The Implication of Fire on Patterns of Plant Species Diversity in Northwest Uluguru Nature Forest Reserve, Tanzania.

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Abstract

This study examines the implication of fire on tree species diversity in northwest Uluguru Nature Forest Reserve (UNFR). The study compared tree species diversity between burned and unburned areas, and determined whether burned and unburned areas depicted any variation in stages of succession. Tree species samples were drawn from eighteen stands, and tree species data were ordinate using Nonmetric Multidimensional Scaling (NMS or NMDS) (PC-ORD version 5.10) to describe relationships (similarity and dissimilarities) between tree species, forest succession, and the effect of fire on tree species. Species richness did not vary significantly between burned and unburned plots. However, species composition was high in burned stands, which contributed to a high basal area in burned stands. Unburned stands had low species composition and low basal area. Fire intolerant tree species dominated unburned areas while species in the burned areas were fire adapted. A few species existed in burned and unburned stands. Trees in burned areas are still at a young succession stage while in unburned stands vegetation development has reached a succession stage that the vegetation is stable with hardwood forest formation. A sustainable management plan for the UNFR must base on empirical data on fire regime variation over space and time.

Key words: Uluguru, Fire, PC-ORD, regime, species, diversity, stand

Introduction

This study investigates the implications of the relationship between fire regime on plant species diversity in the Uluguru Nature Forest Reserve (UNFR). The study compares between burned and unburned areas of the UNFR along a Bohomela-Mbete transect (North-South orientation) (Figure 1). The UNFR, part of the Eastern Arc Mountains (EAM), contains 108 endemic plant species (Myers *et al*. 2000, Burgess *et al*. 2001). Fire is a natural phenomenon that can transform forest ecosystems (Dale *et al.,* 2000) because it may lead to the loss of seed bank, mortality of mature trees and plants that are not fire resistant, shifts in succession direction, and ultimately habitat loss, particularly when plants fail to recover after a fire event (Whelan, 1995). Fires on the UNFR and the EAM as a whole are known to have caused some plant species to go extinct about 10,000 years ago (Mumbi *et al*., 2008). Over the past four decades, the UNFR has experienced frequent drought (Maack, 1996), and this period has experienced more frequent fires than in prior decades (Lyamuya *et al*., 1994). Every year humans cause fire in the UNFR, particularly in the sub-montane zone (Lyamuya, *et al*., 1994).

Climate models predict future drought and warming in this area by about a 1-4^{0}C by 2100 (IPCC, 2007), which may worsen the effects of fire on forest ecosystems (Flannigan, et al., 2013; Bhatia and Bhatia and Ringia, 1996, Lyamuya *et al*., 1994). Weather conditions determine ignition, and winds affect the rate of spread of fire (Johnson *et al*., 1990). Similar factors apply to the UNFR although the UNFR topography and wind patterns may affect the location of fire and fire patterns. Forests near Bigwa, Kilakala and Mbete villages are the most affected by fire, which is in line with observation by Lyamuya *et al*., (1994). Fire poses an urgent threat to conservation of forest plant species in the UNFR (Burgess *et al*., 2007; Frontier-Tanzania, 2005). However, how fire affects forest plant diversity is undocumented. I study this phenomenon by using plant species data from sample plots in the Northwest part of the UNFR along a North-South transect in the sub-montane ecotone. I seek to answer the following questions: 1) How

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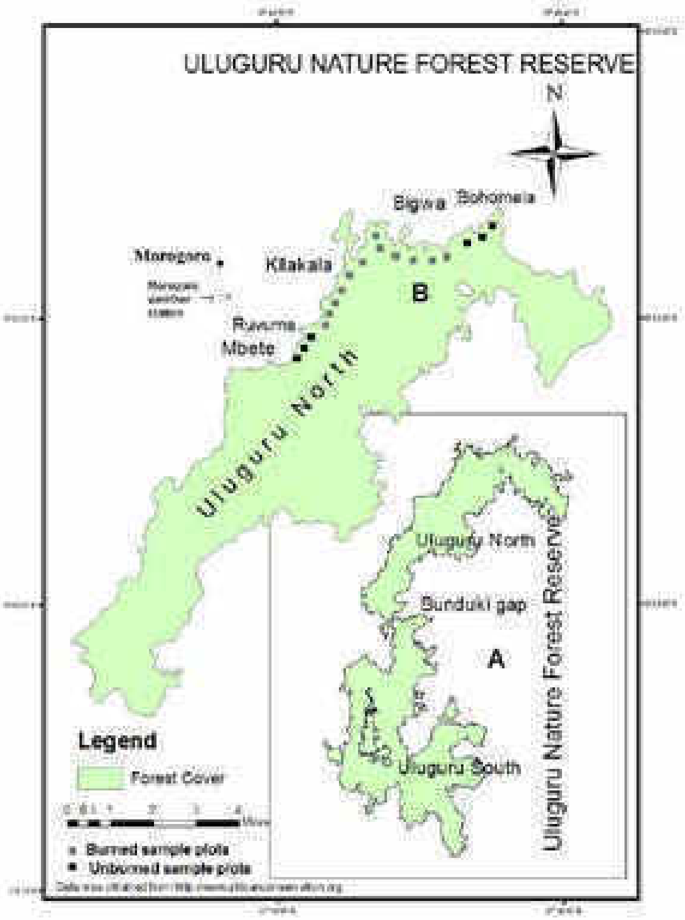
does species diversity in frequently burned areas compare with species diversity in unburned areas of the UNFR? and 2) Do burned and unburned stands depict any sere development that is evidence of the impact of fire? A thorough understanding of these questions will contribute to developing a sustainable management plan for the UNFR that is based on empirical data.

