ANTHROPOGENIC DISTURBANCE ON THE VEGETATION IN MAKURUNGE WOODLAND, BAGAMOYO DISTRICT, TANZANIA

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ABSTRACT

Makurunge woodland is part of the major vegetation component covering coastal forest landscape in Tanzania that has been severely affected by anthropogenic disturbance. The present study determined the effects of anthropogenic disturbance on biomass, diversity, plant communities and plant species distribution pattern using nested sample plots systematically established along transects. Six major vegetation communities with different biomass were found. Plant species diversity ranged from 2.5 to 3.3 and was high in scrub forests, riverine and thicketed habitats, although the difference among these habitats was not significant (P>0.05). About 61-90% of the woodland was affected and this influenced the plant species distribution pattern with strong disturbance gradients in both the first and the second Canonical Correspondence Analysis (CCA) axes. Although fire disturbance rated the highest among variables, its effect was not significant. Monte Carlo test showed that charcoal making, pole cutting and fuel wood cutting had significant effects on the distribution pattern of plant species. Fragmentation of habitats formed patches that have reduced plant species population sizes, and this reduced biodiversity in the study area. Conservation of woodland habitats is necessary for survival of plant populations in the remaining stands.

Key words: Anthropogenic disturbance, biomass, CCA, communities, distribution, diversity

INTRODUCTION

Makurunge woodland is the major vegetation component covering a large part of coastal forest landscape in Tanzania. It forms a link between evergreen coastal forest fragments, hence contributing to habitat heterogeneity in this landscape. The woodland is characterized by thickets, riverine vegetation, scrublands, bushes and grasslands which provide a variety of habitats suitable for a wide range of plant biodiversity. The vegetation communities in this woodland also support large mammals such as *Loxodonta africana, Aepyceros melampus* and *Hippopotamus amphibious* which use these as pasture during the wet season when the adjacent habitat of the Saadani National Park is unhabitable due to water lodging. The high biodiversity makes this woodland a valuable ecosystem worth conserving. However, anthropogenic activities degrade the woodland due to loss of primary habitats suitable for plant biodiversity. Large scale habitat degradation may result in changes of plant species composition and distribution patterns. The major causes include fire, cutting of trees for fuel wood and poles, grazing and charcoal burning. Anthropogenic activities appear to have significantly changed the woodland matrix and the important habitats for coastal endemic plant species (such as *Scorodophloeus fischeri, Uvaria lucida, Sansevieria bagamoyoensis* and *Manilkara sulcata, Encephalators hildebrandtii, Sansevieria bagamoyoensis* and *Tricalysia microphylla* and *Sansevieria bagamoyoensis*) may have been destroyed. Exploited resources from Makurunge woodland are mainly used domestically in most households in rural and urban areas and also for commercial purposes. The coastal area has a long history of human settlements, where environmental resources, particularly those from the nearby woodlands have been used for their establishment and survival. Since human population has continued to increase in these coastal areas, it is expected that the resource requirements have increased and the nearby woodlands have been affected by exploitation (Blomley *et al*. 2008). Anthropogenic activities have dramatically increased in recent decades that affect vegetation communities and habitats in the coastal forest landscape (Ahrends 2005). There has been a big increase in the demand for charcoal in line with the social and economic growth of nearby coastal towns such as Bagamoyo and the Dar es Salaam City. Such increased demand would negatively impact on natural habitats and type of vegetation communities in the woodland. However the impacts of anthropogenic disturbances on vegetation communities, biomass, diversity and the distribution pattern of plant species in Makurunge woodland are little known. This study hypothesized that the existing vegetation communities and distribution pattern of plant species in Makurunge woodland are functions of anthropogenic disturbance. The study determined biomass, diversity, vegetation communities and the impact of anthropogenic disturbance on the distribution pattern of plant species in Makurunge woodland.

MATERIAL AND METHODS

Location of Makurunge woodland

The study area is located in Bagamoyo District, in Coast Region between latitudes $6^0$12'- $6^0$27' S and longitudes 38^0 43 - $38^0$52' E (Figure 1). It borders the Indian Ocean to the east, Dar es Salaam-Tanga railway line to the west, Wami River to the north and Ruvu River to the south, together with Makurunge Village. The woodland is bisected by a road branching from Bagamoyo - Msata main road at Makurunge Village from the south to Wami River in the north. The vegetation typology includes mangrove forest, riverine forest and woodland and a floodplain in the east and it rolls gradually from 8 m to12 m above sea level in the east where a pure stand of *Acacia zanzibarica* woodland dominates and to a steppe of between 13 m to 39 $\leq$ 40 m above sea level to the west where scrub forests, thickets, shrubland and grassland covering a wide land area.

