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VEGETATION DYNAMICS PRIOR TO WILDLIFE REINTRODUCTIONS IN SOUTHERN UMFURUDZI PARK, ZIMBABWE

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ABSTRACT

Vegetation assessments are critical in the status and success of reintroduction programs and are an important aspect in ecological restoration. Vegetation structure and composition influences the suitability and availability of unique habitats for different wildlife species. The objectives of this study were to (1) establish the vegetation structure and composition, and (2) determine the soil-vegetation associations in southern Umfurudzi Park, Zimbabwe, prior to the reintroduction of wildlife species. Using a stratified random design, 15 rectangular plots from three strata were assessed in April and May 2012. A total of 23 woody plants from 58 tree and 68 shrub families as well as 30 grass species were recorded. Tree basal area, canopy cover, tree density, tree and grass species diversity, and tree height for the riverine strata were significantly different from the miombo and vlei strata. The influence of soil properties on the occurrence and diversity of woody and grass species was evident across the three strata. Long-term changes in the vegetation dynamics and primary productivity in southern Umfurudzi Park due to the reintroduced mega-herbivores is recommended for the success of the restoration program.

Key words: restoration ecology, miombo ecosystem, herbivores, species diversity, vegetation structure.

INTRODUCTION

Vegetation surveys are an important aspect of the vegetation science research agenda and helps ecologists to understand complex ecological systems, which is essential for both basic ecological research and applications in biodiversity conservation and environmental protection (Chytrý *et al.* 2011). Periodic vegetation assessments and monitoring in strategic areas such as protected areas are thus critical for predicting changes in status of ecosystems (Munishi *et al.* 2011; Muboko *et al.* 2013; Hansen and Gibson 2014). More importantly, in ecological restoration programs, vegetation surveys are critical in the status and success of reintroduction programs since they would determine the suitability and availability of suitable habitats for different wildlife species (Cheyne 2006; Poulin *et al.* 2012). Clegg and O'Connor (2012) affirm that vegetation structure and composition plays a significant role in structuring the faunal community by providing resources for nesting, foraging and protection of a variety of avian and mammal species. However, the response of plant communities to mammalian herbivores vary widely due to variation in plant composition, herbivore density, forage preferences, soils and climate among other factors (Ryerson and Parmenter 2001; Tessema *et al.* 2011).

Miombo woodlands are characterised by the co-dominance of C_4 grass species that grow alongside *Cyprus* species and trees species of the genera *Brachystegia*, *Julbernadia* and *Isorberia* (Campbell 1996; Banda *et al.* 2006). In this respect, the miombo ecosystem is a globally important carbon store, support humans and wildlife species and thus serves as a critical ecosystem. However, general observations are that miombo ecosystem habitats have low productivity and a resultant low carrying capacity thus reducing the sustainability of wildlife multispecies production (Rodgers 1996). Although the miombo eco-region has distinct seasons and stochastic droughts and well-drained poor nutrient soils, the presence of numerous large termites moulds play a significant role in increasing the species diversity and woodland ecology (Timberlake and Chidumayo 2002; Joseph *et al.* 2013; Seymour *et al.* 2014).

To effectively manage miombo ecosystems, valuable long-term conservation planning and priority setting for resource management is prerequisite (Munishi *et al.* 2011; Muboko *et al.* 2013). More importantly, the diversity and variability of the miombo ecosystem necessitates the need for site-based management approaches (Campbell 1996), as these ecosystem may be exposed to different anthropogenic disturbances (Casey and Mathew 2011) and environmental stressors (Eni *et al.* 2011; Tessema *et al.* 2011; Iwara *et al.* 2011). Similarly, Campbell (1996) argue that the structure and species composition can be considerably heterogeneous owing to the spatial variation in soil and impacts of fire, herbivory, land use and other disturbances or stressors. The existence of different environmental gradients with topographical and edaphic factors would thus determine the plant species associations and community composition in any ecosystem (Munishi *et al.* 2011).

Nonetheless, there has been no study on the vegetation of Umfurudzi Park, Zimbabwe, thus making it difficult to have long term plans without a base line or reference on the vegetation in this area prior to reintroduction of wildlife. This study seek to provide a basic ecological insight on the vegetation of southern Umfurudzi Park, particularly the wildlife reintroduction release enclosure which has been set as part of a restoration program for this important conservation area located in the north-eastern Zimbabwe. Specifically the objectives of this study were to: (1) establish the vegetation structure and composition of southern Umfurudzi Park, and (2) establish the soil-vegetation associations in southern Umfurudzi Park prior to the reintroduction of wildlife species.