Methodology

Study area

This research was conducted in the UNFR near Morogoro, Tanzania (Figure 1). The UNFR extends from 06^{0}51'–07^{0}12'S and from 37^{0}36'–37^{0}45'E and has 291 km^2 of forest area (Burgess *et al*., 2001). The Uluguru Mountains are one of a chain of 12 mountain blocks of the Eastern Arc Mountains (Critical Ecosystems Partnership Fund, 2003). The Tanzanian Ministry of Natural Resources and Tourism, through the Forestry and Bee Division's Catchment Forestry Office in Morogoro, manages the UNFR. The study site was on the northwest part of the Uluguru (Bohomela to Mbete, a north-south transect, Figure 1) at the forest ecotone. The UNFR in this region is bordered by a wooded grassland (governed by the Morogoro Municipal Council), private woodlots, settlements, and individually owned small scale farms. Evergreen montane forests cover Bohomela and Ruvuma while the frequently burned Bigwa-Kilakala area consists of deciduous woodland forest (Burgess et al., 2007). Fire records from the Morogoro Catchment Forest office show that Bohomela (part of Bigwa ward) in the north, and Ruvuma in the south do not burn. The study area is on the leeward (western) side of the EAM and receives less rainfall than the eastern EAM (Burgess, *et al*., 2001). Annual precipitation at Morogoro station (just west of the UNFR) averages 835 mm, with a distinct dry season from June through September. Main soil types are acidic lithosols and ferralitic red, yellow and brown latosols that have developed on Precambian granulite, gneiss and migmatite rocks (Frontier-Tanzania, 2005).

Figure 1 Uluguru Nature Forest Reserve (insert map A) and sample plots in northwest of Uluguru North (map B).



Data Collection

Data were collected from eighteen sample plots (stands) to capture plant species spatial differences between burned and unburned areas. The sample plots were placed at a similar elevation and at a minimum of five meters from the boundary between the UNFR and land outside the UNFR to minimize edge effects (Ito et al., 2004). The transect ran north-south. Twelve plots – three each in Bigwa Lukuyu (BLKY), Bigwa Kisiwani (BKSN), Kilakala Ualimu (KIUM), and Kilakala Bong'ola (KIBG) – represented frequently burned area (Figure 1). Fire burns almost annually in areas that burn recurrently. Six plots – three each in Ruvuma (RUVU) and Bohomela (BOH) – represented unburned areas (Figure 1) of the northwest UNFR. Fire return interval in unburned areas was about 3-5 decade. For each site, the three plots are denoted as P1, P2, and P3 so that, for example, BLKY P1, BLKY P2, and BLKY P3 represent plots in Bigwa Lukuyu. This study used a nested plot approach to obtain the number, basal area, and species of trees (>5cm dbh) in each plot. The nested plot consisted of the entire plot (0.1 ha) and a subplot (0.05 ha) inside the larger plot so it was easier to count, measure and identify tree species. I worked with a knowledgeable local elderly person to identify all species in the plots. I matched local names of all the species with scientific names in existing inventory reports on the Uluguru in Lovett and Pócs (1993), and Doggart *et al.* (2001).

Data Analysis

To answer the questions about spatial species diversity and sere development in burned vs. unburned plots, this study used ordination analysis using the Nonmetric Multidimensional Scaling (NMS or NMDS) module in PC-ORD version 5.10 (Mather, 1976, Kruskal, 1964). The approach helped to describe resemblance and differences between tree species, forest succession, and the effect of fire on tree species. Basal area data were standardized (column relativization using standard deviates) before using the data in NMS with a distance measure (Sørensen). Before doing cluster analysis tree species basal area data were transformed to presence/absence (binary form) McCune and Grace (2002) so as to establish associations among tree species in all stands along the transect. In addition, it was possible to discern variances in species composition between burned and unburned stands. NMS is the most powerful analytical tool for ecological community data because it enables visualization of patterns in two dimensions (McCune and Grace, 2002) and it was the most effective ordination technique to analyze ecological community data from the study area as the data was non-normal (McCune and Grace, 2002). When running the NMS, this study used a Sørensen distance measure, and a random starting configuration. The number of runs with real data was 250, the assessment of the dimensionality of the data was done using the Monte Carlo test with 250 runs to see whether the NMS procedure extracted stronger axes than expected by chance ($p < 0.05$) (Table 1). The study used a best selected solution 2-D [using the criteria of least final stress] and re-run the model with the least final stress ($p \leq 0.0040$) (Table 1). A large decrease in minimum stress from 22 in the first solution to 6 in the second solution (Table 1) suggested that the second axis was useful in explaining species composition. Joint plots based on Pearson correlation values ($p < 0.05$) were developed to determine the strength of the relationship between species patterns and fire occurrence, and each of the first two axes of the NMS. Overlays and correlations of species with the axes, and other illustrative graphics aided interpretation of the dynamics of species between burned and unburned plots in the UNFR.

