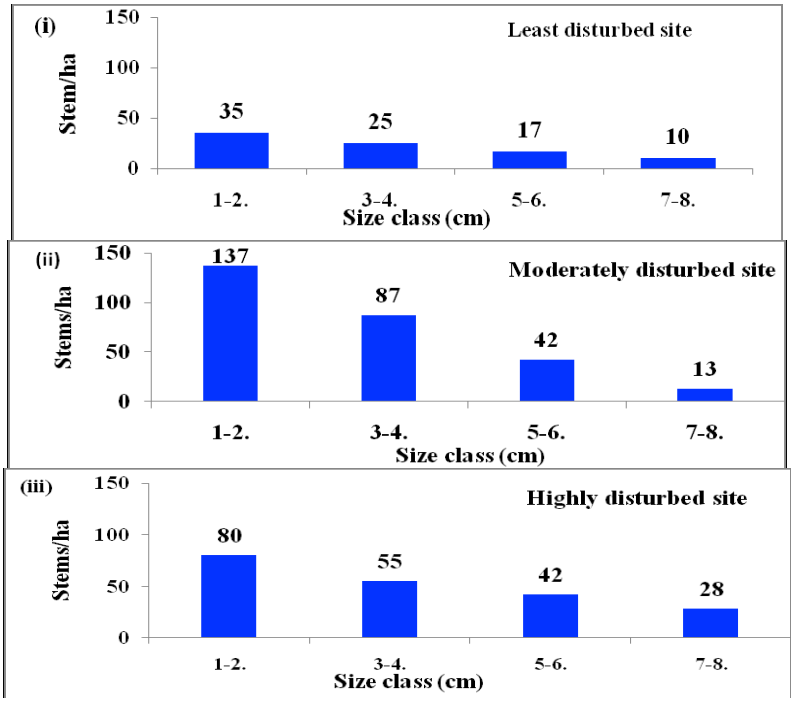


Figure 3: Diameter size class structure of poles and shrubs among sites in Rungwe forest size class distribution of the dominant tree species.

Only six trees and three shrubs that had highest stem density among the three disturbance regimes were selected to determine the population structure (Figures 4-6). Some tree species in the least disturbed sites had an interrupted pattern and included *Myrica salicifolia* (Hochst. ex A.Rich), *Allophylus abyssinicus* (Hochst) and *Prunus africana* (Hook.f.) with poor recruitment. While many of the aforementioned trees had DBH in a range between 10 cm and 59 cm (Figure 4), a smooth inverted J-curve pattern was displayed by *Cassipourea malosana* (Baker) and *Bersama abyssinica* (Sim Verdc) where many individuals were populated at small DBH size classes (Figure 4). With a bell shaped pattern for *Dombeya acutangula* (Cav.) having a few individuals in both small and large DBH size classes was an indication of unstable population (Figure 4).

The plant populations in moderately disturbed sites that displayed a smooth inverted J-shaped pattern were stems from *D. acutangula*, *Diospyros whyteana* (Hiern), *Drypetes usambarica* (Pax Hutch), *B. abyssinica* and *M. salicifolia*, whereby most individuals were at a range between 10 cm and 40 cm DBH sizes with an interrupted pattern displayed by *Strombosia scheffleri* (Engl.) (Figure 5). A sharp decrease in number of individuals with increasing DBH sizes was observed in highly disturbed parts in the forest. It was observed that there were only trees with DBH sizes in a range between 10 cm and 19 cm that included *Rhamnus prinoides* L'Hér., *Zanthoxylum deremense* Kokwaro, *Syzygium cordatum* (Hochst.), *Syzygium guineensis* (Willd. DC.), *Cathaedulis ((*Vahl) Endl.) and *D. whyteana* (Figure 6). This implies that a large number of trees have suffered a high degree of exploitation before attaining 20 cm DBH class sizes (Figure 6).