MATERIALS AND METHODS

The study was conducted in Umfurudzi Park, north-eastern Zimbabwe. The Park has a spatial extent of 760 km² and lies between 17º 15´ and 16º 50´ south, and 31º 40´ and 32º 00´ north with varying altitude from 740 to 1020 m. The population decline and ultimate local extinction of several species in Umfurudzi Park in the late 1980s led to the temporary suspension of hunting activities to-date. Through a public private partnership initiative, in 2010, an agreement was made between the Zimbabwe Parks and Wildlife Management Authority and a private partner, Pioneer Travel and Tours, to reintroduce the locally extinct species into Umfurudzi Park. This initiative resulted in several species being reintroduced into the area in 2011. Among the large mammals that used to thrive in the area were *Loxodonta africana* (African elephant), *Diceros bicornis* (black rhino) and *Syncerus caffer* (African buffalo), which were all locally extinct. Through the rehabilitation program, several wildlife species were reintroduced (e.g., buffalo, zebra (Equus quagga), eland (*Taurotragus oryx*), wildebeest (*Connochaetes taurinus*), and elephant except black) as part of a long-term ecological restoration program of Umfurudzi Park. The vegetation survey was done in southern Umfurudzi Park (Figure 1). The area is located in a miombo ecoregion; an area characterised by the miombo ecosystem dominated by *Brachystegia boehmii*, *Julbernardia globiflora* and *Terminalia* species.

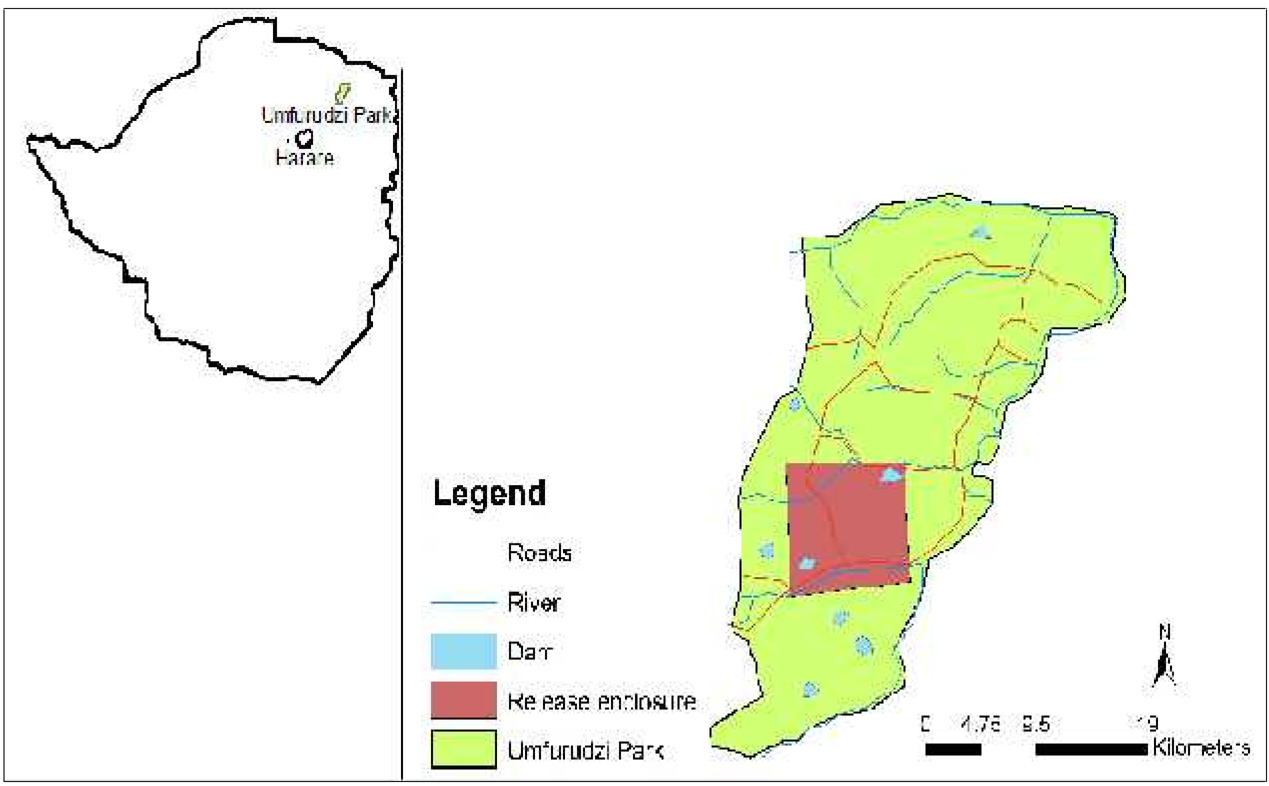

Figure 1: Location of the study area in Umfurudzi Park, Zimbabwe.

Sampling design: A stratified random sampling design was used in this study (Zisadza-Gandiwa *et al.* 2013a). Stratification and location of permanent study plots was based on the habitat types (i.e., Miombo, Riverine and Vlei). The number of plots in each stratum was dependent on the spatial extent of each habitat patch within the release enclosure. Plots were randomly selected using random number tables based on Umfurudzi Park topographical map grid square intercept system. Placement of study plots near roads, rocky outcrops and boundaries between habitats was avoided. A total of fifteen permanent study plots (i.e., Miombo – 10 sample plots; Riverine – 3 sample plots; Vlei – 2 sample plots) were established in the release area.

