International Scholars Journals

African Journal of Water Conservation and Sustainability ISSN 2375-0936 Vol. 11 (1), pp. 001-009, January, 2023. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Plant communities and tree species associations in a Miombo ecosystem in the Lake Rukwa basin, Southern Tanzania: Implications for conservation

Pantaleo K. T. Munishi[1]*, Ruwa- Aichi P. C. Temu[1] and Soka G.[2]

[1]Department of Forest Biology, Sokoine University of Agriculture, P.O. Box 3010, Morogoro, Tanzania.
[2]Department of Wildlife Management, Sokoine University of Agriculture, P.O. Box 3010, Morogoro, Tanzania.

Accepted 22 December, 2022

This study assessed the plant communities and species associations in the eastern Miombo woodlands eco-region of the Lake Rukwa basin southern Tanzania. Information was collected from 288 temporary sample plots in 32 sampling sites established randomly in the area and covering as much variation in the landscape as possible. Detailed analysis of the vegetation identified six tree communities of conservation importance, which included *Brachystegia boehmii-Pericopsis angolensis* woodland, *Julbernardia globiflora* woodland, *Combretum molle-Sclerocarya birrea-Combretum zeyherii-Acacia seyal* var *fistula* woodland, *Bridelia cathartica-Diospyros mespiliformis* woodland, *Brachystegia bussei-Pterocarpus tinctorius* woodland and *Brachystegia microphylla-Isoberlinia tomentosa-Hymenocardia acida- Syzygium owariense* woodland. Majority of the described plant communities are typical of Miombo ecosystems dominated by trees belonging mainly to the genera *Brachystegia* and *Julbernardia*. A mixture of non-legume species but typical of the Miombo ecosystem, however, dominates two out of six described plant communities. Apparently, there is high variability of plant communities in the Miombo ecosystem of southern Tanzania, an indication of the diverse nature of the Miombo ecosystem, also, an implication of high species diversity. This documentation on the patterns of species assemblages is the beginning of unveiling the diversity of assemblage of species in dry forest ecosystems which occupy a wide area in the region. These associations are important targets for conservation and monitoring vegetation changes in this ecosystem.

Key words: Miombo ecosystem, plant communities, species associations.

INTRODUCTION

The Miombo ecosystem is one of the tropical wildernesses in the world covering about 3.6 million km^2 and spanning ten countries in East and Central Africa. Miombo woodlands form the dense forest woodland that bisects Africa directly south of the Congo Basin and East African savannahs. It stretches all the way from Angola in the west to Tanzania in the east. These woodlands are dominated by trees of the subfamily Caesalpinioideae, particularly species belonging to the *Brachystegia*, *Julbernardia* and *Isoberlinia* genera, which seldom occur outside Miombo (Campbell et al., 1996). Much of the area covered by this ecoregion overlaps with White's (1983) floristically impoverished drier Zambezian Miombo woodland. The vegetation of this area is primarily woodland, dominated by trees in the legume sub-family Ceasalpinoideae with the genera *Brachystegia, Julbernardia* and *Isoberlinia* dominating and a well-developed underlying layer of grass. The dominance of one family of trees provides the unifying feature for this ecosystem (Frost, 1996; Chidumuyo, 1997; WWF, 2001; Byers, 2001; Timberlake, 2000). The Miombo ecosystem

*Corresponding author. E-mail: pmunishi2001@yahoo.com. Tel/Fax: 23260 4648, +255 754 591849.

contains a diverse of major woodland types including wet Miombo, dry Miombo, Burkea-Terminalia woodlands, Baikiaea woodland, Mopane woodland, Acacia-Combretum woodland, dry evergreen forests (Cryptosepalum), wetland grasslands and thickets (Itigi thicket) (Byers, 2001). Dominant tree species include *Brachystegia spiciformis*, *Brachystegia boehmii, Brachystegia allenii* and *Julbernardia globiflora* (Campbell et al., 1996). In areas of higher rainfall, a transition to wetter Zambezian Miombo occurs (White, 1983). This vegetation supports greater floral richness and includes almost all the Miombo dominants, such as *Brachystegia floribunda, Brachystegia glaberrima, Brachystegia taxifolia, Brachystegia wangermeeana, Brachystegia utilis, Marquesia macroura, Julbernadia globiflora, Julbernadia paniculata* and *Isoberlinia angolensis*. Deciduous riparian forest lines the numerous rivers in the area, while dry forest and thicket associations are also found in the ecoregion, especially in rocky places. The Miombo ecosystem composes three major eco-regions which include the eastern Miombo woodlands (AT0706), the Angola Miombo woodlands (AT0701) and the Central Zambezian Miombo woodlands (AT0704).

The eastern Miombo woodlands ecoregion covers an area of about 483,900 square kilometers and consists of a relatively unbroken area covering the interior regions of southeastern Tanzania and the northern half of Mozambique, with a few patches extending into southeastern Malawi. The ecoregion experiences a seasonal tropical climate with most rainfall concentrated in the months from November through March followed by an intense drought that can last up to 6 months (Werger and Coetzee, 1978). Mean annual rainfall ranges between 800 and 1,200 mm, although, peaks of up to 1,400 mm per annum are found along the western margins.