Climate of the area

The area has a monsoonal climate controlled by the movement of the Inter-Tropical Convergence Zone (ITCZ), between 20^0 south to north of the equator (Mligo *et al*. 2009). The ITCZ represents several sub-systems including the trade wind systems. This forms the basis for understanding the variability of the local climate and the interaction with numerous other sub-systems in coastal areas. The interaction of sub-systems results in the seasonal displacement of ITCZ that can cause the ecosystem to respond through changes in the composition, forms, functions, vegetation communities and distribution patterns of plant species in coastal areas (Marchant et al. 2006). The maximum average annual rainfall is between 520 mm and 1000 mm (Clarke and Dickinson 1995). The rainfall is bimodal and it starts in March and ends in June, followed by a cool season from June to August, short rains from September to November and the hot season from December to mid March (Mligo *et al*. 2009).

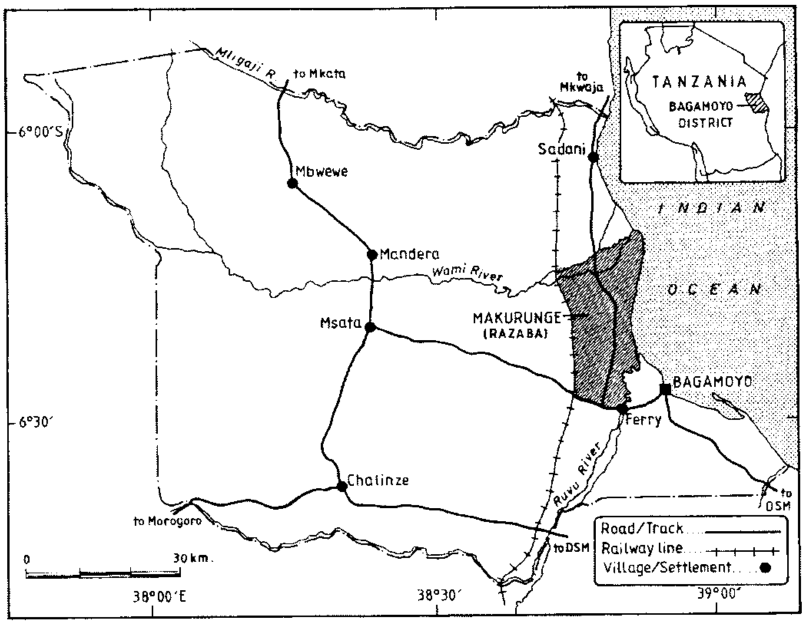

Figure 1: Location of Makurunge woodland in Bagamoyo District, Tanzania.

Sampling procedures

Vegetation community types, habitats and forms of disturbance were identified and the sampling sites were systematically selected. It was then followed by establishing 6 parallel transects 26 km long and 4 km apart, running from north to south, with the long axis cutting across various habitat types (scub forests, shrublands, grasslands, riverine and thickets) in the sampling area. On average 5 quadrats were systematically established at 2 km intervals along transects in the woodland making a total of 33 quadrats or sampling points. The Nested Quadrat Sampling Technique (Stohlgren *et al.* 1995) was used in the sampling of vegetation in the woodland. This technique entails the use of rectangular quadrats as it cuts across several microhabitat conditions, combines the advantage of minimizing edge effect and increasing the chances of including most species in the sample. Trees were sampled using 20 m x 50 m quadrats where the number of individuals of all tree species in this quadrat and the diameter of trees at breast height were recorded. The number of shrubs and saplings were recorded in 5 m x 2 m quadrats nested in the 20 m x 50 m quadrats. The percentages of grass and herb cover were estimated in small quadrats measuring 2 m x 0.5 m and nested in the 5 m x 2 m quadrats. Plant species composition was maximized by recording all species occurring in the big quadrat. Plant species were identified in the field where possible, but specimens of plant species with unconfirmed identification were collected, pressed and taken to the herbarium in the Department of Botany, University of Dar es Salaam for identification using Flora of Tropical East Africa (FTEA) and Flora Zambesiaca (FZ) and by matching with herbarium specimens of known identity.

Biomass estimation

The biomass of trees which has been considered surrogate to wood stem volume was calculated from the basal area multiplied by the height of each individual tree. The basal area was calculated from DBH size classes of individual trees using a mathematical formula below:

$$\text{Basal Area (B.A)} = \frac{\prod x \text{ DBH x DBH}}{4}$$

$$\text{Biomass} = \text{Basal Area x Height}$$

Assessment of the level of disturbance in the Makurunge Woodland

There are several kinds of disturbance affecting vegetation communities and species distribution in Makurunge woodland. Those assessed were charcoal burning, fire, pole cutting, grazing and fuel wood collection, since they exerted high influence in this part of the landscape. A semi-quantitative assessment of disturbance was carried out using a six-point scale (0 – 5), with 0 = (No disturbance), 1= (0-20% of the quadrat disturbed), 2 = (21- 40% of the quadrat disturbed), 3 = (41 - 60% of the quadrat disturbed), 4 = (61 - 80% of the quadrat disturbed), 5 = (81 - 100% of the quadrat disturbed). The level of disturbance on the basis of the six-point scale represents the percentage of the quadrat of 20 m x 50 m that has been disturbed and each form of disturbance was assessed independently from the other. The point scale follows Anderson and Currier (1973) with some modification to accommodate the various forms of disturbance.

