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Woody vegetation structure and composition in Mapembe Nature Reserve, eastern Zimbabwe

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ABSTRACT: We assessed woody vegetation composition and structure in Mapembe Nature Reserve, eastern Zimbabwe. Woody vegetation was sampled during the period May-June in 2012. Using a stratified random sampling design, we delineated the study area into three strata; plains, mountain and wetland areas. We recorded a total of 1 443 woody plants representing 17 woody species assessed from 30 sample plots. Our results from Kruskal Wallis-*H* test showed significance differences in plant height, canopy volume, and tree density across the study strata ($P < 0.05$). In contrast, no significant differences were observed in basal area, shrub canopy volume, shrub density and woody species diversity. Our study results highlighted woody vegetation degradation on wetlands and mountains of Mapembe Nature Reserve, which was attributed to anthropogenic factors. The study recommends in-depth woodland inventory, collaborative arrangements with the local surrounding human communities and improved law enforcement strategies. ©JASEM

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The study was carried out in an area characterized by the miombo ecosystem. Miombo is a colloquial term used to describe the central, southern and eastern African woodlands dominated by *Brachystegia* and *Jubernardia* species (White, 1983). The woodlands generally occur on geologically old nutrient poor soils in uni-modal rainfall zones receiving an average of 1 200 mm (Millington *et al*., 1994). Naturally, the shrub layer of such an ecosystem is variable in density and composition (Frost, 1996). The ground cover varies from a dense course grass growth to a sparse cover of herbs and small grasses (Campbell, 1996). The woodland supports the C_4 grass species. Apart from accommodating a rich biodiversity, miombo woodlands support several people with tangible and intangible goods and services such as cultural/spiritual values and climate regulation but are strongly influenced by anthropogenic activities like pressure for grazing land, uncontrolled fires that occur regularly in miombo ecosystems originating from people making charcoal, preparing land for cultivation, deforestation and herbivory (Campbell, 1996; Casey and Mathew, 2011). Small protected areas bounded by different landuse practices are often vulnerable to anthropogenic activities as they exhibit pronounced edge effects.

Vegetation changes due to such anthropogenic activities remain one of the principal challenges the world is grappling with today. The impacts are usually destructive, often resulting in permanent vegetation structure and composition alterations, but may also be facilitative where, for instance, heat from fire triggers germination especially to woody miombo tree species with protective meristems and under-ground reproductive organs and seeds (Everhan and Brokan, 1996; Trollope *et al*., 2002). However, these alterations vary spatially and temporally and at times with unpredictable outcomes. As these factors alter the vegetation structure and composition, game species diversity will also be affected. Woody vegetation structure and composition have significant roles in structuring faunal community as it provides resources for nesting, foraging and protection of a variety of animal taxa (Adler, 2000; Clegg and O'Connor, 2012).

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Currently, there is a paucity of information on the structure and composition of vegetation in Mapembe Nature Reserve, despite its recognition as a biodiversity hotspot. Against this background, assessing the vegetation structure and composition of Mapembe Nature Reserve could guide current management on its woodland management strategies, as well as inform the game animal reintroduction program intended to restock Mapembe Nature Reserve. Habitat assessment prior to animal species reintroduction is a pre-requisite expected of proposed wildlife habitats (IUCN, 2012). Therefore the study sought to answer the following questions: 1) what is the diversity of woody plant species in Mapembe Nature Reserve? 2) What is the woody vegetation composition and structure in Mapembe Nature Reserve?

MATERIALS AND METHODS

Study Area: Mapembe Nature Reserve, also known as Mapembe Mountain Conservation Project, protects the ecosystem of Mapembe Mountain whose coordinates are 19°4'60" N and 32°22'0" E. The Mapembe Nature Reserve, a state protected area managed by the Zimbabwe Environmental Management Agency, located in an area also known as Mapembe in eastern Zimbabwe, is about 15 km from Odzi Township turn-off at Riverside along Mutare-Harare highway road and about 45 km from Mutare city in Manicaland Province of Zimbabwe. The total protected area of the reserve is 850 hectares and is bordered by communal lands. The Mapembe Nature Reserve lies in agro-ecological zone with annual rainfall ranging from 650 to 800 mm (Moyo *et al*., 1993). The reserve is typically dry miombo woodland dominated by *Brachystegia spiciformis* and *Julbernardia globiflora* species (Timberlake and Chidumayo, 2011). The main socio-economic activities of the people living around the study area include crop production and livestock rearing. Tobacco is the cash crop that is given high priority in the area and small scale farmers within the fringes of the Mapembe Nature Reserve depend on indigenous trees as fuel for tobacco curing.