Data collection

Vegetation sampling: Floristic composition and structure of woody and grass components were assessed at the end of the rain season between March and May 2011. Species composition is most conspicuous at this time of the year (Gandiwa *et al.* 2012). The size if the plots were determined following the methods by Walker (1976) of having at least 15–20 trees inside a plot. Accordingly, plots measuring 20 × 30 m (0.06 ha) were used in this study. Only data on woody vegetation (trees and shrubs) and grasses were collected in this study. A tree was defined as a plant that was ≥ 3 m with one or few dominant trunks with a basal diameter ≥ 6 cm. Whereas a shrub was defined as a plant that was < 3.0 m with one or a few dominant trunks or having a basal diameter of < 6.0 cm (Gandiwa and Kativu 2009). Plants occurring along plot margins were included if at least half of the canopy was inside the plot (Walker 1976). The plots were assessed once during the study period. In each sample plot, the following variables were measured: tree and shrub height, stem circumference, woody vegetation species, short and long canopy diameter for trees and shrubs. The sampling procedures for woody vegetation as described by Gandiwa and Kativu (2009) were used. The line intercept method (Canfield 1941) and quadrate sampling using 1m² quadrates (Wiegert 1962) were used to sample grass species data. Vegetation species identification was done with the aid of field guides by Coates Palgrave (2002) and Van Wyk and Van Wyk (1997) with assistance from an experienced field technician.

Soil sampling: Soil samples were collected concurrently with the vegetation assessments. In each sample plot, four soil samples at a depth of 0–20 cm were collected. The soil samples at each sampling plot were further pooled to form one composite soil sample per sampling plot. Plant material and pebbles were removed from the samples and later stored in plastic bags, labeled, sealed and transported to Research and Specialist Services Laboratory in Harare, Zimbabwe for physical and chemical analysis. The soil texture and pH of the samples were determined using the bouyoucus hydrometer method (Bouyoucos 1962). The sodium saturation ratio of Reeuwijk (1992) was used to determine electrical conductivity (EC), whereas cation exchangeable capacity (CEC) was analyzed following the methods of NRC (1996). The methods of Walkley and Black (1934) and Jackson (1970) were adopted for determining the percentage organic carbon (OC), and total nitrogen using the Kjeldahl procedure respectively. Available phosphorus (P), exchangeable potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) were analyzed after the methods outlined by Olsen *et al.* (1954).

Data analysis: Woody vegetation basal circumference values were used to calculate the basal area for each woody stem using the following formula:
$\text{Basal area} = (C^2/4\pi)$, where C is the stem circumference.
Shrub and tree density for each plot were calculated using the following formula of Gandiwa and Kativu (2009):
$Density\ (y/ha) = [(x \times 10\,000\ m^2)/\ (plot\ area\ m^2\ )]$,
where y denotes any of the trees or shrubs and x is the recorded number of trees and shrubs.

Relative density (%), relative dominance and important value index of each species were computed following the formulae as outlined by Brashears *et al.* (2004):
$RD\ (\%) = (n_i/N) \times 100$, where, RD is the relative density of the species; n_i is the number of individuals of species i and N is the total number of all individual trees.
$RDo\ (\%) = (\sum Ba_i \times 100)\ /\ (\sum Ba_n)$, where, RDo is the relative dominance of the species; Ba_i is the basal area of all individual trees belonging to a particular species *i*; Ba_n is the basal area of the stand.
$IVI = (RD \times RDo)/2$, where, RD is the relative density and RDo is the relative dominance.

The Shannon-Weiner (*H'*) diversity index was used to calculate the woody vegetation a grass species diversity values of each sample plot, using the following formulae (Ludwig and Reynolds 1988):
$H' = -\Sigma\,(p_i \times \ln(p_i))$, where *pi* is the fraction of the entire population made up of species *i*, and ln is the natural logarithm.

Statistical analyses were conducted using Statistical Package for Social Sciences (SPSS) version 20 for Windows (SPSS Inc, Chicago, USA). Vegetation and soil attributes data were tested for normality and homogeneity of variance using Kolmogorov-Smirnov test and Levene's test for homogeneity of variance respectively. Data were found to be conforming to the normality assumptions. To test for differences in the measured vegetation and soil variables across the habitat categories, a one-way analysis of variance (ANOVA) with the habitat strata being categorical predictor and vegetation and soil variables as dependent variables was computed. For variables with significant differences ($p < 0.05$), Fisher's least significant difference (LSD) *post-hoc* tests were used to determine differences between the three habitat strata. We further used two ordination approaches, (1) an indirect ordination approach, principal component analysis (PCA), to explore the main components of variation in the vegetation attributes in relation to each habitat strata, and (2) a direct gradient analysis, Canonical Correspondence Analysis (CCA) to establish the association between the grass and tree species with the selected soil attributes across the three habitat strata using CANOCO Version 5.0 software for windows (ter Braak and Smilauer 2002).

RESULTS

Vegetation species composition and structure: A total of 23 woody plants from 58 tree and 68 shrub families as well as 30 grass species were sampled in the Umfurudzi Park reintroduction release area. The most dominant and least important woody species recorded in the reintroduction release based on the IVI were *Brachystegia boehmii*, *Julbernadia globiflora* and *Grewia monticola*, *Strychnos spinosa* respectively (Table 1). Most of the species sampled were from the family *Fabaceae caesalpinioideae* whilst a few species were recorded from the family Combretaceae and only one species *Combretum zeyheri* was among the 10 dominant trees species.

Table 1: The relative density, dominance, frequency and important value index (IVI) of the ten most dominant and ten least important woody species recorded in the reintroduction release area of Umfurudzi Park, Zimbabwe.