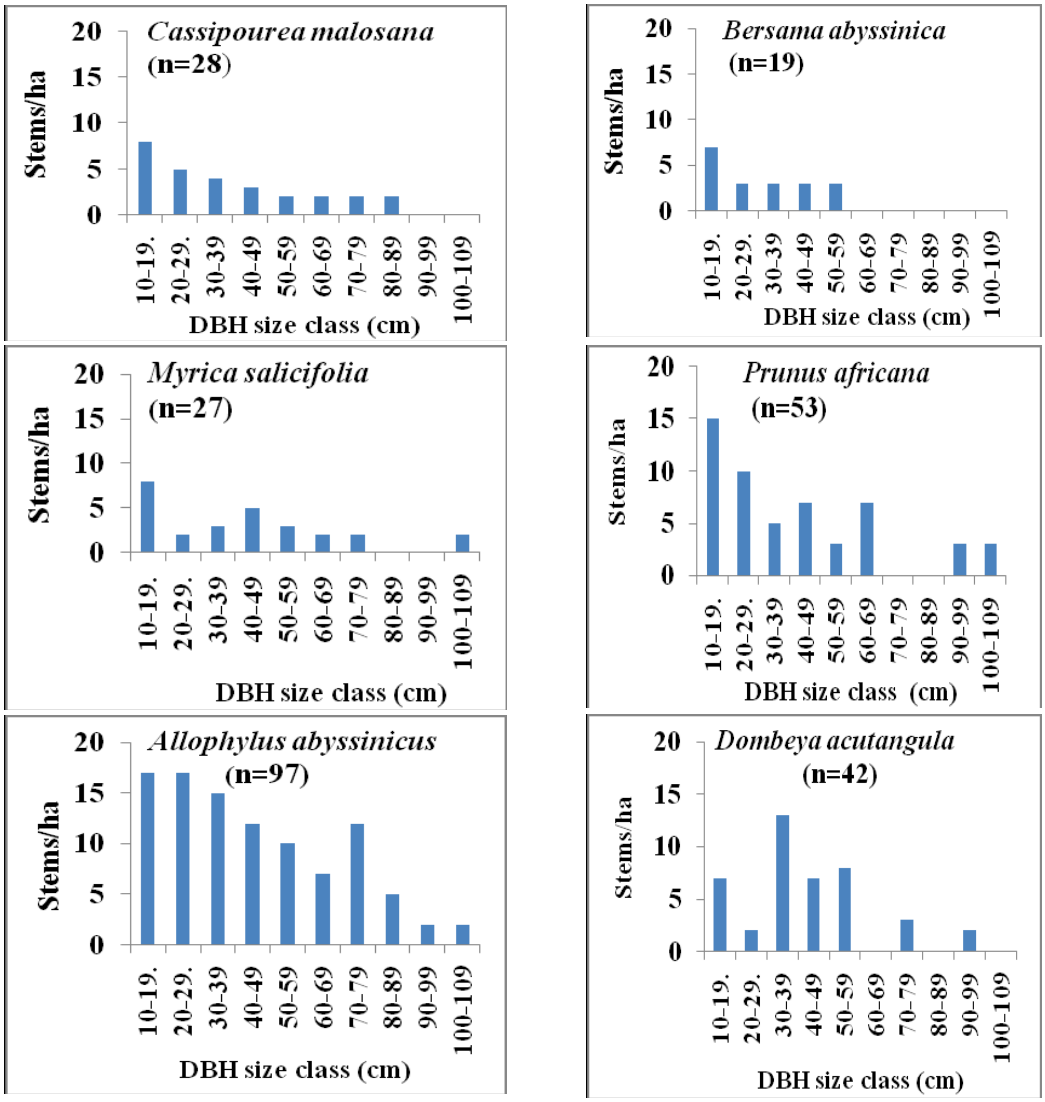


Figure 4: DBH size class distribution among dominant trees in the least disturbed site in Rungwe forest **.**