The Central Zambezian Miombo woodland ecoregion covers an area of 1,184,200 square kilometers and lies beyond Lake Malawi to the west, while to the north, the ecoregion is bordered by Acacia-Commiphora bushland and thicket belonging to the Somali-Masai phytochorion (White, 1983). The East African coastal mosaic of White's (1983) Zanzibar-Inhambane regional center of endemism lines the shore. The Zambezian and Mopane woodland ecoregion lies to the south. This ecoregion covers about 70% of central and northern Zambia, the southeastern third of the Democratic Republic of Congo (DRC), western Malawi, much of Tanzania and parts of Burundi and northeastern Angola. Consisting mainly of broadleaf, deciduous savannas and woodlands, it is characteristically interspersed with edaphic grassland and semi-aquatic vegetation, as well as areas of evergreen groundwater forest. The extensive Angolan Miombo woodlands (660,100 square kilometers) are part of an even larger Miombo ecosystem covers all of central Angola and extends into the Democratic Republic of Congo. This ecoregion comprises moist, deciduous broadleaf savannahs and woodlands interspersed with areas of edaphic and secondary grassland. It forms the westernmost part of the large Miombo woodland belt that is the dominant type of savannah woodland in the Zambezian center of endemism (White, 1983; Campbell et al., 1996). Most of the Angolan Miombo woodland is found at elevations between 1,000 and 1,500 m above sea level. The mean annual rainfall in the ecoregion ranges from less than 800 mm in the south to about 1,400 mm in the north and west (Huntley, 1974).

The region is home to at least 4,500 endemic plants species and 163 endemic animals' species. It is a center of diversity for underground trees whereby of the 98 species known from Africa 86 are confined to this region. The Miombo ecosystem is also a globally important carbon store. It is an area where humans have co-evolved with wildlife over millions of years and contains about 23 and 29% of the worlds black rhino and white rhino populations respectively, 42 to 45% of Africa's elephant population, most of the Africa's surviving wild dogs and over 66 million people and different livelihoods (White, 1983; WWF, 2001; Byers, 2001; Campbell, 1996; Rodgers, 1996).

According to WWF (2001), among the conservation challenges of the Miombo ecosystem include maintaining the habitat diversity and integrity, the hydrologic systems and species diversity and status. Other challenges includes maintaining the biological and social values of landscapes of biological significance, restoration of degraded areas and those invaded by exotics and improving livelihoods by sustainable use of natural resources. Addressing such challenges needs an effective long term conservation planning and priority setting for resource management. The variability of the region requires site-based approaches to conservation though much larger landscape approaches may also be needed. The success of these approaches entails efficient assessment and appraisal of the resource status and distribution. While there is good knowledge on the distribution and extent of the Miombo ecosystem in Africa the plant community patterns and species association which are important in holistic approaches to conservation has not been well documented. This study assessed the plant communities and species associations in part of the vegetation of the eastern Miombo woodlands eco-region in Lake Rukwa basin, Southern Tanzania.

MATERIALS AND METHODS

Study site

The study was conducted in the Lake Rukwa basin woodlands in Chunya District southern Tanzania (Figure 1) as a representative of the eastern Miombo woodlands eco-region in Tanzania. The woodlands are composed mainly of both wet and dry Miombo vegetation and some wetland/grassland patches with an area of 18,200 km^{-2} (Chunya District Socio-economic Profile, 1997). The