Species	Relative Density	Relative Dominance	Relative Frequency	I.V.I
Most important woody species				
Brachystegia boehmii	38.24	24.46	7.77	70.48
Julbernardia globiflora	16.44	10.66	6.11	33.21
Diplorhynchus condylocarpon	4.31	5.08	5.00	16.97
Terminalia stenostachya	5.27	5.00	6.11	15.35
Diospyros kirkii	3.53	4.53	6.66	14.74
Pseudolachnostylis maprouneifolia	4.89	3.74	5.00	13.64
Combretum zeyheri	3.84	3.20	4.44	11.51
Lannea discolor	2.91	3.20	5.00	11.12
Bauhinia petersiana	3.07	4.01	3.88	10.97
Colophospermum mopane	7.14	1.60	1.11	9.86
Least important woody species				
Flueggia virosa	0.02	0.26	0.55	0.84
Monotes engleri	0.13	0.13	0.55	0.83
Pterocarpus angolensis	0.08	0.13	0.55	0.77
Bauhinia thonningii	0.05	0.13	0.55	0.74
Diospyros lycoides	0.03	0.13	0.55	0.72
Commiphora mossambescensis	0.01	0.13	0.55	0.70
Ozoroa reticulate	0.009	0.13	0.55	0.70
Peltophorum Africana	0.009	0.13	0.55	0.70
Strychnos spinosa	0.009	0.13	0.55	0.69
Grewia monticola	0.009	0.13	0.55	0.68

Most of the vegetation attributes, i.e., basal area, canopy cover, tree density, tree species diversity, grass species diversity and tree height were significantly different (one way ANOVA, $p < 0.05$) across habitat strata. In contrast, shrub density was not significantly different across the three habitat strata (one-way ANOVA, $F_{2, 12} = 1.175$, $p = 0.342$). Fisher's LSD post-hoc tests showed no significant differences ($p < 0.05$) between miombo and vlei strata for the following attributes: basal area, canopy cover, tree density, grass species diversity and tree height (see Table 2). However, the riverine strata showed significant differences in the former vegetation attributes with that of the miombo and vlei strata. Generally, the riverine strata had high values of all the attributes than the miombo and vlei except for the grass species diversity.

There were significant differences (One-way ANOVA, $p < 0.05$) in all the soil physical and chemical parameters across the three strata. Fisher's LSD post hoc tests for the soil parameters for the three strata are shown in Table 3.

Table 2: Vegetation attributes (mean ± standard error) for the three habitat strata in Umfurudzi Park, Zimbabwe.

Vegetation attribute	Habitat strata			P-value
	Miombo	**Riverine**	**Vlei**	
Basal area (m^2/ha)	4.39 ± 0.53^a	8.04 ± 1.07^b	3.40 ± 0.28^a	**0.011**
Canopy cover (m^2/ha)	179.53 ± 17.34^a	327.17 ± 53.15^b	142.55 ± 4.15^a	**0.006**
Tree density (no. of trees/ha)	799.70 ± 95.34^a	1305.33 ± 187.70^b	375.00 ± 92.00^a	**0.014**
Shrub density (no. of shrubs/ha)	476.70 ± 40.61^a	795.67 ± 48.15^a	383.00 ± 50.00^a	0.342
Tree species diversity (*H′*)	1.84 ± 0.07^a	2.23 ± 0.29^a	1.25 ± 0.15^b	**0.010**
Grass species diversity (*H′*)	1.75 ± 0.19^a	0.50 ± 0.06^b	1.80 ± 0.30^a	**0.011**
Tree height (m)	6.15 ± 0.26^a	13.13 ± 1.48^b	4.20 ± 0.30^a	**0.000**

Significant levels are from one-way ANOVA tests. Different letter superscripts within rows for each variable denote significant differences (Fisher's LSD, $p < 0.05$). Significant values are indicated in bold.

Table 3: Physical and chemical soil parameters (mean ± standard error) for the three habitat strata in southern Umfurudzi Park, Zimbabwe. Significant levels are from one-way ANOVA tests. Different letter superscripts within rows for each variable denote significant differences (Fisher's LSD, p < 0.05). Significant values are indicated in bold.

Soil parameter	Habitat strata			$F_{2,12}$	P-value
	Miombo	**Riverine**	**Vlei**		
pH	6.70 ± 0.09^a	6.12 ± 0.01^b	6.93 ± 0.02^c	175.73	< 0.001
EC (mmhos/Cm)	0.17 ± 0.00^a	0.12 ± 0.01^b	0.15 ± 0.02^a	13.72	0.001
CEC (Meq/100g Soil)	13.22 ± 0.01^a	24.31 ± 0.02^b	18.12 ± 0.02^c	94859.11	< 0.001
Total nitrogen (%)	1.56 ± 0.02^a	2.48 ± 0.02^b	1.33 ± 0.01^c	410.03	< 0.001
P (mg/kg Soil)	2.58 ± 0.02^a	12.21 ± 0.02^b	7.29 ± 0.02^c	31027.24	< 0.001
Ca (Cmol(+)/Kg Soil)	31.55 ± 0.02^a	26.20 ± 0.02^b	28.13 ± 0.02^c	10311.68	< 0.001
Mg(Cmol(+)/Kg Soil)	26.53 ± 0.02^a	39.11 ± 0.01^b	31.21 ± 0.01^c	73700.81	< 0.001
K (Cmol(+)/Kg Soil)	2.19 ± 0.01^a	3.52 ± 0.02^b	2.20 ± 0.01^a	3493.01	< 0.001
Sand (%)	34.01 ± 0.02^a	43.48 ± 0.02^b	34.3 ± 0.49^a	2502.66	< 0.001
Silt (%)	32.10 ± 0.03^a	38.13 ± 0.01^b	32.57 ± 0.60^c	618.92	< 0.001
Clay (%)	21.47 ± 0.03^a	26.18 ± 0.02^b	32.12 ± 0.02^c	13956.16	< 0.001
Organic carbon (%)	1.82 ± 0.01^a	3.53 ± 0.03^b	1.74 ± 0.03^a	738.50	< 0.001