Alpha diversity was measured as species richness per plot (the total number of species per plot), a plot defined as a 0.1ha (Mueller-Dombois and Ellenberg, 2002). Shannon-Wiener Diversity (*H'*) and Simpson's Dominance (*D*) were computed for all plots and averaged for the entire transect (Magurran, 1988). Diversity was calculated using Simpson's diversity index (a measure of dominance) and Shannon's diversity index (a measure of evenness). Simpson's diversity index measures the likelihood that

Table 1 STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)

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        Stress in real data         Stress in randomized data

           250 run(s)             Monte Carlo test,  250 runs

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Axes  Minimum     Mean  Maximum  Minimum     Mean  Maximum      p

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  1   22.045   45.120   55.242   30.181   47.517   54.433    0.0040

  2    6.135   10.384   38.074   16.769   22.746   37.184    0.0040

  3    4.540    4.758   15.005    9.753   13.970   17.891    0.0040

  4    2.673    3.005   21.468    7.233    9.626   20.541    0.0040

  5    1.604    2.012   13.659    5.160    6.924   14.523    0.0040

  6    1.223    1.490   14.388    3.618    5.048    8.458    0.0040

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p = proportion of randomized runs with stress < or = observed stress

i.e., p  = (1 + no. permutations <= observed)/(1 + no. permutations)
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two species chosen at random will be different. The addition or loss or rare species does not affect this measure because Simpsons' index considers common species, which makes it stable with sample size (McCune and Grace, 2002). Cluster analysis (Ward's method and Euclidean distance measure) was done to define species groups based on their similarities using data on the presence/absence of species in all plots (Sneath and Sokal, 1973, McCune and Grace, 2002). Using the same approach similar plots was grouped (Figure 4). Coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space using 18 entities, 153 entity pairs and Sørensen (Bray-Curtis) distance measure for original distance were calculated.

Results and Discussion

Forest structure and topography

In both burned and unburned plots the terrain was rugged and deeply dissected by rivers, narrow ridges, minor valleys, rocky outcrops and cliffs. The forest in Bohomela (unburned) is composed of tall (30-50 m) evergreen montane forest with closed canopies. Beneath the canopy was a layer of young trees. Some mature trees were big (200+ cm dbh) and buttressed. Tree species such as *Grewia similis* was the most dominant followed by *Myrianthus arboreus* and *Suregada zanzibariensis*. *Grewia goetzeana* and *Erythrophleum suaveolens* were the third dominant species. A closed tree canopy structure also existed in Ruvuma (unburned). In Ruvuma smaller trees were most dominant. *Parinary excelsa sabine* tree species dominated the most, next was *Newtonia buchanani,* and "Mhalasindi" (second most dominant), and *Scolopia zeyheri, Vangueria infausta, Dodonea viscose,* and *Costus sarmentosus* (third most dominant).

The Bigwa and Kilakala (burned) plots were characterized by open canopy woodland forests with species such as *Brachystegia microphylla* and *Harrisonia abyssinica,* dominating most of the landscape, and at different levels of growth. Other common tree species included *Diplorhynchus condylocarpon, Bothriocline tomentosa, Bobgunnia madagascariensis,Cassia abbreviate, Dalbergia melanoxylon, Combretum* *collinum Brachysteria bussei, Albizia petersiana,Combretum adenogonium* "Mkalangananga", and *Syzygium cordatu*. In Bigwa Lukuyu and Bigwa Kisiwani there were more mature trees while younger trees dominated in Kilakala.

PC-ORD NMS Landscape level dynamics

The NMS ordination retained 89.7% of the variance in the original species data. Axis 1 explained 78.4% of variance and axis 2 explained 11.3% of variance (Figure 3). The primary gradients represented by Axis 1 were negatively correlated with *Parinari excels sabine, Grewia similis, Suregada zanzibariensis, Newtonia buchanani,* "Mhalasindi", and *Myrianthus arboreus* species, and positively correlated with *Harrisonia abyssinica, Combretum mole, Brachystegia microphylla,* "Mkalangananga" *(Albizia amara)*, *Cassia abbreviate, Combretum collinum, Bobgunnia madagascariensis, Dalbergia melanoxylon, Bothriocline tomentosa,* and *Diplorhynchus condylocarpon*. Axis 2 was negatively correlated with *Parinari excels sabine*, "Mkalangananga" *(Albizia amara)*, *Newtonia buchanani,* and 'Mhalasindi' species, but it was positively correlated with *Harrisonia abyssinica, Grewia similis, Combretum mole, Brachystergia microphylla, Suregada zanzibariensis, Cassia abbreviate, Combretum collinum, Bobgunnia madagascariensis, Dalbergia melanoxylon, Bothriocline tomentosa, Diplorhynchus condylocarpon* and *Myrianthus arboreus*.