Data analysis

Plant species communities and distribution pattern

The effects of anthropogenic activities on vegetation communities, habitats and distribution pattern were assessed through the ordination method using the Canonical Community Ordination (CANOCO) software package (ter-Braak 2005). Two spread-sheet data files were used in the ordination. The first file was of primary data containing plant species (in terms of presence absence of a species) from every sampling point as a vegetation data matrix (dependent variable data file). The second file was classified as secondary data file which containing the level of anthropogenic disturbance recorded from each sampling point as an environmental data matrix (independent variables data file). Both vegetation and environmental data matrices were exported directly to CANOCO for determining gradients of distribution of plant species in relation to the influence disturbance variables. Monte-Carlo permutation test was used to identify anthropogenic disturbance that significantly influenced the distribution pattern of plant species. Vegetation communities were classified using Arc GIS software (Anon 2008).

Species diversity

Diversity of plant species was determined from the raw data obtained using Shannon's diversity index (Shannon and Weaver 1949) as follows:-

$$\textit{Diversity Index } (H') = -\sum_i^{\infty} pi \ln pi$$

Where pi = ni/N, the number of individuals found in the *ith* species as a proportion of the total number of individuals found in all species.

In = Natural logarithm to base ***e***

Shannon -Weaver diversity index assumes that individual species are sampled randomly from an even larger population and that each representative sample species has an equal chance of being included at each sampling point (Magurran 2004). Evenness (E) was calculated following (Alatalo 1981) as:

$$\textit{Evenness } (E) = \frac{H'}{\ln S}$$

Where H' is the Shannon-Weaver diversity index and S is the total number of species in a site. Analysis of variance was used to compare species diversity and evenness among vegetation community types in the woodland (Zar 1999).

RESULTS

Vegetation communities in Makurunge woodland

Six vegetation communities existed in the woodland where the *Acacia-Spirostachys* community dominates a large part followed by *Acacia-Terminalia* and *Diospyros-Manilkara* associations (Figure 2). The *Diospyros-Manilkara* community was characterized by *Manilkara sulcata, Diospyros cornii, Albizia petersiana, Afzelia quanzensis, Spirostachys africana* and *Lannea stulhmanii*. *Diospyrous bussei* and *Haplocoelum inopleum* were the indicator species of scrub habitats where with variation of 26% implies low variation in species composition among sites. Riverine vegetation was confined to seasonal streams, floodplains and river riparian with high abundance of *Ficus sur* and *Syzygium guineense* and these species were indicators of favourable habitats including. Within thicketed and scrub forest habitats *Scorodophloeus fischeri, Uvaria lucida, Sansevieria bagamoyoensis* and *Manilkara sulcata, Encephalators hildebrandtii, Sansevieria bagamoyoensis* and *Tricalysia microphylla* (coastal endemic) were found co-existing with *Garcinia buchananii, Strychnos madagascariensis* and *Haplocoelum inopleum*. *Acacia zanzibarica* woodland occurred as a pure stand of an isolated population in water-lodged, black cotton soils and was characterized by having very low diversity. The mangrove community was confined along the coastline of the Indian Ocean and the Wami- Ruvu river estuaries was composed of *Avicennia marina, Bruguiera gymnorrhiza, Sonneratia alba, Ceriops tagal* and *Rhizophora mucronata* (Figure 2). The *Acacia-Spirostachys-Terminalia* woodland community covered the largest part in the woodland and randomly distributed (Figure 2).

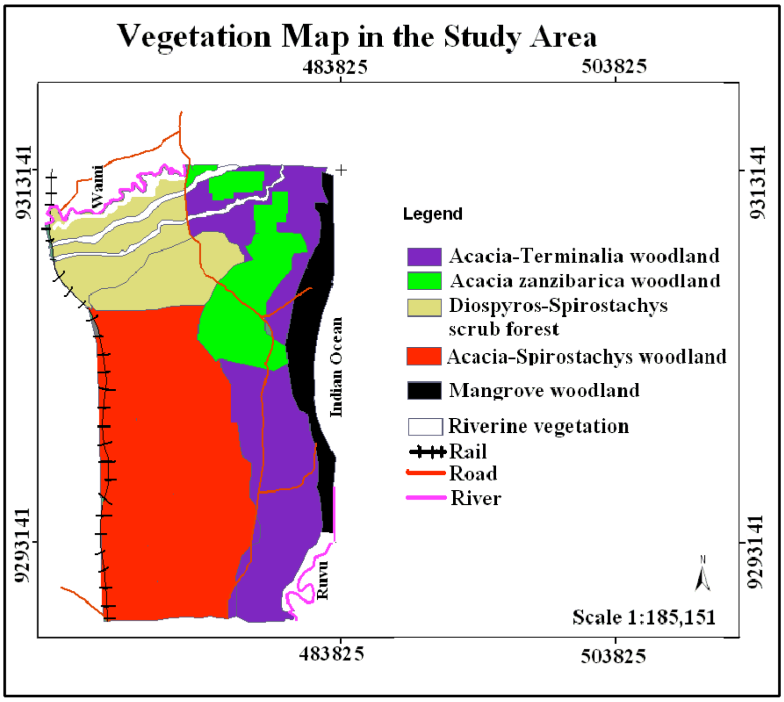

Figure 2: A map showing vegetation community types in Makurunge woodland, Bagamoyo District, Tanzania.