EC = electrical conductivity, CEC = cation exchange capacity, P = phosphorus, Ca = calcium, Mg = magnesium, k = potassium.

Vegetation composition and structure patterns: The PCA output of study vegetation variables shows principal component 1 accounting for 57.74 % (eigenvalue = 0.58) and principal component 2 accounting for 24.37 % (eigenvalue = 0.24) of the total explained variance. Principal component 1 defines a gradient from sample plots with higher grass species diversity to sample plots with high shrub and tree density. Principal component 2 defines a gradient from sample plots with greater tree height to sample plots with high grass species diversity and shrub density. There was a distinct separation of sample plots for the PCA ordination diagram for the two axes in relation to the three strata in southern Umfurudzi Park (Figure 2).

In the CCA for tree species in association with the selected soil attributes (Figure 3a), Axis 1 accounted for 41.69 % (eigenvalue = 0.56) whilst Axis 2 accounted for 24.06 % (eigenvalue = 0.32) of the explained cumulative fitted variation in the tree species across the three strata. Generally, the soil attributes accounted for 50.8 % of the observed variation of tree species across the three strata in southern Umfurudzi Park. Only EC explained a significant proportion of the variation in the tree species occurrence (12.3 %: Monte Carlo permutation test, pseudo-F = 2.0, $p = 0.024$), whereas the other five soil attributes were statistically insignificant. Similarly, EC was also the only soil attribute explaining a significant variation in the grass species occurrence (15.8 %: Monte Carlo permutation test, pseudo-F = 2.4, $p = 0.002$). The CCA for the grass species had Axis 1 accounting for 40. 58 % (eigenvalue = 0.48) and Axis 2 accounting for 17.72 % (eigenvalue = 0.21) of the explained cumulative fitted variation in grass species across the three strata (Figure 3b).

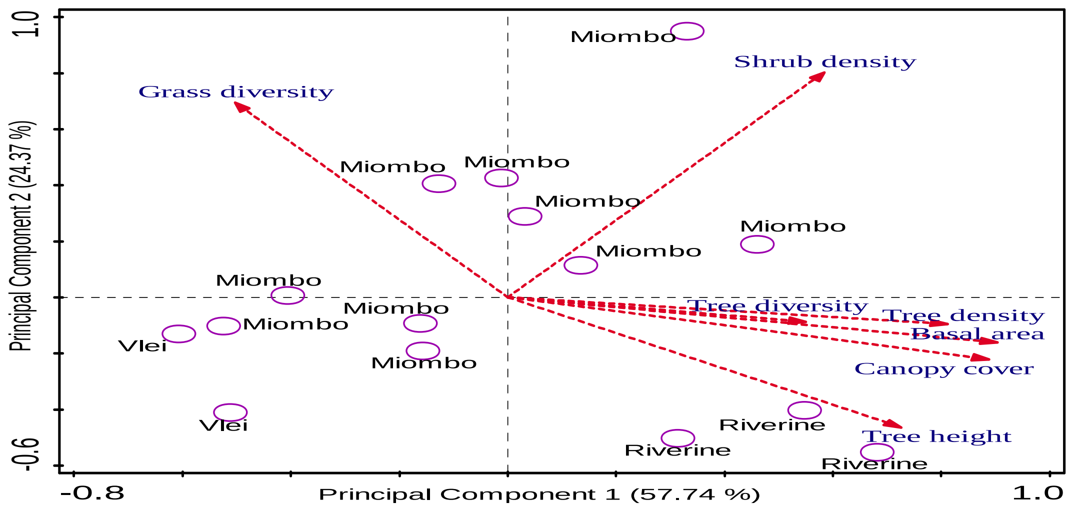

Figure 2: Principal component analysis (PCA) ordination diagram based on the woody and grass species attributes in southern Umfurudzi Park, Zimbabwe.