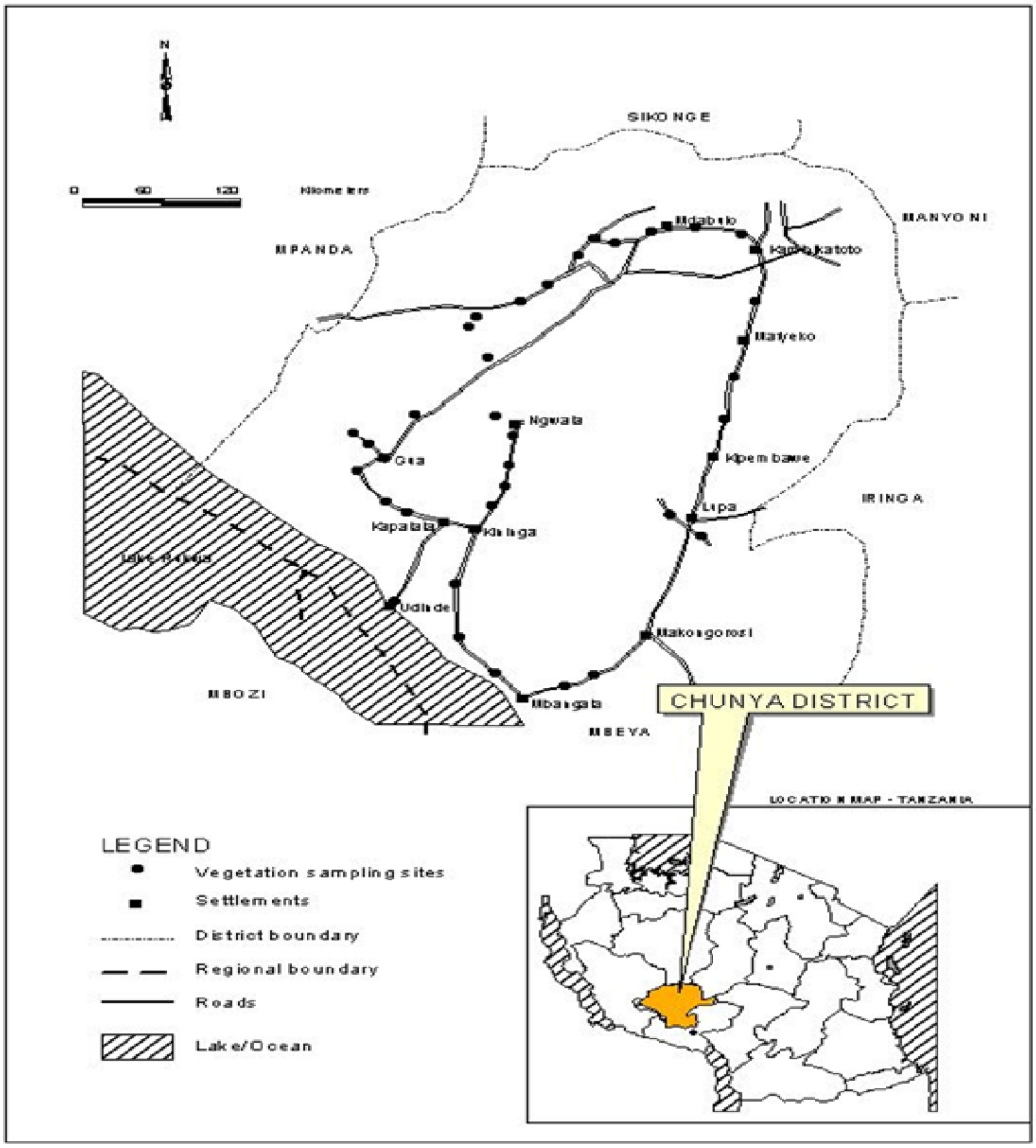

Figure 1. Vegetation sampling points in the lake Rukwa basin woodlands.

Lake Rukwa basin topography ranges from about 800 m on the shores of Lake Rukwa to a little bit above 1700 m above sea level on Kwimba hill. The areas surveyed in this study covered an elevation range from 833 to 1570 m. About 92% of the plots surveyed had an elevation between 1000 and 1500 m. 3% were less than 1000 m and 4% were above 1500 m. Slopes ranged from 0 to 55%. About 57% of the plots had slopes of less than 2%. Slopes between 2 and 10% made up about 35% of the surveyed plots, while slopes between 11 and 20% represented 5% of the plots. Only 3% of the plots had slopes greater than 20%. The underlying geology of the Miombo woodlands consists mainly of metamorphosed upper-Precambrian schists and gneisses, interspersed with intrusive granites (Bridges, 1990). The combination of the crystalline nature of these rocks, low relief, moist climate and warm temperatures has produced highly weathered soils that are commonly more than 3 m deep (Frost, 1996). The soils are typically well-drained, highly leached, nutrient-poor and acidic with low organic matter.

Data collection

Survey plots were selected randomly in sites that represented the vegetation types of the study area as represented by the general vegetation Tanzania Natural Resource Information Centre (TANRIC) maps of the region (Figure 1) in the Lake Rukwa basin southern Tanzania. Temporary circular plots of different sizes were established in the site. In closed woodlands and open woodlands plots of 0.07 ha (15 m radius) and in grasslands/wooded grasslands plots of 0.28 ha (30 m radius) were established. Plots were established systematically along line transects on a predetermined bearing from the road/track side, the first plot being 50 m from the roadside. Plots were established to cover as much variation in the landscape as possible from valley bottoms to ridge tops so as to