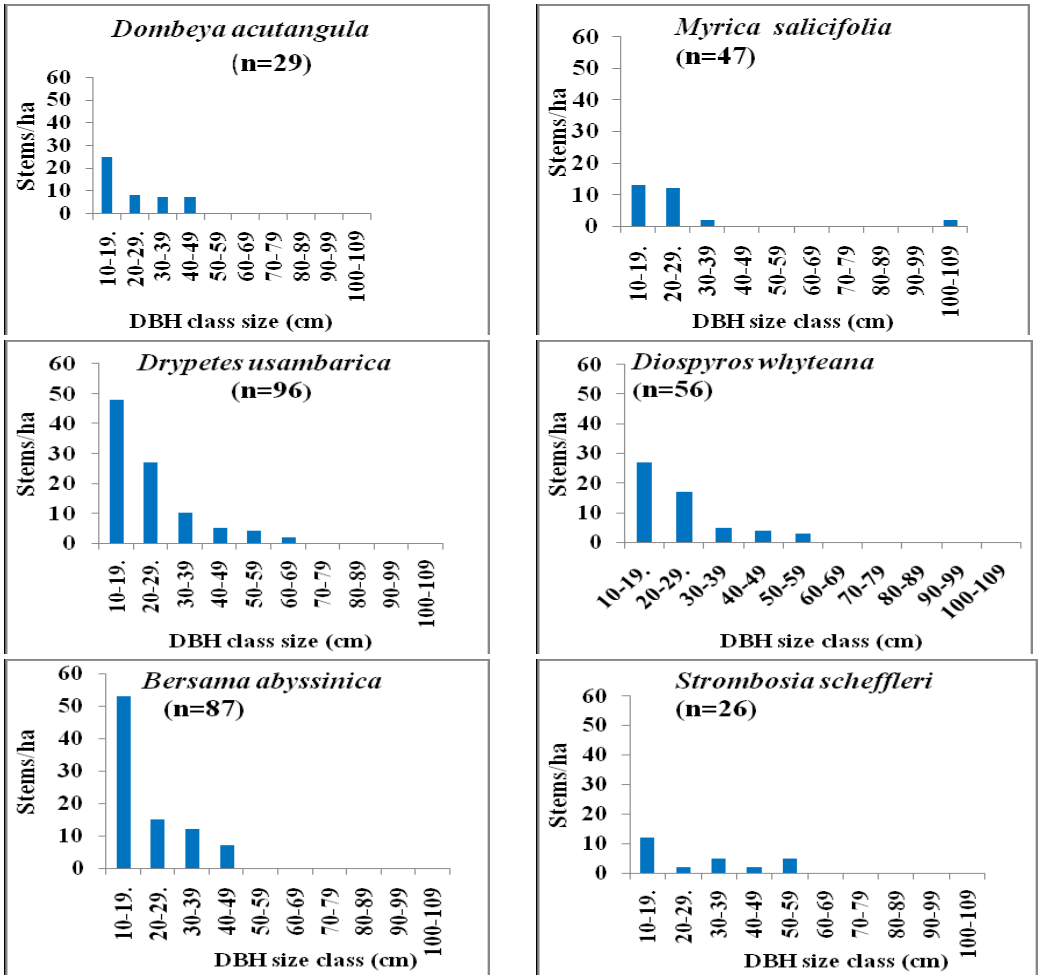


Figure 5: DBH size class distribution among dominant trees in the moderately disturbed sites in Rungwe forest**.**

The plant communities within the forest

Two clusters of plant communities denoted as A and B were generated using Two Way Indicator Species Analysis (TWINSPAN) according to their differences and similarities in plant species compositions between them (Figure 7). Plant communities in cluster A represented the least and moderately disturbed sites. The indicator species of least-moderate disturbed habitats were *Prunus africana* and *Cassipourea malosana* and the associated indicator species of increased disturbance gradients were *Trema orientalis (*L. Blume) and *Podocarpus latifolius* (Thunb.). However, the most common trees within communities of cluster A were *Allophylus abyssinicus, Bersama abyssinica, Pavetta abyssinica, Diospyros whyteana* and *Dombeya acutangula, Multidentia crassa* and *Oxyanthus goetzei (*K.Schum). Plant communities within cluster B composed only samples from highly disturbed sites with *Panicum trichocladum* (K.Schum) being an indicator species of disturbed habitat condition. The dominant plant species in highly disturbed plant communities included

shrubs and herbs, however, with a few trees including *Syzygium cordatum*, *Zanthoxylum deremense*, *Syzygium guineense* and *Rhamnus prinoides* were observed. The common shrubs in this community were *Maytenus acuminata* (L.f. Loes.), *Rutidea orientalis* (Bridson), *Rawsonia lucida* (Gilg) and *Vernonia myriantha* (Hook). The field data showed a high representation of herbs and grasses in plant communities cluster B that included *Bidens pilosa* L, *Justicia flava* (Vahl), *Panicum monticolum* (Hook.f) and *Setaria homonyma* (Hochst. Hack.). The percentage variation in terms of species composition between community cluster A and B was 71.21% was large enough to tell about negative impacts of anthropogenic activities within Rungwe Mountain Forest Reserve.