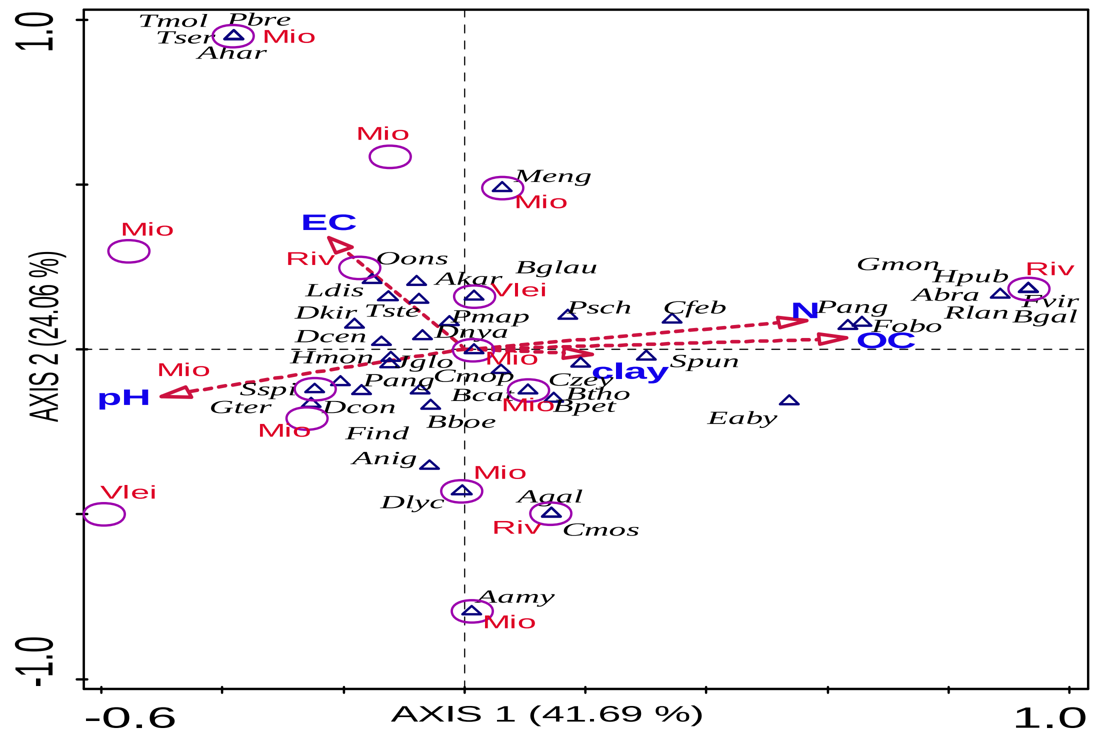

Figure 3a: Canonical correspondence analysis triplot woody species association with the selected soil attributes in southern Umfurudzi Park, Zimbabwe. Mio denotes sample plots in the Miombo habitat strata; Riv denotes sample plots in the Riverine habitat strata and Vlei denotes sample plots in the Vlei habitat strata. N = total nitrogen, OC = organic carbon, EC = electrical conductance. *Bboe*: *Brachystegia boehmii, Aamy: Acacia amythethophylla, Cmos: Commiphora mossambescensis, Gter: Gardenia ternifolia, Sspi: Strychnos spinosa, Dcon: Diplorynchus condylocarpon, Anig: Acacia nigrescens, Find: Flacourtia indica, Agal: Acacia galpini, Bpet: Bauhinia petersiana, Eaby: Erythrina abyssinica, Btho: Piliostigma thonningii,Bcat: Bridelia cathartica, Pang: Pterocarpus angolensis, Cmop: Colophospermum mopane, Jglo: Julbernardia globiflora, Hmon: Hexalobus monopetalus, Dcen: Dichrostachys cinerea, Dnya: Dalbegiella nyasae, Pmap: Pseudolachnostylis maprouneifolia, Dkir: Diospyros kirkii, Spun: Strychnos pungens, Fobo: Friesodielsia obovata, Bgal: Bauhinia galpinii, Rlan: Rhus lancea , Fvir: Flueggea virosa, Abra: Annona brachypetalus, Gmon: Grewia monticolar, Cfeb: Crossopteryx febrifuga, Psch: Pevata schumanniana, Tste: Terminalia stenostachya, bglau: Brachystegia glauscencens, Oons:Ozoroa onsignis , Ldis: Lannea discolor, Akar: Acacia karroo, Meng: Monotes engleri, Ahar: Albiza harveyi, Tser: Terminalia sericea, Tmol: Terminalia mollis, Pbre: Pterocarpus brenani.*