Sampling design and data collection: We marked a total of 30 sample plots each measuring 20 × 30 m, within the study area, basing on the stratified random sampling technique (Mueller-Dombois and Ellenburg, 1974). This sample plot size is considered suitable for savanna vegetation studies (Walker, 1976). We delineated Mapembe Nature Reserve into three strata, namely; plains with 11 sample plots, wetland with 7 plots and mountain area with 12 sample plots. The sample plots within a particular study stratum were randomly selected using the grid intercepts on topographical maps. We distributed sample plots in each study stratum according to the percentage a particular study stratum makes to the total area of Mapembe Nature Reserve. Following Balinga *et al*. (2006), the sample plots were spatially distributed so as to have a comparative analysis of results of the whole coverage of the Nature Reserve. Data were collected between May and June in 2012. Woody species identification followed the guide of Coates-Palgrave (1997). Woody vegetation comprised trees and shrubs. In addition, the following variables were assessed in each sample plot following methods outlined by Gandiwa and Kativu (2009): tree height (tree ≥ 3 m), shrub height (shrub < 3 m), basal area, canopy diameter, canopy height, number of shrubs, number of trees and woody species name.

Data analysis: Descriptive statistics were calculated for all the woody vegetation variables. STATISTICA version 6 for Windows (StatSoft, 2001) was used for data analysis. As the woody vegetation data were not normal, a non-parametric test, the Kruskal-Wallis H ANOVA test (KWH test), was used to test for differences across the three study strata. *Post-hoc* analyses using the Mann-Whitney U test (MWU test) were carried out where significant differences across strata had been recorded. Furthermore, we performed a Principal Component Analysis (PCA) to show the pattern and structure of woody vegetation data.

RESULTS AND DISCUSSION

A total of 1 443 individual woody plants representing 17 woody species were recorded from the 30 sample plots. Significant differences were recorded on tree height, tree canopy volume, tree density and woody species evenness across the study strata, KWH test ($P < 0.05$) (Table 1). A MWU test for tree height, tree canopy volume and tree density between the Plains and Mountains showed a significant diffence ($P < 0.05$), with the plains being significantly higher than the mountains statum. Whereas, there were no significant differences in shrub height, basal area, shrub canopy volume, shrub density, woody species diversity and species richness across the study strata KWH test ($P > 0.05$).

Table 1: Summary of statistical analyses from Kruskal-Wallis *H* test results of the study variables in the plains, mountains and wetlands of Mapembe Nature Reserve, Zimbabwe. *Notes*: Values in bold indicate significant differences and those in brackets indicate the range.

	Median (Range)			
Variables	Plains	Wetland	Mountain	*P*-value
Tree height (m)	6.52 (2.95)	6.51(1.56)	5.79 (2.92)	**0.0043**
Shrub height (m)	1.99 (2.45)	2.20 (2.46)	2.13 (2.60)	0.3756
Basal area (m²/ha)	0.21 (0.35)	0.19 (0.13)	0.14 (0.19)	0.109
Tree canopy volume(m^3)	153 (241.14)	125.50 (104.03)	66.40 (122.78)	**0.0008**
Shrub canopy volume (m^3)	1.70 (4.32)	1.63 (3.70)	0.64 (2.68)	1.1747
Tree density/ha	1033.33 (916.67)	300 (483.33)	550 (466.67)	**0.0001**
Shrub density/ha	116.67 (466.67)	66.67 (100)	58.33 (200)	0.1019
Diversity (H')	1.91 (1.06)	1.46 (0.80)	1.81 (0.74)	0.118
Species richness	2.1 (1.41)	1.57 (1.42)	2.12 (1.33)	0.0653

A total of 17 species were recorded in plains, 15 in wetlands and 12 in mountain stratum. The most dominant species in mountain stratum were *Brachystegia spiciformis* and *Julbernardia globiflora*, and the same scenario existed in wetlands. In plains the dominant species included *B. spiciformis, J. globiflora, P. curatolifolia* and *B. africana.*

PCA results are shown in Figure 1 with Factor 1 explaining about 34% (eigenvalue = 2.8), whereas Factor 2 explains about 29% (eigenvalue = 2.3) in woody vegetation structure and composition in sample plots across the three strata in Mapembe Nature Reserve. Factor 1 gradient is negatively correlated to low basal area and tree height and positively correlated to high species diversity and tree density. It defines a gradient of low basal area, tree height and tree canopy volume to high tree density and diversity. Factor 2 is negatively correlated to high shrub canopy volume and positively correlated to high tree canopy volume, basal area and high species diversity. It defines a gradient of low species diversity to high species diversity.