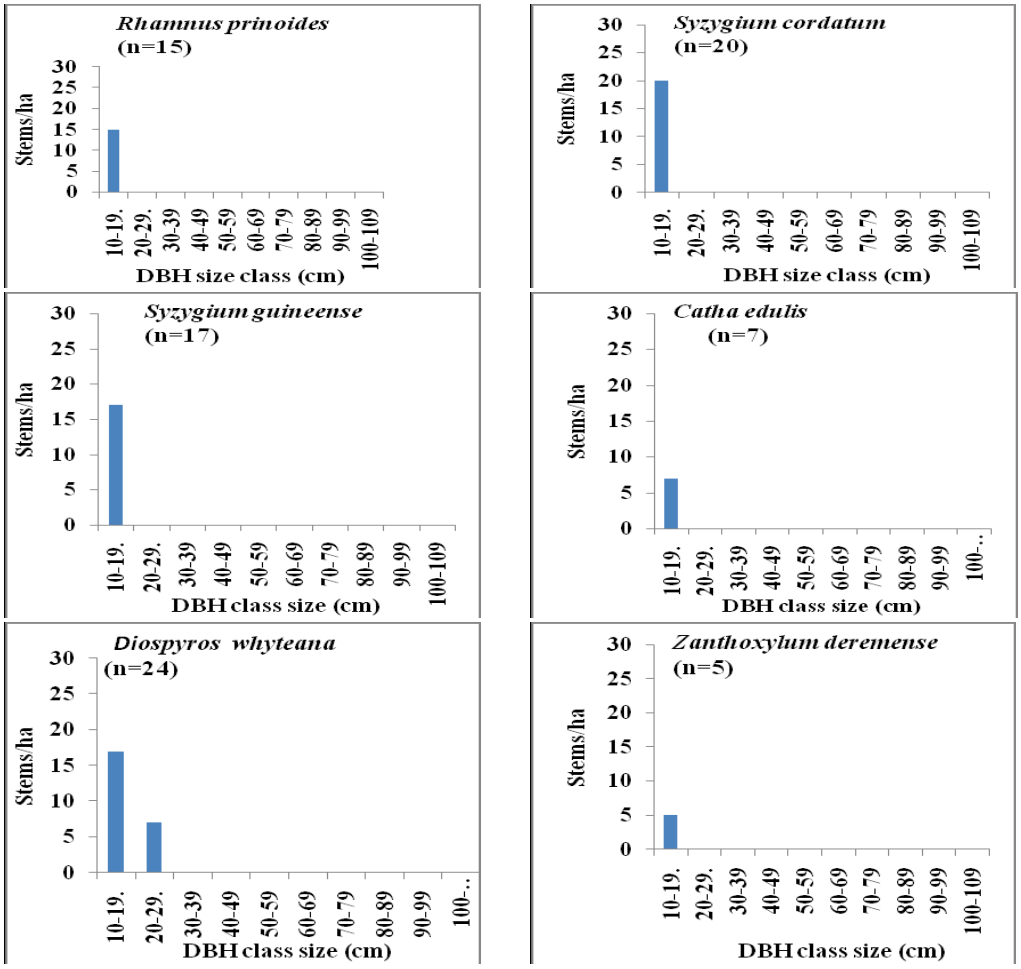


Figure 6: DBH size class distribution among dominant trees in the highly disturbed site in Rungwe forest reserve.