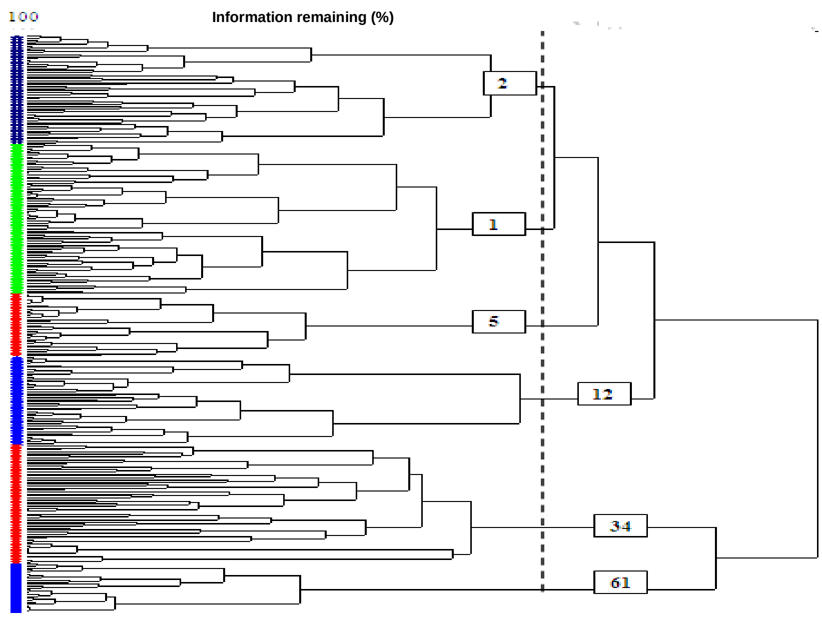

Figure 2. Community dendrogram of Sørensen distances between plant communities indicating importance value relationships in the woodlands of Lake Rukwa basin. The numbered clades indicate different vegetation communities (associations). 1 = *Brachystegia boehmii-Pericopsis angolensis* woodland; 2 = *Julbernardia globiflora* woodland; 5 = *Combretum molle-Sclerocarya birrea-Combretum zeyherii-Acacia seyal* woodland; 12 = *Bridelia cathartica-Diospyros mespiliformis* woodland; 34 = *Brachystegia bussei-Pterocarpus tinctorius* woodland; 61 = *Brachystegia microphylla-Isoberlinia tomentosa-Hymenocardia acida-Syzygium owariense* woodland (Figure 3 and Table 1).

capture vegetation variations in different microhabitats. The distance between plots on transect lines was approximately 100 m and each transect extended into the interior of the woodland about 0.5 to 2.0 km, depending on the number of plots along a transect line. Occasionally, opportunistic sampling was done in areas observed to represent unique habitats in order to capture as much representation of the different habitats of the area as possible.

A total of 288 plots were established and surveyed in 31 selected sites selected to represent the study area as shown in Figure 1. The following information was collected at each sampling plot; plot location and elevation using GPS/Altimeter, plot slope using Suunto hypsometer, diameter at breast height (dbh) of all trees with diameter $\geq$ 6 cm. Species were identified by both local and botanical names. Local names were given by a local plant identifier and botanical names were accorded by using a checklist. For species that could not be adequately identified in the field, voucher specimens were collected for identification and confirmation at the National Herbaria in Arusha, Tanzania.

Data analysis

The data were analyzed for basal area, density and species importance value index (IVI). Species importance values (IV) for each plot were computed for each species as the average of the relative basal area and relative density (Munishi, 2001; Munishi et al, 2007). The plots were classified by agglomerative hierarchical cluster analyses of the IVs (Orloci, 1967; Gauch, 1982; Greig-Smith, 1983), using Sørensen's distance measure and a group linkage method with flexibility of -0.45. The plots were ordinated by non-metric multidimensional scaling (NMS) using the PC-ORD version 4.0 software (McCune and Mefford, 1999). The data were first run using detrended correspondence analysis (DCA) to get a starting configuration (the graph file from the DCA), then, NMS was run using Sørensen's distance measure (McCune and Mefford, 1999). The number of axes was set to two, with hundred iterations, fifty runs with real data (after Monte Carlo test and stability criteria of 0.005). The topographic variables (elevation and slope) were correlated with plant community composition in the NMS ordination. Indicator species analysis was performed using the method of Dufrene and Legendre (1997) contained in the PC-ORD version 4.0 software. Plant community types were named following procedures of the nature conservancy (Anderson et al., 1998), where the names of the dominant and diagnostic species are used as the foundation of the association name. The first three to five dominant member species with the highest significant indicator values (p = 0.05) (Dufrene and Legendre, 1997; Kershaw and Looney, 1985; Barbour et al., 1987) were used to name the associations.

RESULTS AND DISCUSSION

Plant communities and species associations

On examination of the dendrogram (Figure 2) and significance of the indicator values for different species, six distinct plant communities were identified, characterized and described based on species composition and associations (Table 1, Figures 2 and 3).

The plant communities for these woodlands were *Combretum molle-Sclerocarya birrea-Combretum*

Table 1. Plant communities and species associations in the Miombo woodlands of Lake Rukwa basin, Chunya District.