Six dominant patterns emerge from the ordination. First, in both burned and unburned stands, overall species diversity is high (Simpson's Index between 0.93-0.96); however, species richness (alpha values) in the burned area had an inverse relationship with tree basal area, whereas there was a direct relationship between richness and basal area in the unburned plots. Second, species richness between burned and unburned areas was not significantly different, although overall mean species richness was higher in unburned plots than in burned plots (Figure 2). In the unburned plots both basal area and species richness were higher in the northern (Bohomela) than in the southern (Ruvuma).

Third, the mean basal area was significantly ($p \leq 0.05$) higher in unburned plots (21.33 m^2/ha) than in burned plots (8.5 m^2/ha). The difference in basal area between unburned and burned plots suggests that the higher number of species per unit area in unburned plots corresponds with higher trees basal area, while the opposite is true for burned areas. In the burned areas, the basal area of trees is larger in the north and smaller toward the south (Bigwa Lukuyu-Kilakala Bong'ola), although the variation in species richness is not significantly different.

Fourth, different sere development was observed between unburned and burned areas. The forest in unburned areas is near equilibrium (as discussed later) but early- and middle forest succession dominates the burned areas.

Fifth, a large of proportion of tree species that dominated burned areas of the northwest UNFR (Table 3) were not found in unburned areas. However, a few tree species such as Mkalangananga (*Albizia amara*), *Suregada zanzibariensis,* and *Bothriocline tomentosa* grew in burned and unburned stands. *Albizia amara* was found in Kilakala Bong'ola and Bigwa Kisiwani (burned) and in Ruvuma (unburned). *Suregada zanzibariensis* thrived in Bohomela (unburned) and in one stand only in Kilakala Ualimu. *Bothriocline tomentosa* dominated 10 of 12 stands in burned areas in Bigwa and Kilakala whereas *B. tomentosa* existed in one stand in Ruvuma (unburned). A dendrogram of species presence/absence (Figure 4) shows these distinct tree species groups, and tree species that cross over burned and unburned stands in the transect.

Sixth, two groups of stands of tree species emerge within the unburned stands indicating that there were differences in tree species types within unburned stands in Bohomela and Ruvuma. For example, tree species such as *Schefflera lukwangulensis*, *Strombosia scheffleri, Myrianthus arboreus, Grewia similis, Piliostigma thorningii,* and *Blighia unijugata* growing in Bohomela only. Stands in Ruvuma had tree species such as Chuwasesi, *Tabernaemontana pachysiphon, Scolopia zeyheri,* and *Dodonea viscose,* which grew in this area only. However, a few tree species such as *Newtonia buchanani, Macaranga capensis*, and "Mbabala" were found in both Bohomela and Ruvuma stands.

Figure 2. Species dominance based on species richness (S, number of species per ha) and on basal area (BA, m²/ha) for plots in the burned and unburned areas.