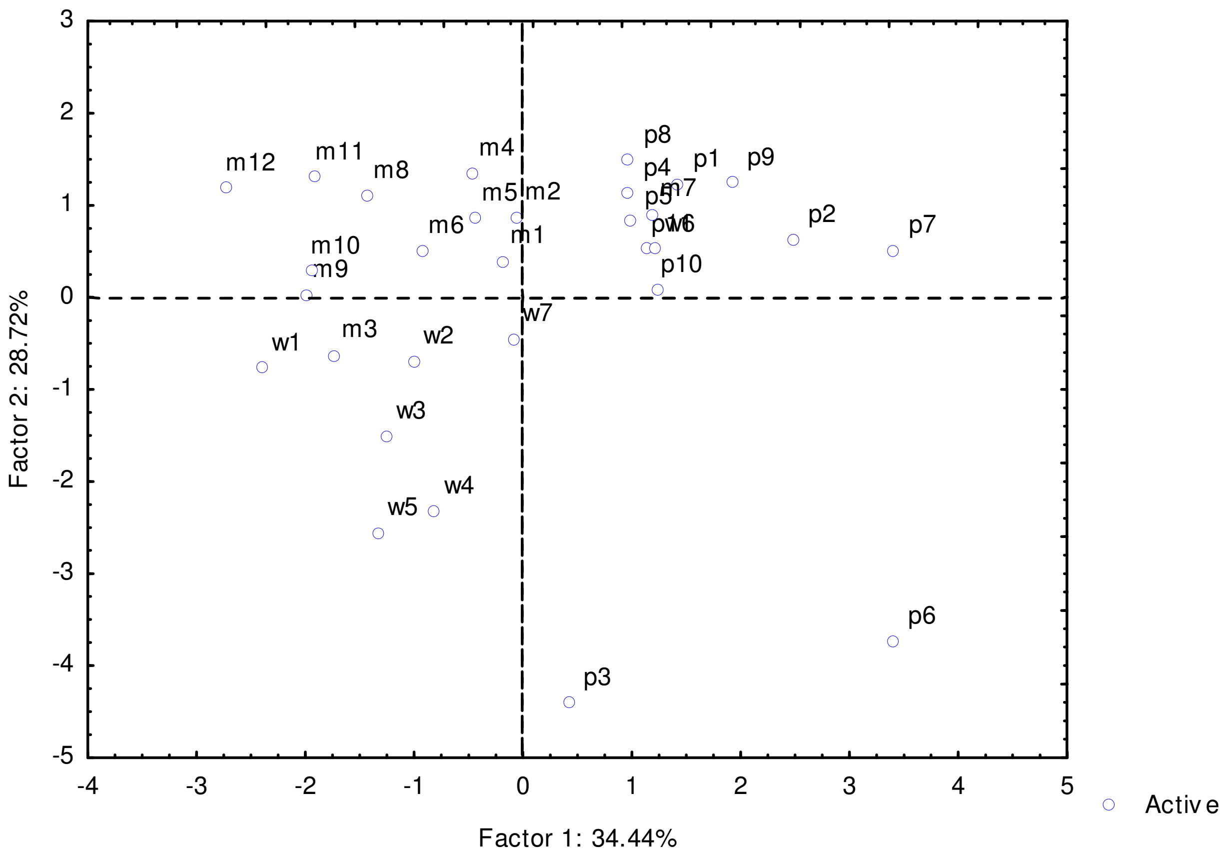

Fig: 1. PCA bi-plot of 30 sample plots in Mapembe Nature Reserve, Zimbabwe: Notes: p = Plains, w = Wetlands, m = Mountains