Community type	Associated species	Indicator value
Combretum molle-Sclerocayia birrea-Combretum zeyherii-Acacia seyal var. fistula woodland 51	*Combretum molle*	55.8
	Sclerocarya birrea	19.0
	Combretum zeyherii	18.8
	Acacia seyal var. fistula	15.2
	Acacia tortilis ssp spirocarpa	13.7
	Terminalia mollis	13.5
	Bauhinia petersiana	13.0
	Commiphora fischeri	12.9
	Shrebera trichoclada	12.2
	Ozoroa insignis	9.6
	Acacia nigrescens	6.8
	Styichnos innocua	5.4
Brachystegia bussei-Pterocarpus tinctorius woodland 34	*Brachystegia bussei*	96.7
	Pterocarpus tinctorius	22.7
	Stereospermum kunthianum	12.1
	Ormocarpum trachycarpus	12.0
	Albizia antunesiana	9.2
	Ochna sp	8.0
	Zanha africana	5.8
	Euphorbia grantii	4.9
Brachystegia microphylla-Isoberlinia tomentosa-Hymenocardia acida-Syzygium owariense woodland 61	*Brachystegia microphylla*	61.8
	Isoberlinia tomentosa	37.1
	Hymenocardia acida	30.4
	Syzygium owariense	19.6
	Uapaca nitidula	6.8
	Phyllanthus discoideus	4.5
Bridelia cathartica-Diospyros mespiliformis woodland 12	*Bridelia cathartica*	75.5
	Diospyros mespiliformis	19.0
	Lonchocarpus bussei	6.0
	Ximenia americana	3.2
Brachystegia boehmii-Pericopsis angolensis woodland 1	*Brachystegia boehmii*	45.3
	Pericopsis angolensis	16.4
	Pterocarpus angolensis	13.0
	Mundulea sericea	7.3
Julbernardia globiflora woodland 2	*Julbernardia globiflora*	60.6
	Monotes elegans	6.4
	Strichnos potatorum	4.0
	Ximenia caffra	3.8
	Brachystegia spiciformis	2.7

1 Numbers 1,2, 5, 12, 34 and 62 represent the different plant associations on Figures 2 and 3.

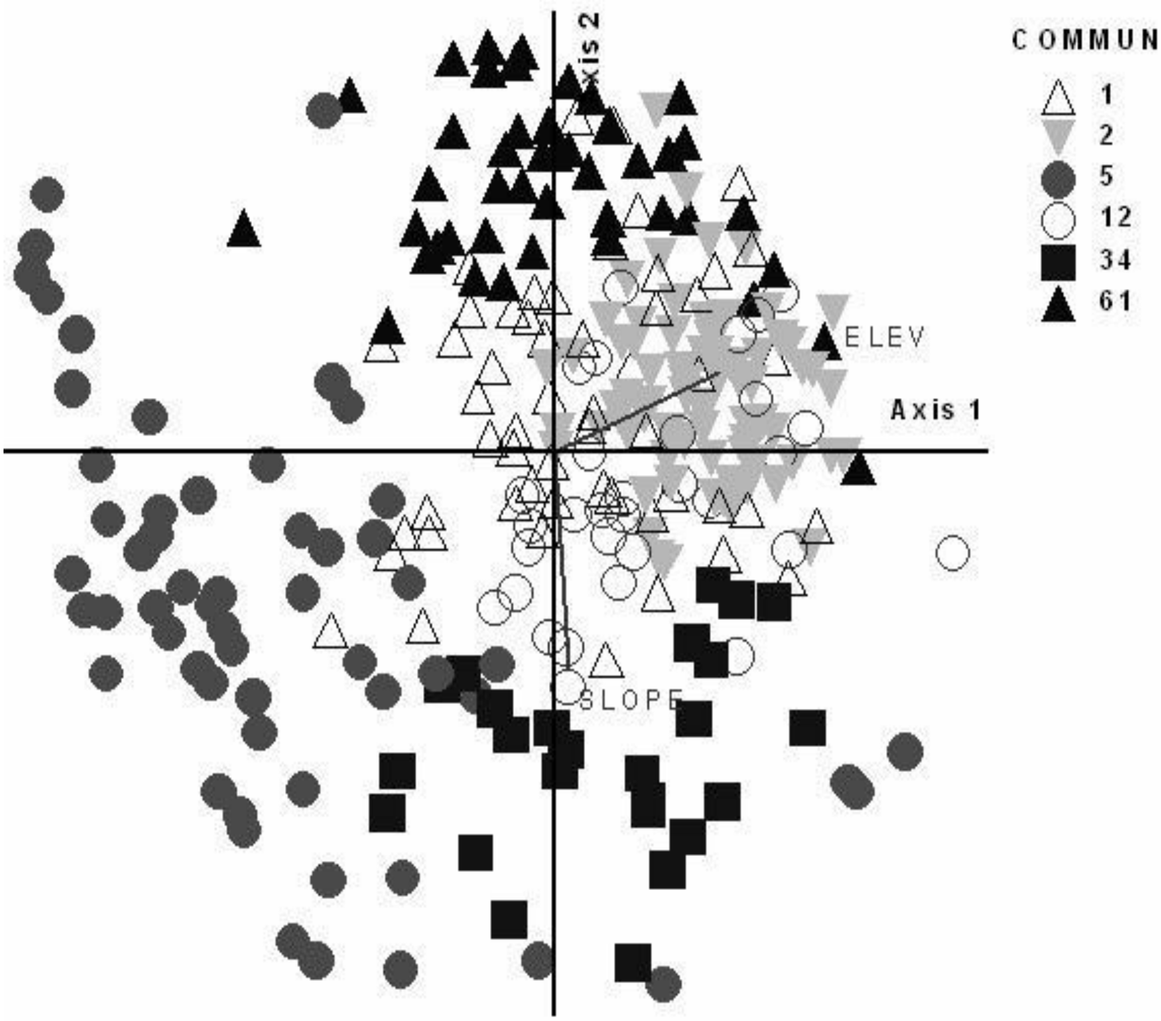

Figure 3. Compositional gradients and plant communities in NMS ordination of 288 vegetation plots in the woodlands of Lake Rukwa basin, Chunya District. Six plant communities are recognized. 1 = *Brachystegia boehmii-Pericopsis angolensis* woodland; 2 = *Julbernardia globiflora* woodland; 5 = *Combretum molle-Sclerocaria birrea-Combretum zeyherii-Acacia seyal* woodland; 12 = *Bridelia cathartica-Diospyros mespiliformis* woodland; 34 = *Brachystegia bussei-Pterocarpus tinctorius* woodland; 61 = *Brachystegia microphylla-Isoberlinia tomentosa-Hymenocardia acida-Syzygium owariense* woodland. COMMUN = Plant communities (Table 1).