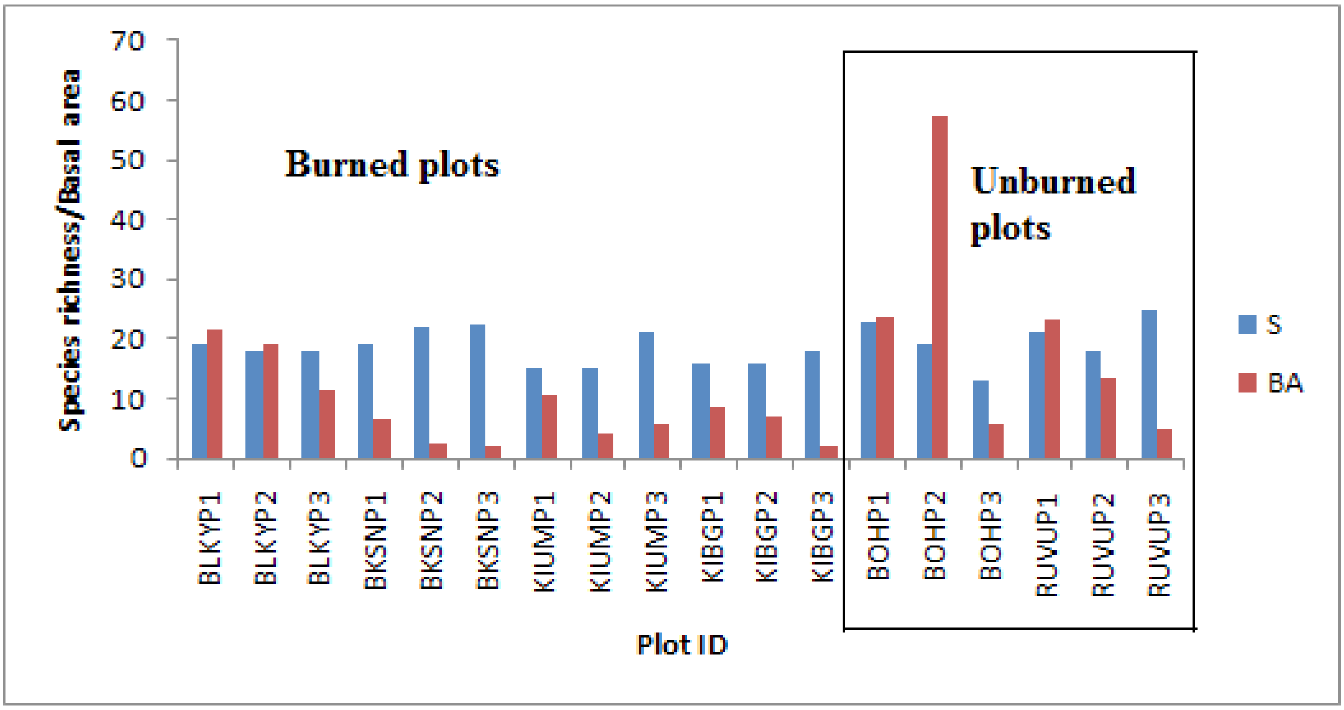


Figure 3. Scatterplot of abundance of species in relation to two ordination axes and stand type. 0=Unburned and 1=Burned plots. += Tree species. Closer points means those tree species are more associated with each other than with the species represented by the more dispersed points. Clustering of species in burned and unburned categories indicate ability of tree species to survive in those conditions.