Species diversity and evenness in Makurunge woodland

Plant species diversity among communities ranged from 1.95 to 2.28 and evenness from 0.376 to 0.4408 (Figure 3). Scrub forest habitats and thickets were more diverse in terms of evenness in distribution pattern of plant species and the number of species than that in riverine community and the lowest was recorded in grassland and shrub communities (Figure 3). However, analysis of variance showed insignificant differences in species diversity and evenness among the communities (P>0.05).

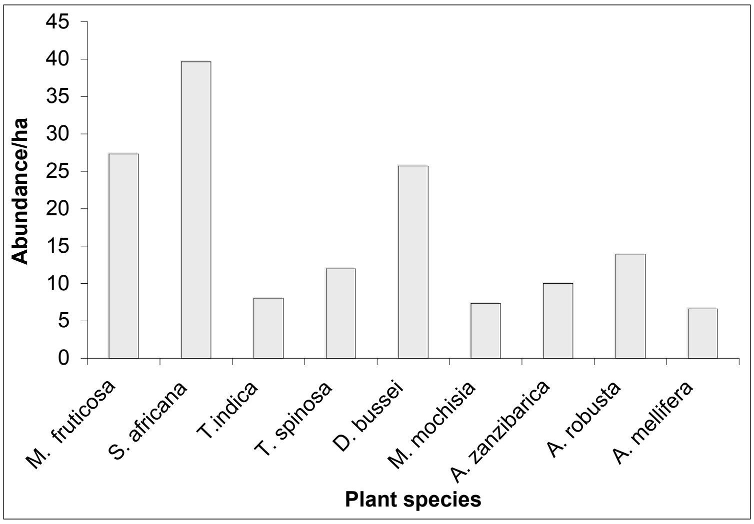

Figure 3: Variation in abundance among dominant tree species in the 2007 woodland

The biomass of tree species in Makurunge woodland

The total biomass in the woodland ranged between 85.80 and 229.41 m^3/ha (Figure 4). Higher biomass was found in the riverine, thickets and scrub forest habitats than in other habitats and hence was unevenly distributed in the Makurunge woodland. The highest biomass was contributed by *Spirostachys africana, Mimusops fruticosa, Diospyros bussei* and *Acacia robusta* (Figure 5). Although *Spirostachys africana* was the most abundant with the highest number of individuals and wide-spread in the woodland, its biomass was lower (85.80 m^3/ha) than those of *Diospyros bussei* (229.41 m^3/ha) and of *Tamarindus indica* (139.79 m^3/ha) found in thickets and scrub forest habitats (Figure 4).

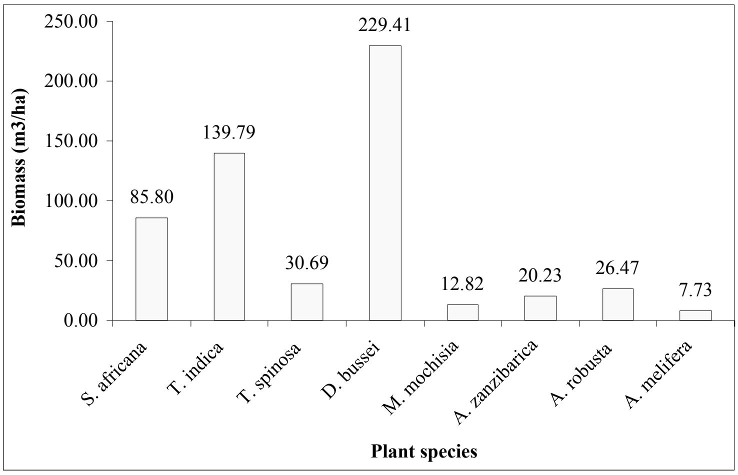

Figure 4: Variation in biomass among dominant tree species in Makurunge woodland

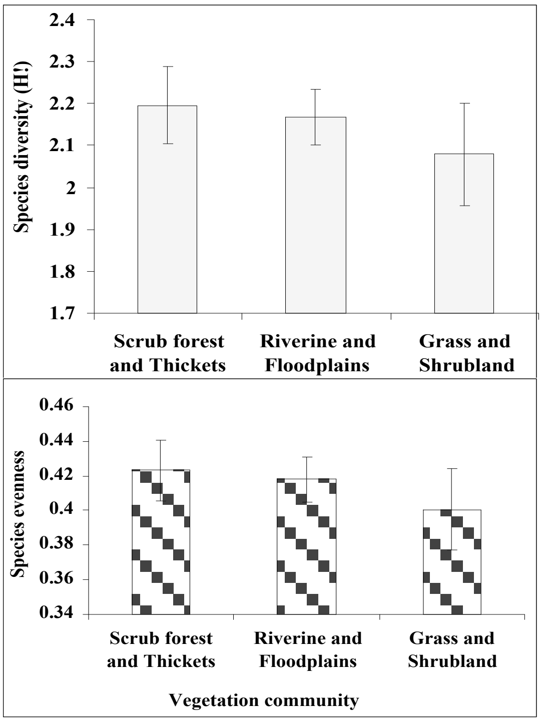

Figure 5: Variation in plant species diversity among vegetation community types in Makurunge woodland