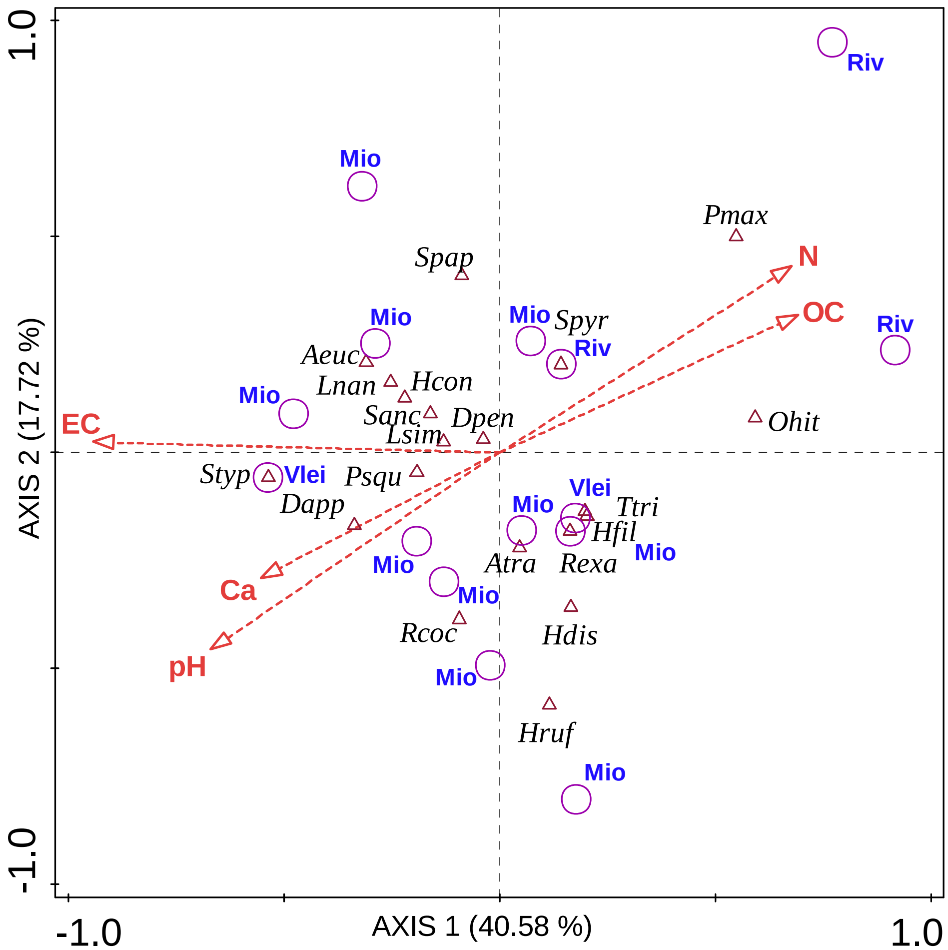

Figure 3b: Canonical correspondence analysis ordination diagram of 15 sample plots in southern Umfurudzi Park, Zimbabwe showing the grass species and soil attributes associations. Mio denotes sample plots in the Miombo habitat strata; Riv denotes sample plots in the Riverine habitat strata and Vlei denotes sample plots in the Vlei habitat strata. N= total nitrogen, OC= organic carbon, EC = electrical conductance and Ca = calcium. *Lnan*: *Lipocarpha nana, Hcon*: *Heteropogon contortus, Rcoc: Rottboellia cochinchinensis, Spap: S pappophoroides, Psqu: Pogonarthria squarrosa, Dapp: Diheteropogon amplectens, Hdis: Hyperthelia dissoluta, Hruf: Hyperrhenia rufa, Lsim: Loudetia simplex, Hfil: Hyperrhenia filipendula, Pmax: Panicum maximum, Spap: Schmidtia pappophoroides, Spyr: Sporobolus pyramidalis, Dpen: Digitaria pentizii, Sanc: Setaria anceps, Aeuc: Andropogon eucomus, Styp: Sacciolepis typhura, Rexa: Rotboelia exaltata, Atran: Aristida transvalensis, Ttri: Themeda triandra.*

DISCUSSION

Vegetation composition and structure: Our findings show that the southern section of Umfurudzi Park is a typical miombo ecosystem which is dominated by the *Fabaceace caesalpinioideae* family in accordance to observations by other researchers (Chidumayo 1987; Rodgers 1996; Burgess *et al.* 2004). Although our findings show the dominance of the Fabaceace taxa, which is a distinctive characteristic of the miombo biome (Campbell 1996; Ribeiro *et al.* 2013); we found several other species from other taxa such as *Combretum*, *Terminalia*, *Acacia* and *Grewia* which concurs with the arguments brought forward by Banda *et al.* (2006) in respect to Katavi-Rukwa ecosystem in western Tanzania. Similar observations were made in the Lake Rukwa basin, southern Tanzania, which is an indication of the diverse nature of miombo ecosystems and the associated high species diversity (Munishi *et al.* 2011). Although this is a first attempt to document the vegetation of Umfurudzi Park, we note that our findings are comparable to other similar ecosystems in the region (Munishi *et al.* 2007; Scogings *et al.* 2012). This diverse nature of the miombo biome thus makes it capable to sustain even the livelihoods of local people other than provision of habitats for wildlife species as in most cases with protected areas for biodiversity conservation purposes (Topp-Jorgensen *et al.* 2005; Sileshi *et al.* 2007).

The occurrence of several grass species such as *Heteropogon contortus, Diheteropogon amplectens, Panicum maximum, Digitaria, Setaria* and *Themeda triandra* within the open miombo and vlei system of southern Umfurudzi Park would provide much of the basic needed forage for the grazers since they are considered to be fairly palatable by most grazers (Bothma 2002; Venter and Watson 2008; Arsenault and Owen-Smith 2008; Arshadullah *et al.* 2009; Snyman *et al.* 2013). Although the miombo ecoregions are associated with low productivity (Rodgers 1996), the abundance and diversity of these grass species within elaborate and heterogeneous patches of vleis and open miombo and extensive termite moulds in the southern Umfurudzi Park would be able to sustain most grazers within this ecosystem as argued by Timberlake and Chidumayo (2002). The non significant levels of shrub diversity across the three strata could be a result of long-term absence of mega herbivores such as elephants as well as the frequency of uncontrolled wild fires due to lapse in management which characterised this area for almost a decade. This observation is congruent with the findings of in Sengwa, north-western Zimbabwe by Mapaure and Moe (2009) where they concluded that elephants and fire may contribute significantly to the changes in miombo woodlands. Similarly, such observations have been made in southern Gonarezhou National Park, southern Zimbabwe on *Colophospermum mopane, Combretum apiculatum* and *Acacia tortilis* woodlands (Gandiwa and Kativu 2009; Gandiwa *et al.* 2011; Zisadza-Gandiwa *et al.* 2013a).