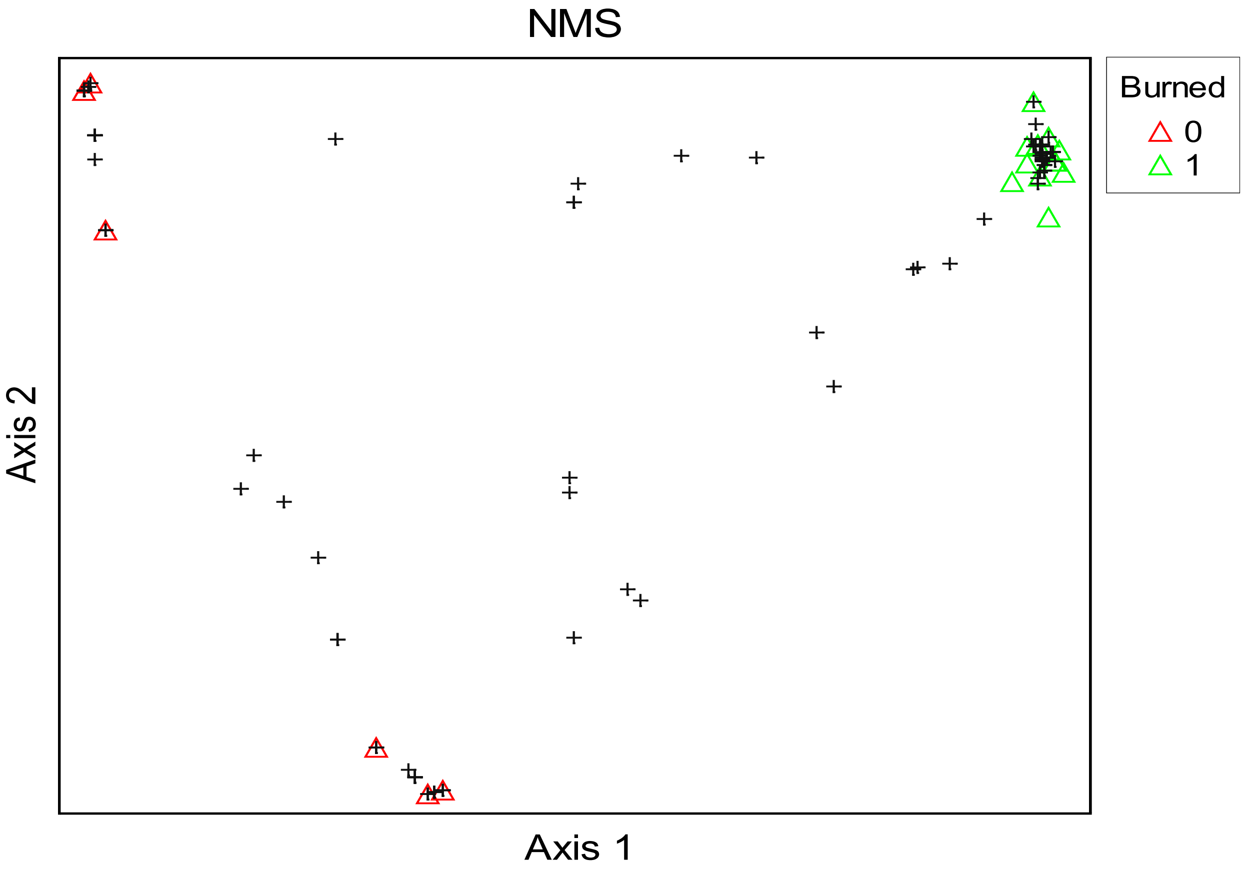
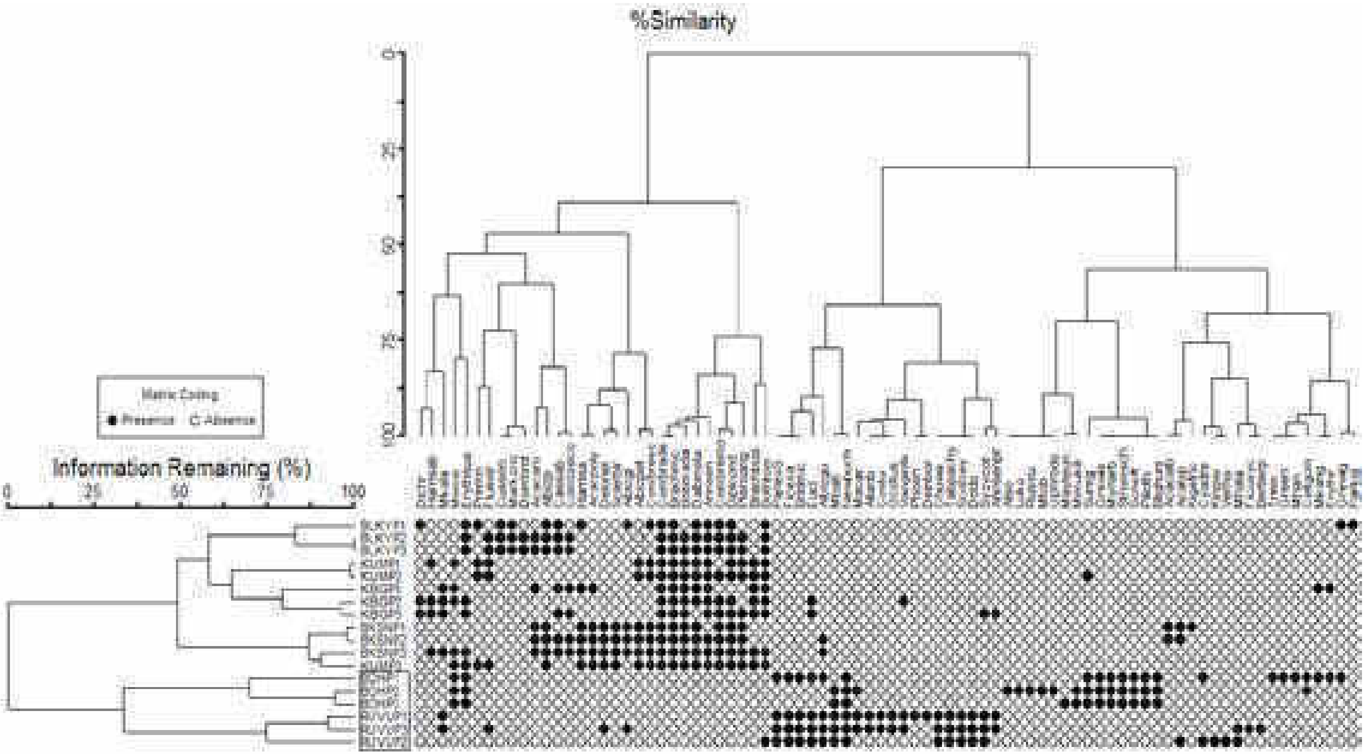


Figure 4 Dendrogram showing similarity (%) of species on the landscape and within plots, based on presence/absence of a species.