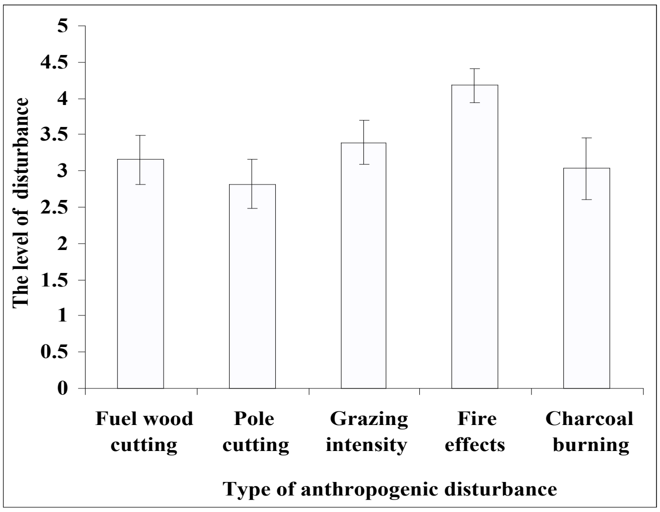

Figure 6: Various forms of anthropogenic disturbance in Makurunge woodland

Influence of disturbance on the distribution pattern of plant species in Makurunge woodland

The levels of anthropogenic disturbance were above average (4-5 i.e. 61-90%) (Figure 6). Fire greatly affected the woodland, followed by grazing, fuel wood cutting and charcoal burning and their effect were significant based on CCA F-ratios (P<0.05). Ordination showed that the first two CCA axes accounted for 52% of total variation in plant species distribution. The variation was high in the first axis (30%) than in the other axes and of total inertia of 4.631, 3.887 remained unexplained. 6.5% explained by the first axis and the combined first two axes explained a cumulative variance of 11.3% (Table 1). Similarly, 40.5% of the cumulative variance of the species-environmental relationship was explained by the first axis progressively decreased in other axes (Table 1). The abundance of *Strychnos madagascariensis, Panicum maximum, Grewia burtii, Microchloa kunthii, Cyperus exelsa* and *Dalbergia melanoxylon* increased along fire gradient and was positively correlated in the first species axis (r = 0.366) (Table 2). Also the abundance of *Grewia bicolor, Solanum incanum, Albizia petersiana, Mytenus senegalensis, Ochna holtzii, Duosperma crenatum, Scleria foliosa, Dichrostachys cinerea* and *Crabbea velutina* increased along increasing gradients of charcoal burning, fuel wood cutting and pole cutting and were positively correlated with this axis (Figure 7). Fuel wood cutting (r = -0.583) and pole cutting (r = -0.536) activities were negatively correlated with abundance of *Asparagus africana, Kigelia africana, Phoenix reclinata, Scorodophloeus fischeri, Ficus sur* and *Syzygium guineense* (Table 2, Figure 7). Such species may not be suitable for poles, charcoal making and as well as fuel wood collection therefore negatively correlated with such anthropogenic disturbances. CCA ordination revealed a significant influence of the assessed anthropogenic disturbance on the distribution of plant species (*F-ratio = 1.879; P = 0.012*). Based on Monte Carlo permutation test, charcoal making pole cutting, and fuel wood cutting significantly affected the distribution pattern of plant species in the woodland (F > 1.39; P < 0.05). Although disturbance by fire showed high influence in an ordination space at the first axis, its influence on plant species distribution pattern was not significant (F<1.39, P>0.05).

Table 1: Summary of CCA ordination of species using the first four-axes

Axes	1	2	3	4	Total inertia
Eigenvalues :	0.301	0.22	0.113	0.097	4.631
Species-environ. correlations :	0.829	0.843	0.676	0.599	
Cum. %variance of species data	6.5	11.3	13.7	15.8	
Cum % species-environ relation:	40.5	70.1	85.3	98.3	
Sum of all eigenvalues					4.631
Sum of all canonical eigenvalues					0.744
Eigenvalue = 0.301; F-ratio = 1.879; P-value = 0.012					