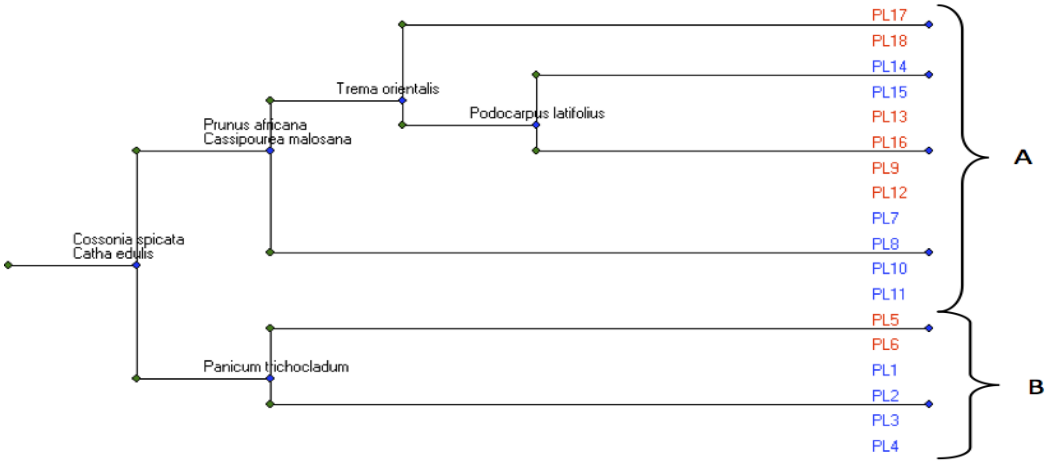


Figure 7: The clusters of plant samples from western parts in Rungwe forest (Plot number 1-18, A= Community A and B = Community B).

DISCUSSION

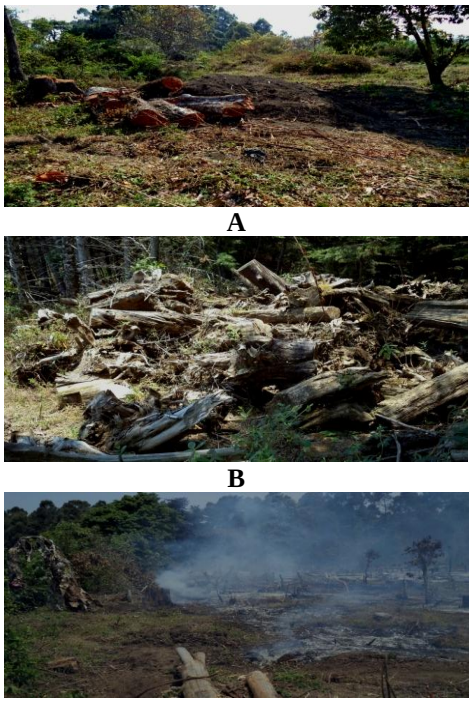
The diameter size class structures of trees in the forest

It was observed that large numbers of trees were represented by stems with small diameter sizes in all study sites with some differences in stem densities at the large stem sizes (Figure 2). The unequal representation of stems with large diameter sizes regardless of high similarities in habitat conditions is a function of anthropogenic disturbances. Kuo and Fan (2003) pointed out that the decrease in trees of large DBH sizes is caused by severe exploitation pressure that targets large trees. While a few tree stems with DBH sizes above 20 cm existed in the highly disturbed site (Figure 2), tree stems of *Syzygium cordatum* (Hochst.), *Zanthoxylum deremense* (Kokwaro) and *Ficus sur* (Forssk) existed. This could be contributed by their unsuitable known use values by the local community around Rungwe Mountain Forest Reserve.

An inverted J-shaped pattern observed for *Drypetes usambarica* (Pax Hutch.), *Bersama abyssinica* (Sim Verdc.), *Cassipourea malosana* (Baker), *Diospyros whyteana* (Hiern) and *Dombeya acutangula* (Cav.) in the least and moderate disturbed areas (Figures 4 and 5), implies that the selectively harvested trees with large DBH sizes are likely to be replaced by those with small DBH sizes if the intensity of disturbance decreased in the forest. McLaren *et al.* (2005) pointed out that an inverse J-shaped distribution curve in plant populations indicates an active regeneration. It is anticipated that under improved conservation management, the forest may recover from its disturbed conditions through naturally regenerating indigenous plant species. An interrupted size class distribution pattern that existed in *Myrica salicifolia* (Hochst. ex A.Rich), *Allophylus abyssinicus* (Hochst.), *Prunus africana* (Hook.f.) and *Strombosia scheffleri* (Engl.) was an indication of excessive negative impacts of anthropogenic activities in the forest. A bell-shaped pattern shown by *Dombeya acutangula* (Cav.) is an indication of poor recruitment and the populations are vulnerable to catastrophic factors which may crash upon failure to recover through natural regeneration. It can be considered that forests whose populations are unstable provide an alarm that they are not capable to withstand the prevailing anthropogenic pressure whereas a hyperbolic distribution pattern is an indication of the regeneration failure because of intensive anthropogenic disturbances.