Discussion

The next discussion is in the context of fire, human disturbance, status as burned or unburned, topography, and the relationship between local climatic conditions and teleconnections. The great diversity of tree species in both burned and unburned stands underscores the importance of the Uluguru Nature Forest Reserve for conservation of flora. The findings on high species diversity are in accord with results from other parts of Uluguru and at other locations of similar altitude in the Eastern Arc Mountains (Burgess et al., 2007, Lovett, 1996). Diverse plant communities in burned stands result from a number of factors. Burned stands' canopies are open. Trees such as *Brachystegia microphylla, Cassia abbreviate, Dalbergia menaloxylon, Diplorhynchus condylocarpon, Brachystergia bussei, Combretum collinum, Combretum molle, Combretum adenogonium, Bobgunnia madagascariensis, Harrisonia abyssinica,* and *Cassia abbreviate* dominate in burned stands. The study did not find any of these species in unburned stands. The occurrence and dominance of these species only in burned areas suggests that these species have adapted to fires. Trees in burned plots adapt through regeneration after fire and survival during fire, by developing bark that is capable of surviving low intensity fires. It was observed in the field, particularly in the Bigwa area, that mature larger trees such as *Brachystegia microphylla* have a relatively thick bark that would enable them to withstand low intensity fires. Other species such as *Erythrophleum suaveolens* not only have thick barks that enable them to thrive in low intensity fires but also they are able to regenerate after fires. However, few tree species thrive in burned and unburned stands, these tree species include Mkalangananga (*Albizia amara*), *Suregada zanzibariensis,* and *Bothriocline tomentosa*. *Albizia amara* prefer to grow in areas with plenty of light (open) because it was found in burned and unburned stands that had no shed (Kilakala and Bigwa). In unburned Ruvuma stand *Albizia amara* tree species, grew in well lit areas too. Because of the flat shape and lightness of trees pods northwesterlies during the early and late dry season could have dispersed seeds from Bigwa to Ruvuma because the later is located south of the former. Orwa et al. (2009) describes *Albizia amara* as tree species that grow in strong light condition, the tree's shallow and spreading root system enables it to grow in areas with low rainfall (400-000 mm) and soils poor in nutrient. *Suregada zanzibariensis* and *Bothriocline tomentosa* thrives in burned and unburned stands of the northwestern UNFR suggesting that they have the ability to grow in variable soil conditions. However, *Bothriocline tomentosa* dominated burned areas and was rare in unburned plots, the opposite was true for *Suregada zanzibariensis*. *S. zanzibariensis and Bothriocline tomentosa* has the ability to grow at different altitudes and shallow soils, and it is a common species in the coastal forests of East Africa (Burgess and Clarke, 2000).

Although there is a lack of significant variation in species richness between burned and unburned plots of the northwest UNFR, the study found that the types of species varied significantly between burned and unburned areas. Tree species that have adapted to fire dominated burned areas while tree species that are dominant in unburned areas are rare in the burned plots, suggesting that the dominant species in the unburned areas are not fire adapted.

The forest structure suggests that community succession in burned areas could be categorized as at a middle succession stage while in other burned areas the forest community could be categorized as near-middle succession. A combination of factors such as fire, human encroachment for agriculture, and cutting of trees for construction material can explain the succession stage of, for example, the Kilakala Ualimu area, because of the settlement bordering the forest. Past variations in the intensity of human-induced forest disturbances may explain the current observable differences in forest structure and succession stage. The observed vegetation structure may be a legacy of intense past land use of the area, unlike in other, under less- utilization pressure areas of transect. When frequent fires compound prior land uses it results in species such as *Brachystegia microphylla* competing favorably in these areas, hence, its dominance in the burned areas. Fire provides nutrients to early growing trees but when multiple species have grown in the area the occurrence of fire modifies succession through killing of some tree species while other tree species survive the fires.

The uniqueness of size distribution of tree species and tree species types that grow in Ruvuma and Bohomela (unburned) suggests that trees growing in these two areas do not require fire to sustain them. A few tree species that grow understory in Ruvuma and Bohomela tolerate shed. In the burned area (Bigwa through Kilakala), fire is a major controlling factor. However, fire is not the only factor controlling tree growth because the current trees may be a relict of past succession stages that were interrupted by human induced land use changes, or at least human land use of the area may have been more significant than in the unburned areas. There were areas of the UNFR that were settled in the past but where people had been evicted, and where vegetation has regenerated to a level similar to areas that are known to have frequently burned. For example, although there are no settlements there now, it is known that the area around Kilakala was settled and farmed around the 1870s (personal communication, elderly resident of the Kilakala area, 2008), so that human-caused disturbance is a likely contributor to the present structure of the forest. The current vegetation structure in Kilakala shows a late early-to-middle seral stage of succession.

In unburned areas, the presence of large non-dominant trees, such as *Celtis gomphophylla* Bohomela, suggests that the stand in the area has reached or is near equilibrium. These big trees create closed canopies that control the amount of light reaching the ground, inhibiting other species from establishing. Stands in Ruvuma are similar to Bohomela because trees are well established in this area too, indicating a succession stability. The geology and climate of the Eastern Arc Mountains have been relatively stable (Mumbi et al. 2008, Lovett 1996), resulting in succession stability in the absence of fire or minimal fire interference. However, at local scale and in the northwestern UNFR in particular, short-term climate variations help to explain fire frequency in the burned areas. The study found that the Bohomela and Ruvuma areas are not much affected by fire[12] because the amount of dry fuel in these areas is very low where closed canopies create fuel moisture content at which fire is unable to spread (moisture of extinction). In contrast, at Kilakala and Bigwa, 1 and 10-hour fuel dominate the area, especially at forest margins.