Cum = cumulative; environ = environmental

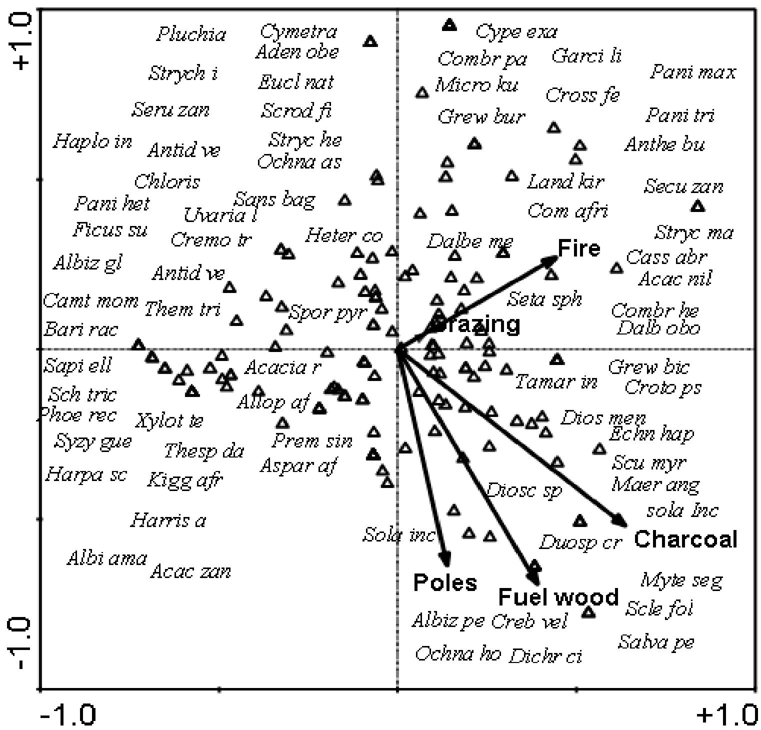

Figure 7: The plant species composition gradient under the influence of anthropogenic disturbance using the first two CCA ordination axes (Plant species are represented by the first four letters of the genus and three letters of the species) found in Makurunge woodland in Bagamoyo District

Table 2: Correlation matrix of vegetation data from Makurunge woodland

	SPEC AX1	SPEC AX2	SPEC AX3	SPEC AX4	ENVI AX1	ENVI AX2	ENVI AX3	ENVI AX4	Fuel wood	Pole	Grazing	Fire	Charcoal
SPEC AX1	1												
SPEC AX2	-0.06	1											
SPEC AX3	-0.16	0.16	1										
SPEC AX4	-0.16	-0.12	-0.23	1									
ENVI AX1	0.83	0.00	0.00	0.00	1								
ENVI AX2	0.00	0.84	0.00	0.00	0.00	1							
ENVI AX3	0.00	0.00	0.67	0.00	0.00	0.00	1						
ENVI AX4	0.00	0.00	0.00	0.6	0.00	0.00	0.00	1					
Fuel wood	0.32	**-0.58**	-0.19	0.21	0.39	**-0.69**	-0.29	0.36	1				
Poles	0.11	-0.53	-0.41	0.17	0.14	**-0.63**	-0.60	0.21	**-0.91**	1			
Grazing	0.07	0.04	-0.18	0.56	0.08	0.04	-0.28	-0.93	0.50	0.50	1		
Fire	0.37	0.23	-0.32	0.14	0.44	0.27	-0.48	0.23	0.47	0.48	0.54	1	
Charcoal	0.53	-0.44	-0.26	-0.01	**-0.64**	-0.52	-0.38	-0.02	0.54	0.49	0.02	0.04	1

DISCUSSION

Species diversity in different vegetation communities in Makurunge woodland

Plant species diversity was influenced by habitat heterogeneity and the varying levels of anthropogenic disturbances. The scrub forests and thickets had higher diversity of plants species than grassland and shrub habitats. Although scrub forests have natural micro-habitat conditions that favour co-existence of a variety of plants, disturbance may be an important factor decreasing plant species diversity in the woodland. Disturbance is known to affect microsites for plant diversity (Hobbs 1992). Grasslands and shrublands are communities mostly affected by fire in the woodland and the dominance of *Panicum maximum, Panicum trichocladum, Hyparrhenia filipendula* and scattered woody species such as *Spirostachys africana, Acacia robusta Strychnos madagascariensis*, *Acacia zanzibarica, Terminalia spinosa* and *Adansonia digitata* can be explained by the fact that most of them are fire-tolerant and because they have adapted to frequent burning in the woodland. Even if grasses and woodland co-exist in a dynamic equilibrium, their interaction with a combination of disturbance and edaphic factors does not exclude either plant life forms (Coetzee 2008). However, the grassland and shrub layer are frequently set alight, with the result that wide-spread fires in the woodland affect species diversity in all habitats. Any disturbance that fragment habitats result into microhabitat alterations (Sharma 2000). Regardless of the presence of high representation of *Encephalartos hildebrandtii*, *Sansevieria bagamoyoensis* and *Tricalysia pandensis, Scorodophloeus fischeri, Cissus quadrangularis, Uvaria lucida, Manilkara mochisia, Manilkara sulcata, Diospyros cornii, Albizia petersiana, Afzelia quanzensis, Haplocoelum inopleum* and *Spirostachys africana* and many of these are endemic plants at local or regional scale and they have suffered from various kinds of anthropogenic disturbance. Fire is ignited by pastoralists in the grassland and shrubland, which is accelerated by wind and penetrates other habitats (through the ecotone) affecting species with localized distribution patterns. The thickets and scrub habitats contain woody plant with high biomass, although they have been excessively exploited for charcoal, poles and fuel wood and the herbaceous plants suppressed by burning and overgrazing. The riverine habitats and the floodplains have persistent moist conditions that support the establishment of a variety of plant species including *Syzygium guineense*, mangrove plants (*Avicennia marina, Bruguiera gymnorrhiza, Sonneratia alba, Ceriops tagal* and *Rhizophora mucronata*), *Garcinia buchananii* and *Tamarindus indica*. However this community is being equally exploited for building poles and fuel wood. Overgrazing occurs during the dry season in the riverine area because it supports plants that remain green throughout the year. Anthropogenic fires in Africa are an ancient form of environmental disturbance, which have probably shaped up the savanna vegetation more than any other human-induced disturbance (Sheuyangea 2005). Frequent burning revert vegetation to grassland and the unburnt areas may revert to woodland (Peterson 2001). Even though *Spirostachys afircana* is a dominant tree and widely distributed in the woodland, its individuals had low DBH sizes and hence low biomass. This woody species is massively exploited for building poles due to its resistance property to termites and other destructive insects.