zeyherii-Acacia seyal woodland; *Brachystegia bussei-Pterocarpus tinctorius* woodland; *Brachystegia microphylla-Isoberlinia tomentosa- Hymenocardia acida-Syzygium owariense* Woodland; *Bridelia cathartica-Diospyros mespiliformis* woodland; *Brachystegia boehmii-Pericopsis angolensis* woodland; and *Julbernardia globiflora* woodland**.** The number of plant communities is comparable with those observed in submontane rain forests where six plant communities were characterized and described in a forest of the eastern Arc Mountains of Tanzania (Munishi, 2001) and other classifications of the eastern Arc vegetation (Póc's et al., 1990; Lovett, 1990). However, the species composition and dominance differ between the current vegetation and those on submontane forests, because they occur on different eco-regions. Banda et al. (2006) observed that species richness in protected areas of Miombo woodlands was significantly higher than in the other areas.

Majority of the described plant communities are typical of Miombo ecosystems as they are dominated by trees belonging to the legume sub-family Caesalpinioideae mainly the genus *Brachystegia* and *Julbernardia* (Table 1). According to Byers (2001), the Miombo ecosystem in botanic terms could be called southern Ceasalpinoideae woodlands and can be defined by the dominance or high frequency of trees belonging to the legume subfamily *Caesalpinioideae* such as *Brachystegia, Julbernardia, Isoberlinia, Baikiaea, Cryptosepalum, Colophospermum* and *Burkea.* Two out of the six described plant

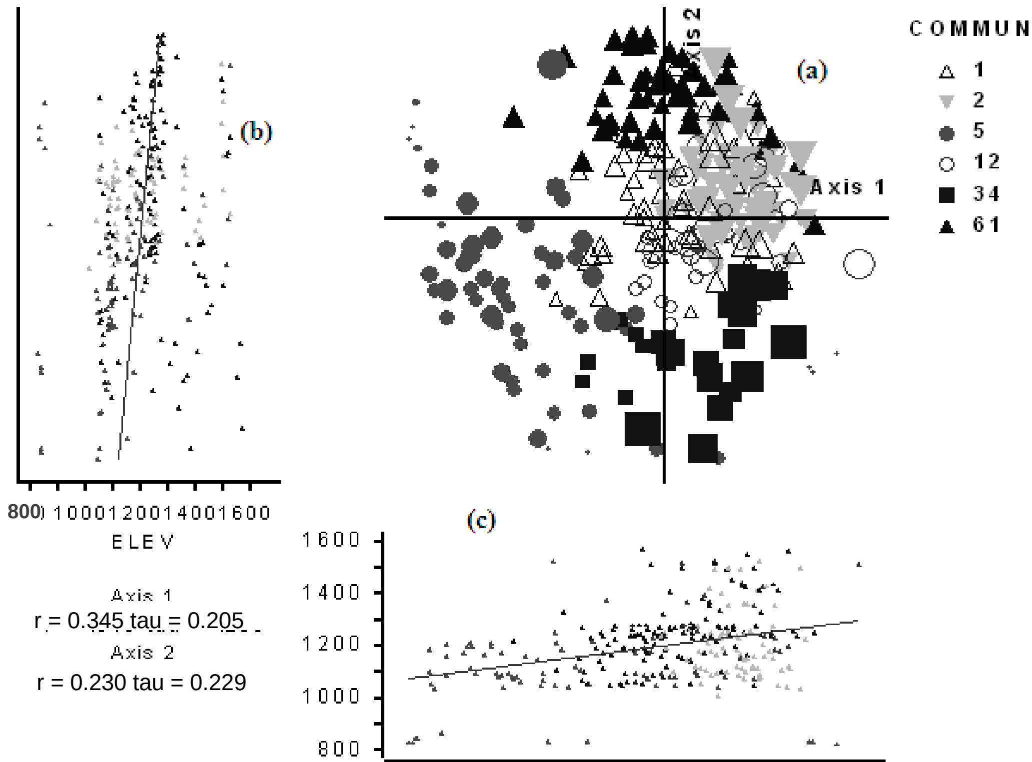

Figure 4. Elevation influence on plant community patterns in the woodlands of Rukwa basin, Chunya District. (a) Ordination diagram showing plant community alignment along the ordination axes; (b) axis 1 of the ordination correlations with elevation; (c) axis 2 of the ordination correlation with elevation. Axis 1 of the ordination correlates well with elevation. COMMUN = Plant communities.

communities are however dominated by a mixture of non-legume species but these species are typical of the Miombo ecosystem. This variety of plant communities is an indication of the diverse nature of the Miombo ecosystem, also an implication of high species diversity (Table 1).