Stands in burned areas (Bigwa Lukuyu, Bigwa Kisiwani, Kilakala Ualimu, and Kilakala Bong'ola)

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[12] Based on personal observation and interviews with forest officers in charge of UNFR, local people, and available fire records Ruvuma and Bohomela did not burn regularly like other areas of northwest UNFR.

have higher stem density than stands in unburned areas (Bohomela and Ruvuma), although the basal area in burned areas is lower than for unburned stands. In Ruvuma in particular, trees were tall and had small dbh, suggesting a high competition for soil nutrients and light. The inverse relationship between stem density and basal area per unit area in burned areas is due to trees growing under the legacy of past human encroachment for agriculture, settlement and construction material, species competition for available resources (soil nutrients and light), and fire. The burned area's soil formation is poor, a problem that is compounded by fire occurrence. Burned forests reduce the soil's ability to hold water (Leslie et al., 2014; Cochrane, 2009) because when vegetation cover has burned the rain falling on the steep slopes of the UNFR would easily wash away soil nutrients. Trees in the burned areas are slow growing trees with hard dense wood and the vegetation in this area represents a middle stage of forest succession. However, in Bohomela and Ruvuma there are lower stem densities but larger basal areas than in the burned areas, because trees have grown tall and have closed canopies that minimize species competition. The trees in Bohomela and Ruvuma utilize nutrients for maximum growth rather than trying to outcompete other tree species for the same available resources. The competition for available resources in the study area is crucial because soils in the UNFR, as in most parts of the Eastern Arc Mountains, are nutrient poor and highly leached (Newmark, 2002) so any competition for soil nutrients is detrimental for a tree species survival.

In the unburned plots both basal area and species richness show the highest values in the north (Bohomela) as compared to the south (Ruvuma). Because Bohomela and Ruvuma are located slightly north and south, respectively, of the highest peaks of the UNFR, they may benefit from moisture carried by the prevailing easterly flow from the Indian Ocean, which can sometimes reach these areas before being deprived of its moisture as it crosses the mountain ridge. The moisture, *ceteris paribus,* makes Bohomela somewhat humid, which enable trees to grow well in Bohomela than Ruvuma. The position of these sites relative to the UNFR may help to explain the differences in the tree growth of the UNFR. The study also observed that soils in Bohomela and Ruvuma were relatively deep, as compared to the shallow soils in the burned areas.

At local scales fire, soils, and precipitation influence the distribution of tree species as well as species dominance and basal area. Because soils in the burned area are shallow, moisture stress not only affects tree growth but also increases the chances of trees being killed by fire. Trees that are already experiencing moisture stress are vulnerable to death when they are burned (Pohl and Camberlin, 2006). Precipitation in the short rain season (October, November) is positively correlated with warm sea surface temperature (SST) anomalies in the western Indian Ocean (Ummenhofer *et al*., 2009, Behera, *et al*., 2005). Rainfall in the UNFR also varies in response to the El Niño-South Oscillation (ENSO), receiving normal to above normal rainfall in the short (October-December) and long rain (March-May) seasons during warm (El Niño) events (Indeje, *et al*., 2000, Mutai, 2000). (Mumbi *et al*. 2008, Lovett, 1994, Burgess *et al*., 2008) this long term stability obscures the effects of short term variations in climate. Year to year variation in precipitation affects the fire regime in the UNFR, which in turn alters plant species survival, growth and distribution. There is likely to be an increase in fire events with increasing dry weather in the UNFR.

Species richness is not significantly different between burned and unburned stands but species types do. A few species were found in burned and unburned stands indicating that they are ubiquitous. However, basal area varies between burned and unburned areas indicating that fire constrains stand growth in burned areas. Unburned areas are dominated by species that are not fire tolerant while species in the burned areas were fire adapted. The large basal area of species in unburned areas indicate the absence of fire, less tree species competition for resources, and the stability of long-term climatic conditions. Trees in Bigwa and Kilakala are still at a young succession stage while in Bohomela and Ruvuma the succession process is stable with hardwood forest formation.

Short term climate variability determines the frequently of fires occurence in the UNFR. It is logical to assume that as climatic conditions, and populations, in and around the UNFR change, so will both the fire regime and the frequency of other human-caused forest disturbances. Currently, fuel build up is very high because of the ongoing fire suppression efforts, should fire occur, it will likely be severe and possibly retune the process of succession in the burned area. The findings indicate that a mixture of factors determine the distribution of tree species in the UNFR. Comparisons of burned and unburned stands show dissimilarity in tree species types that grow in the two stands indicating varying tree species tolerance to fire. Larger differences in basal area between burned and unburned areas indicate that unburned areas have approached a later succession stage (larger basal area) while the burned area is approaching or is in a middle stage of succession (small basal area).

The conservation of plant and animal species in the UNFR require taking into account the role of fire on forest tree species and ecosystem function. Therefore, conservation should not solely be the responsibility of the Tanzania's conservation agency because the benefits of conserving the UNFR accrue to both Tanzanians and the international community. Rather it should be role for local, regional, and international nature conservation agencies interested in biodiversity conservation because the benefits of biodiversity benefit the global community.

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