Variations in species compositions among plant communities in the forest

The observed differences in plant species compositions among plant communities signify the importance of human activities in Rungwe Mountain Forest Reserve (Figure 7). Plant communities cluster A included samples from both least and moderately disturbed sites because of high similarity in plant species compositions than in community B (7-18 Figure 7). Disturbances that targeted some trees have affected the habitat conditions that resulted into variations in habitat conditions that ultimately affected the plant species compositions among plant communities. White (1983) pointed out that *Prunus africana (*Hook.f.) and *Cassipourea malosana* (Baker) were being characteristic plant species in the least disturbed forest community. During data processing using TWINSPPAN *Allophylus abyssinicus* (P.Beauv.), *Bersama abyssinica* (Sim Verdc.) and *C. malosana* and *P. africana* emerged as indicator species of least disturbed conditions of the plant communities in cluster A. *Cussonia spicata* (Thunb.) and *Catha edulis* (*(Vahl)* Endl.) were identified growing best in forest gaps and edges where light is accessible and therefore favoured by the moderate disturbed conditions in the forest. However, shade intolerant plant species may have increased with disturbance gradients such that *Trema orientalis* was only restricted to forest gaps as pointed out by Joseph *et al.* (2005) and Kuo and Fan (2003). Therefore, the gaps created by anthropogenic disturbances favoured colonization by *T. orientalis* in this community. It was considered that *T. orientalis* together with *Macaranga capensis* (Baill. Sim) as an associated indicator species of disturbed plant community were over-represented with increased disturbance gradients. The large forest gaps colonized by opportunistic plant species (*T. orientalis*) have been created following exploitation of large trees in Rungwe Forest Reserve. The dominancy by *T. orientalis* and *Panicum heterostachyum* Hack. (early colonizers) in highly disturbed forest parts was also an indication of a depleted indigenous plant species. The aforementioned two plant species might be the superior competitors over indigenous plant species under anthropogenic influence similar to what was observed in coastal forest of Tanzania by Mligo (2010). Von (2005) pointed out that shade intolerant plant species perform better in disturbed vegetation communities. Intensive disturbance created gaps in Rungwe Forest that favoured performance by *Polyscias fulva* (Hiern Harms) that was regarded as shade intolerant species because it preferred habitats with no light interception. However, a wide spread *Myrica salicifolia* (Hochst. ex A.Rich) in this community was an indication of plenty of light conditions because this plant is a light demanding species (Whitmore 1990) regardless of the presence of a few other trees (*Zanthoxylum deremense* (Kokwaro), *Syzygium guineensis* (Willd. DC.) and *Ficus sur* (Forssk*)* that have apparent known uses by the local community. It was observed that plant communities cluster B in the heavily degraded parts of the forest where the left behind pit saws and charcoal kilns (plate 1) were indications of an extensive utilization of wood plants that left only a few trees dominated with herbaceous and shrubby species. Elizabeth (2011) pointed out that in highly disturbed site only herbaceous and shrubby vegetation dominate. This interpretation has been supported by White (1983) that high cover by *Justicia flava* (Vahl), *Bidens pilosa* (L), *Hyparrhenia filipendula* (Hochst.) and *Setaria homonyma* (Hochst. Hack.) provides an indication of the negative impacts of anthropogenic disturbance.



A

B

C

Plate 1: Photos showing the ongoing anthropogenic activities in the highly disturbed parts in the western Rungwe forest reserve (A =charcoal kiln, B= uprooted trunks and C = burning).

CONCLUSIONS

The observed plant communities in the western parts of Rungwe forest reserve have been shaped by the impacts of anthropogenic activities at varying intensities from one point to another within the forest. Because of intensive exploitation, low density of trees with large diameter sizes was observed in the heavily degraded parts. The small trees have survived extreme anthropogenic disturbance because they are unsuitable for the known use value by the local community around the forest, however, by the time large trees have been exhausted, small trees will be an option. This could result into depletion of wood plants leaving behind only shrubs and herbaceous communities. Regardless of the findings in this study, to reflect the observations reported to exist in many tropical forests, anthropogenic activities have resulted into the current degraded conditions of Rungwe Mountain forest reserve. The Rungwe district council needs to intervene the ongoing degradation of the forest and direct the management of the tea factory to use more environmentally friendly technologies for their daily activities than depending on fuel wood resources from the local community. Likewise, the local community needs to establish woodlots for domestic uses and commercial gains as there is a potential market from the tea factory.

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