The woody vegetation community in Mapembe Nature Reserve showed domination by *B. spiciformis* and *J. globiflora*. The dominant woody plant family is *Fabaceae* sub-family *Caesalpinoideae* of the prototype Miombo woodland (Timberlake and Chidumayo, 2011), specifically resembling the Miombo woodlands of southern Africa savanna (Grundy, 1995). Related woodlands in southern Africa include those with *B. spiciformis*, *B. boehmii* and *J. globiflora* in Zambia (Chidumayo, 1997), and those dominated by *B. spiciformis* and *P. angolensis* in Tanzania (Fors, 2002; Dondeyne *et al*., 2004). Important similarities our study observed in broad categories included, canopy volume, a relatively high tree density and large plant basal area per unit area. The species richness (17) of woody species in this area contrast sharply with miombo forests occurring elsewhere. Giliba *et al* (2011) recorded 110 species in Bereku Forest Reserve while Mafupa (2006) recorded 46 species in Igombe Forest Reserve, all in Tanzania. Gandiwa *et al* (2013) enumerated 59 species and 43 species in Save-Runde and Manjinji Pan Important Bird Areas respectively in southern Zimbabwe. Low woody species richness may be as a result of heavy illegal anthropogenic activities targeting specific species leading to local species extinction. Tree density compared well with an average of 341trees h^{-1} and an average of 342 trees h^{-1} in Mapembe Nature Reserve and the two important bird areas (Save-Runde and Manjinji Pan) respectively. PCA explains that mountain and wetlands strata are heavily affected by high human activities like deforestation, hence, the significant shrub canopy volume observed as opposed to the plains which had high tree densities. Selective hardwood timber harvesting likely as source of fuel for tobacco curing and other anthropogenic disturbances may have amplified the dominance of *B. spiciformis* and *J. globiflora* over all of the other woody species. Elsewhere, according to the findings of Hogberg and Nylund (1981) the occurrence of the fungi, ectomycorrhizae in the roots of these dominant woody species in the Miombo woodlands, may facilitate a woody species' exploitation of the infertile soils more effectively than those without the fungi. What factors favour the dominance of *B. spiciformis* and *J. globiflora* in Mapembe Nature Reserve remains a research question largely unanswered by our current study.

We observed from the field that the mountains and wetlands sites represented recovering woodland that had been disturbed to an earlier succession stage, or which is on a trajectory towards a different woodland sere. However, by way of management, it may be desirable to facilitate the recovery of *Baikiaea plurijuga, Vitex payos, Piliostigma thonningii* and *Flacourtia indica* within the disturbed wetlands and mountains sites. The long-term timber harvesting by humans from the mountains and wetlands sites could thus be attributed to the random woody species dispersion found there. In addition, timber harvesting of selected woody species could decrease their abundance, and this in turn would lead to declines in their Important Value Index.

Our study found significant differences in the composition and structure of the wetland, plains and mountain sites within Mapembe Nature Reserve. Tree height was greatest in the plains and lowest in the mountains, whereas, tree density was greatest in the plains and lowest in the wetlands.

Other social and ecological factors not investigated by our current study could have influenced the woody vegetation composition and structure in Mapembe Nature Reserve. The Miombo eco-region can be considered as a socio-ecological system in which humans play a significant role in shaping woody vegetation structure and composition. Since the soils are of low nutrient level, crop production has historically been based on various forms of shifting cultivation, involving fallowing that allows woodlands to regenerate (Zolho, 2005). This form of land use has shaped the present day landscape cover over large parts of southern Africa savanna. Man can also affect the structure indirectly through their ability to manipulate fire and to influence herbivore numbers and distribution (Adler *et al*., 2001). The structural and compositional differences across Mapembe Nature Reserve suggest woodland disturbances which can have a long term effect in influencing woodland degradation, although there are other factors such as topography, edaphic and moisture variations which we did not investigate.

Significant difference ($P<0.05$) in tree height, tree canopy volume and tree density across the study area highlighted variances in intensity of factors influencing the observed woody vegetation structural variability. Woody vegetation structural changes have consequences for management because of their effects on forage quantity, composition and nutrient dynamics. Therefore, long-term monitoring in woodland composition and structure is necessary in order to determine possible changes over time and institute appropriate management practices to conserve habitat biodiversity. This study revealed that woody vegetation structure in Mapembe Nature Reserve was significantly different, but composition was relatively uniform as there were no significant differences in woody species diversity across the three strata. We recommend for further studies to ascertain other factors influencing status of woody vegetation structure in Mapembe Nature Reserve.

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