Factors determining plant community patterns and species associations

In the Miombo woodlands of southern Tanzania, elevation and percent slope seem to be among the factors that determine plant community patterns (Figures 4 and 5). The plant communities identified and hence, species associations seem to align themselves along two gradients; low and high elevation and gentle and steep slopes. In this respect there was a fairly good correlation between plant species distribution patterns and the slope of the landscape as represented by the correlation coefficient (Figures 4 and 5). Though edaphic (soil factors) were not assessed, they may not be ruled out as they may interact with physiographic factors to form complex patterns in plant communities (Munishi, 2001). Based on this analysis, *C. molle-Sclerocarya birrea-Combretum zeyherii-Acacia seyal* var. *fistula* woodlands (5) are found on gentle slope-low elevation sites, *Brachystegia bussei-Pterocarpus tinctorius* woodlands (34) are found on steep slopes, mid to high elevation areas, *Brachystegia microphylla-Isoberlinia tomentosa-Hymenocardia acida-Syzygium owariense* woodlands (61) are found on gentle slopes mid elevation areas, *Bridelia cathartica-Diospyros mespiliformis* woodlands (12) are found on gentle slopes, mid to high elevation areas, *Brachystegia boehmii-Pericopsis angolensis* woodlands (1) are found on gentle slopes, mid elevation areas and *Julbernardia globiflora* woodland (2) are found on gentle to medium slopes, high elevation areas (Figures 4 and 5, Table 1). Different species have the same physiographic preferences and will have higher abundances in areas with those preferences or characteristics. The abundance, distribution and diversity of vegetation are strongly influenced by the qualities of the physical landscape with plant species responding uniquely to the opportunities and constraints arising from physical and chemical characteristics of the landscape. Such responses are especially more pronounced on mountain ecosystems, where there are abrupt changes in altitude, slope, moisture gradients, hydrology, aspect, temperature and rainfall (Munishi et al., 2007). Such

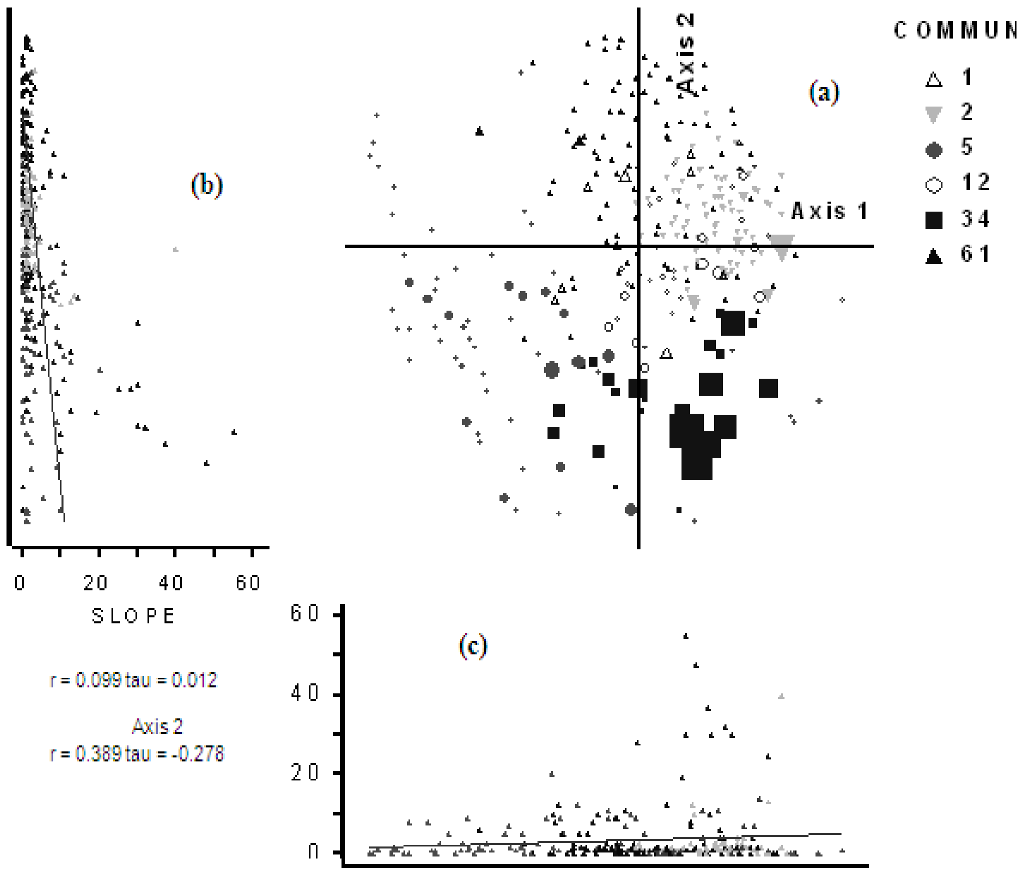

Figure 5. Slope influence on plant community patterns in the woodlands of Rukwa basin, Chunya District. (a) Ordination diagram showing plant community alignment along the ordination axes; (b) axis 1 of the ordination correlations with slope; (c) axis 2 of the ordination correlation with slope. Axis 2 of the ordination shows a strongly negative correlation with slope. COMMUN = Plant communities.