Anthropogenic disturbance in various parts of Makurunge woodland

Anthropogenic disturbance eliminated some plant species, reduces wood species populations and reduced biomass in the woodland. However, disturbance might serve to overcome the inertia of vegetation through lessening the dominance of established plants and creating opportunities for under-represented plant species to regenerate and perform in the present conditions. Thonicke (2001) pointed out that areas opened up by disturbance allow the regeneration of vegetation, thereby often maintaining the composition and succession cycles of species. The grasslands persisting in many parts in the woodland are apparently a result of suppression of tree growth and establishment through frequent burning and the human exploitation of woody plants. Regeneration of woody plant species in an anthropogenically disturbed landscape tends to proceed slowly (Dzownko 1997). This is because disturbance results in poor dispersal ability of woodland species (Peterken 1984). In Makurunge woodland regeneration of woody species was heavily suppressed by fire and grazing. Fire is an environmental factor affecting tropical savanna dynamics (Chidumayo 1984). Fire was mostly ignited to stimulate re-sprouting of grasses for livestock, however, it has been a major threat to the vegetation in the woodland where the natural habitats have been altered and the previous continuous vegetation communities have now been transformed into scrubland, thickets and grasslands. Presence of scrubland and thickets amidist the woodland, and the abundance of succulent plant species (*Sansevieria bagamoyoensis* and *Cissus quadrangularis*) in thickets, suggests that fire has been the primary determinant of the vegetation dynamics in this woodland. The combined effects of fire and grazing including other forms of disturbances that cause loss of biodiversity, can be predictive using multiple models (Garner 1999, Thonicke 2001). Pastoralism in Makurunge woodland is currently practiced by the Barbaig people who keep large herds of including cattle, goats, sheep and donkeys. These graze and browse on plant species which reduce plant diversity and consequently other cohabiting species in the communities. A great number of livestock rotates within the woodland and their density increased in the dry season when the quality of the graze in the nearby pastureland decreased and the woodland thus become overgrazed.

The effects of anthropogenic activities of the woodland habitats

Fragmentation of terrestrial landscape is a worldwide problem and is associated with loss of suitable patches (Andren 1994, Brooks *et al*. 2002). The spatial and temporal disturbance in an ecosystem gives rise to a mosaic of an area where patches of vegetation communities are created (Hobbs 1992, Strandberg 2001). In Makurunge woodland, *Encephalartos hildebrandtii*, *Sansevieria bagamoyoensis* and *Tricalysia pandensis* were localized in a few patches with suitable microhabitats and therefore depend on a constrained connected network of patches for their dispersal. They were therefore susceptible to population decline due to increased disturbance in patches and loss of suitable microhabitats. Aggravated anthropogenic disturbance in the woodland will ultimately deplete the existing patches. Habitat destruction is the chief cause of biodiversity loss and ecosystem degradation (Raghubashi 2009). The scrubland, woodland patches and riverine habitats function as potential dynamic areas for regeneration of species with restricted habitats. Through continued unchecked disturbance these habitats may disappear completely and species diversity in the coastal landscape decreases. The existing multiple patches at various levels of disturbance can be regarded as a dynamism that determines the pattern of recovery. The multiple patches in the woodland forms the basis for defining a minimum dynamic area which is the critical size of the woodland patches suitable for minimum viable populations. With continued destruction of suitable habitats in Makurunge woodland, the plant species such as *Encephalartos hildebrandtii*, *Scorodophloeus fischeri, Diospyros cornii, Mimusops fruticosa*, *Sansevieria bagamoyoensis* and *Tricalysia pandensis* are likely to disappear from this woodland because modified habitat conditions will not favour their performance and population expansion. Habitat-constrained plant species depend on a constellation of patches in relatively close proximity, since no single patch can meet the needs of a population. A scrub that has been unburned for long periods can support scrub-dependent species (Schmalzer 2005). Close proximity of the adjacent patches ensures migration of sufficient number of individuals between viable metapopulations. This is because plant species among fragments and thickets require a wide array of pollinators. Since thickets and scrubs are critical habitats for vegetation and are separated by the barrier of grasslands created by anthropogenic disturbance, this may result in rapid decline in the population as the barrier continues to be broadened. Structural contrast between patches and the matrix in which plant species exist is regarded as a measure of fragmentation in the woodland. As the coastal landscape is progressively altered, the functional isolation among populations increases which puts at risk the localized plant species. A structurally rich matrix, such as the scrub forest thickets and riverine communities serve as marginal habitats and buffer population fluctuations in the woodland and promote dispersal among patches. However, due to continued disturbance the complexity of matrices is reduced and the plant species are drawn to low quality habitats in this woodland. Since anthropogenic disturbance has to a large extent contributed to the current woodland degradation, it is recommended that the woodland be conserved so that the remaining populations in the thickets and scrubland can regenerate naturally in the open gaps. This could help to restore the coastal landscape through enlarged and interconnected coastal forest fragments that harbour diverse plant species.