We consider this study to form a reference point for future vegetation studies post reintroduction of mega herbivores such as buffalo, zebra, blue wildebeest and elephant into the southern section of Umfurudzi Park through the restoration programme that started in 2012. However, the riverine system had elevated levels of basal area, canopy cover, tree density and height compared to miombo and vlei systems. These observations concur with those of Zisadza-Gandiwa *et al.* (2013b) for Gonarezhou National Park although they were comparing three perennial river systems. The absence of herbivory within this ecosystem could also have contributed to these variations. However, we argue that bush encroachment on most of the vlei system in the southern Umfurudzi Park may reduce forage resources for the grazers and thus requires active management to ensure that the open miombo and vlei system is maintained in the area.

Low grass species diversity within the riparian strata could be related to the high tree density and canopy area of woody species that tend to induce shading and reduce herbaceous vegetation establishment. We found our findings related to those of Peterson and Reich (2008), where spatially variable shading from over storey trees reduced grass species diversity. Similar observations were also noted in Ukulinga Research Farm, Pietermaritzburg, South Africa where the influence of over story trees influenced the interaction between tree saplings and the surrounding grass sward as they both are affected by shading (Tedder *et al.* 2014). On the contrary, Riginos (2009) postulates that grass competition in productive (nutrient-rich) savannah may limit tree growth as much as herbivory and fire, and thus, should be incorporated into savannah models if tree-grass interactions and savannah dynamics are to be understood in the context of wildlife habitats. The absence of strong herbivory pressure and occurrence of repeated and frequent uncontrolled wild fires provided a complimenting effect in the shaping of vegetation in Umfurudzi Park and need to be interrogated further.

Soil vegetation associations: We found very little variation in the soil properties measured for the miombo and vlei strata whereas the riverine strata were significantly different from the other two strata. This could be attributed to the flood-pulses that create unique micro habitat patches through constant alluvial deposits during the rainy season as reviewed elsewhere (Furch 1997). The presence of a perennial Umfurudzi river with fluctuating hydrological regimes is a vital factor for determining both nutrient dynamics and plant production, but it is not straightforward to characterise due to the complex and variable nature of the flood pulse (Spink *et al.* 1998). More importantly, the high levels of organic carbon observed were of more than 3 % which was comparatively high for the riverine strata which complements well with the amount of organic matter since most of the tree species occurring therein were deciduous (Kumar *et al.* 2010). Our findings are similar to those of Joshi (2012) who recorded between 2.23 to 2.81 % organic carbon and considered it to be fairly high. The soil parameters did influence the occurrence of both the grass and tree species in the southern Umfurudzi Park as observed in our multivariate analysis.

The riverine strata had a cluster of species influenced mostly by a gradient of nitrogen, organic carbon and electrical conductivity. Our findings correspond well with the assertion of Munishi *et al.* (2007) who argue that different species respond uniquely to different environmental gradients with topographic and edaphic factors determining the plant species associations and community composition. The total variation explained by the soil parameters in multivariate tests were about 51% showing that there are other factors that may be influencing the vegetation structure and composition in the southern Umfurudzi Park. We, therefore, argue that although edaphic factors are known to determine the structure and composition of vegetation (Munishi *et al.* 2011), vegetation structure and composition may be influenced by novel factors such as fire, herbivory, frost, topography and past management practices that interact in a complex way in determining plant community architecture (Banda *et al.* 2006; Kutsch *et al.* 2008; Gandiwa *et al.* 2012).

Conclusions and recommendations: We conclude that: 1) there is high species woody species diversity and relatively low grass species diversity within the riparian habitats of southern Umfurudzi Park compared to the other open upland areas and vlei strata, 2) the open upland (miombo) and vlei strata have high grass species diversity and have the potential of supporting large mammalian herbivores being introduced in the area, and 3) soil physical and chemical properties within the southern Umfurudzi Park influenced the occurrence and abundance of both woody and herbaceous species across the three strata. Accordingly, the influence of fire and herbivory need to be further interrogated given that the restoration of the area through reintroduction of wildlife species, creation of watering points, prescribed burning among other active management initiatives may somehow change the vegetation structure and composition as well as nutrient patch dynamics in Umfurudzi Park. The southern section of Umfurudzi Park has heterogeneous habitats and relatively high grass and tree species diversity, thus would provide proper habitat and feed resources for a variety of reintroduced wildlife species. Active management towards bush encroachment of vlei systems and fire management need to be done to ensure that the primary productivity of the area is improved. We further recommend long-term vegetation monitoring and primary productivity of the southern Umfurudzi Park after the wildlife reintroduction program and the creation of watering points. This would be vital to ensure the maintenance of the ecosystem heterogeneity and integrity as well as the sustainability and success of the restoration program.

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