variations greatly influence patterns in plant communities and their diversity. According to Munishi et al. (2007) different species respond uniquely to different environmental gradients with topographic and edaphic factors determining the plant species associations and community composition in the eastern Arc Mountains of Tanzania. Banda et al. (2006) observed that, different management regimes had significant influence of the plant species composition and richness in the Miombo woodlands.

CONCLUSIONS AND RECOMMENDATIONS

The Miombo woodlands of southern Tanzania consist of unique plant communities and species associations that are important targets for monitoring vegetation changes and conservation. Periodic vegetation assessment and monitoring in strategic areas are important for predicting changes in the status of the ecosystem. Among the best ecological option in developing monitoring strategies is to target species of ecological significance within an ecosystem such as those species that are indicators of specific associations or plant communities.

REFERENCES

Anderson M, Bourgeron MT, Crawford, R Engelking, Faber-Langendoen LDGM, Goodin K, Grossman HD, Landaal S, Metzler K, Patterson KD, Pyne M, Reid M, Sneddon L, Weakley SA (1998). International classification of Ecological Communities: Terrestrial Vegetation of the United States Volume II. The National Vegetation Classification System: List of Types. Nat. Conservancy, p. 501.

Banda T, Schwartz MW, Caro T (2006). Woody vegetation structure and composition along a protection gradient in a miombo ecosystem of western Tanzania. For. Ecol. Manage., 230: 179-185.

Barbour GM, Burk HJ, Pitts WD (1987). Terrestrial Plant Ecology 2nd Ed. The Benjamin / Cummings Publishing Company, Inc. California, USA. p. 634.

Bridges EM (1990). World Geomorphology. Cambridge University Press, UK.

Byers AB (2001). Conserving the Miombo Ecoregion. Reconnaissance Summary. WWF, Southern Africa Regional Program Office, Harare Zimbabwe, p. 24.

Campbell B (1996). The Miombo in Transition: Woodlands and Welfare in Africa. Center for International Forestry Research (CIFOR), Bogor, Indonesia, p. 266.

Dufrene M, Legendre P (1997). Species assemblages and indicator

species: the need for a flexible asymetrical approach. Ecol. Monogr., 67: 777-795.
Frost PGH (1996). The Ecology of Miombo Woodlands. In Campbell, B. (Ed). The Miombo in Transition: Woodlands and Welfare in Africa. Center for International Forestry Research (CIFOR), Bogor Indonesia, pp. 11-57.
Gauch HG (1982). Multivariate Analysis in Community Ecology. New York: Cambridge University Press UK.
Greig-Smith P (1983). Quantitative Plant Ecology. Third edition. Oxford. Blackwell Scientific Publications, Oxford, London, Edinburgh. p.359.
Kershaw AK, Looney HHJ (1985). Quantitative and Dynamic Plant Ecology 3rd ed. Edward Arnold (Publishers) Limited, London, p. 282.
Lovett JC (1990). Altitudinal variations in large tree associations on the west Usambara mountains. I. Hedberg, and E. Persson (eds.) Research for conservation of the Tanzania catchment forests. Proceedings from a workshop held in Morogoro, Tanzania March 13-17, 1989. Upsala University, Sweden, pp. 48-53.
McCune B, Mefford MJ (1999). PC-ORD. Multivariate Analysis of Ecological Data, Version 4. MjM Software Design, Gleneden Beach, Oregon, p. 237.
Munishi PKT (2001). The Eastern Arc Mountain Forests of Tanzania: Their role in biodiversity, water resource conservation, and net contribution to atmospheric carbon. PhD Dissertation. North Carolina State University, USA, p. 128.
Munishi PKT, Shear TH, Wentworth T, Temu RPC (2007). Compositional Gradients in Plant Communities in Submontane Rain Forests of Eastern Tanzania. J. Trop. For. Sci., 19 (1): 35-45.
Orloci L (1967). An agglomerative method for classification of plant communities. J. Ecol., 55: 193-205.
Rodgers WA (1996). The Miombo woodlands. In: East African Ecosystems and Their Conservation. McLanahan, T.R. and Young, T. P. (eds.), Oxford University Press, Oxford, pp. 299-326.
Timberlake JR (2000). Biodiversity of the Zambezi Basin Wetlands. Consultancy Report for IUCN ROSA. Biodiversity Foundation for Africa, Bulawayo/Zambezi Society Harare, Zimbabwe.
White F (1983). The Vegetation of Africa. Natural Resources Research No 20 UNESCO, Paris, p. 356.
WWF (2001). The Miombo Ecoregion. WWF, Southern Africa Regional Programme Office Harare Zimbabwe, p. 22.