Plant species compositional gradient in Makurunge woodland

CCA anthropogenic gradients showed strong impact on distribution pattern of plant species in the woodland. Variation in the first axis (30%) was higher than in the other axes, implying that strong gradients were based on this axis and it explains the influence of anthropogenic disturbance on the pattern of distribution of plant species. Correlation weights indicated by long arrows in the direction of maximum influence where fire and grazing had the highest influence along the first axis and were strong positively correlated with *Strychnos madagascariensis, Panicum maximum, Grewia burtii, Microchloa kunthi, Cyperus exelsa* and *Dalbergia melanoxylon* (Figure 7). These species are adapted to fire and grazing pressure. Moreover charcoal making, fuel wood cutting and pole cutting activities seemed to favour the abundance of *Grewia bicolor, Solanum incanum, Albizia petersiana, Mytenus senegalensis, Ochna holtzii, Duosperma crenatum, Scleria foliosa, Dichrostachys cinerea* and *Crabbea velutina,* likely because some of them are herbs, shrubs or early colonizers in the disturbed communities and have not been exploited. However, *Asparagus africana, Kigelia africana, Phoenix reclinata, Ficus sur* and *Syzygium guineense* were negatively correlated with fire, charcoal, pole cutting, fuel wood cutting and grazing (Figure 7). This means the above plant species are not suitable for the anthropogenic use and hence not exploited. These plant species scored low gradients in an ordination space and therefore these plants cannot perform in anthropogenically disturbed habitats or avoided because of poor use value. Axis 1 being the fire-grazing gradient and axis 2 being the fuel cutting, charcoal burning and pole cutting gradients means that these kinds of imply disturbance determined the distribution of plant species in the woodland. This was confirmed by Monte Carlo permutation tests ($P<0.05$).

CONCLUSION

Disturbance in Makurunge woodland culminated to habitat destruction that result in variation in plant species diversity among communities. Scrubforests, thickets and riverine communities were more diverse since they provide favourable conditions for the performance of diverse life forms than the grassland and scrubland habitats. High diversity of woody plant species in thickets and scrubforest have resulted into higher biomass than in the grassland and shrublands. This is because of suitable microhabitat conditions that favour large number of tree species that contribute high biomass per unit area than other habitats. However exploitation of woody species and fire that suppresses their establishment in the area has reduced their biomass in the woodland. *Spirostachys africana* and *Terminalia spinosa* are wide-spread in the woodland, but their biomass is lower than *Diospyros bussei* and *Tamarindus indica* that are localized in the thickets and scrublands. It was found that fire ignitions and grazing were the most destructive activities in the woodland and this affected many plant species that are not adapted to these forms of disturbance. The CCA ordination gradients showed *Strychnos madagascariensis, Panicum maximum, Grewia burtii* and *Microchloa kunthii* to perform best under frequent burnt areas, whereas Grewia *bicolor, Solanum incanum, Dichrostachys cinerea* and *Crebbia velutina* survived in areas disturbed by charcoal burning, fuel wood collection and pole exploitation. Regardless of the fact that fire we ranked the most disturbing factor in the woodland, its influence was not significant, while exploitation for fuel wood, poles and charcoal was significant, based on the Monte Carlo permutation test ($P<0.05$). This means disturbance affected the vegetation communities and the scrub habitats are continued being fragmented into patches and this increases the distance between the resulting patches. The wide separation of patches also increases the dispersal distance which can put the populations at risk due to barrier between patches. The constrained dispersal networks for localized plant species between patches are particularly important for guiding the selection of target areas for the management, mitigation and restoration of habitats in Makurunge woodland.

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