Vegetation Structure and Composition across Different Land Uses in a Semiarid Savanna of Southern Zimbabwe

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1. Introduction

Wildlife conservation in today’s world is increasingly confronted by the challenges of understanding the dynamics shaping vegetation cover and species diversity as wildlife habitat straddles across the land use divide [1, 2]. One of the assumptions which have not been adequately tested is the protection of wildlife habitat in areas of different land uses surrounding protected areas. The International Union for Conservation of Nature defines a protected area as “a clearly defined geographical space, recognized, dedicated and managed through legal or other effective means to achieve the long-term conservation of nature with associated ecosystem services and cultural values” [3]. Moreover, the world commission on protected areas recently estimated that there are over 100,000 protected areas ranging from areas that strictly limit human activity to those that allow for sustainable human use [4]. Despite their prevalence in both developed and developing countries, there have been surprisingly few assessments on the ecological effectiveness of protected areas [5] and evaluation of vegetation structure and composition inside the protected areas and adjacent areas.

It is assumed that biodiversity is best managed in protected areas and other areas where land has not been fragmented due to human population pressure [6, 7]. Biodiversity conservation outside protected areas is increasingly taking centre stage in global conservation discourse [8–10]. Although it is seldom the focus of scientific investigations, wildlife habitat loss has alarmed conservationists because of its potential implications for native biodiversity [11]. However, little is currently known about the ecological consequences of the increasing demographic pressure of human and livestock populations to terrestrial wildlife habitat in areas of different land uses, yet some conservationists suggest that it may result in biodiversity loss [12, 13].
2. Materials and Methods

2.1. Study Area. Our study focussed on the northern Gonarezhou National Park (GNP), Chibwedziva Communal Area (CCA) which is a CAMPFIRE area, and Chizvirizvi Resettlement Area (CRA)—a resettlement area (Figure 1). The entire GNP is about 5000 km² in extent whereas CCA and CRA are 315 km² and 240 km² in extent, respectively. All the selected sites are within the Great Limpopo Transfrontier Conservation Area in southeastern Zimbabwe, and wildlife conservation is a recognised form of land use. The plant communities in the study area are typical of the savanna vegetation, comprised of a mosaic of trees and grass dominated by *Colophospermum mopane* and *Combretum apiculatum*.

Three climatic seasons can be recognized in the study area: hot and wet (from November to March), cool and dry (from April to July), and hot and dry (from August to October). The average annual precipitation ranges from 200 to 600 mm. Average monthly maximum temperatures are 25°C in July and 38°C in January. Average monthly minimum temperatures range between 11°C in June and 25°C in January [16]. The area is generally low-lying with a mean altitude of mostly 400 m above sea level [17].

2.2. Data Collection. A stratified random sampling procedure was used in this study. Three strata were defined according to land use, namely, (i) strictly wildlife conservation, (ii) communal area, and (iii) resettlement area. Data collection was conducted from April to May 2012. The estimated variables of the woody vegetation (trees and shrubs) were plant species richness, plant height, and dead trees. Trees and shrubs were classified based on height; that is, rooted, woody, and self-supporting plants ≥ 3 m in height were...
Table 1: Vegetation attributes for sample plots across different land use areas (mean ± standard error) and significant levels from one-way ANOVA with unequal sample size tests.

<table>
<thead>
<tr>
<th>Variable</th>
<th>GNP</th>
<th>CRA</th>
<th>CCA</th>
<th>F&lt;sub&gt;2,57&lt;/sub&gt;</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree density ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>842.78 ± 110.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>416.67 ± 93.59&lt;sup&gt;b&lt;/sup&gt;</td>
<td>407.87 ± 185.25&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.41</td>
<td>0.007</td>
</tr>
<tr>
<td>Shrub density ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>240.00 ± 56.73&lt;sup&gt;a&lt;/sup&gt;</td>
<td>80.00 ± 17.68&lt;sup&gt;b&lt;/sup&gt;</td>
<td>111.11 ± 48.87&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.71</td>
<td>0.075</td>
</tr>
<tr>
<td>Sapling density ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>694.44 ± 152.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>204.44 ± 54.44&lt;sup&gt;b&lt;/sup&gt;</td>
<td>147.78 ± 61.88&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.36</td>
<td>0.007</td>
</tr>
<tr>
<td>Dead tree density ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>2777 ± 7.84&lt;sup&gt;a&lt;/sup&gt;</td>
<td>28.88 ± 11.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>42.22 ± 17.66&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.44</td>
<td>0.647</td>
</tr>
<tr>
<td>Tree height (m)</td>
<td>4.56 ± 0.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.63 ± 0.38&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.42 ± 0.87&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11.13</td>
<td>0.000</td>
</tr>
<tr>
<td>Shrub height (m)</td>
<td>1.44 ± 0.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.51 ± 0.22&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.08 ± 0.25&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.11</td>
<td>0.335</td>
</tr>
<tr>
<td>Woody species diversity (H')</td>
<td>1.78 ± 0.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.54 ± 0.26&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.66 ± 0.24&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.37</td>
<td>0.003</td>
</tr>
<tr>
<td>Grass species richness per plot</td>
<td>11.27 ± 0.88&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.80 ± 0.85&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.47 ± 0.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.68</td>
<td>0.001</td>
</tr>
</tbody>
</table>

GP represents Gonarezhou National Park, CRA represents Chizvirizvi Resettlement Area, and CCA represents Chibwedziva Communal Area. Significant values are indicated in bold; values with different superscript letters within rows differ significantly (Tukey’s HSD; P < 0.05).

classified as trees whereas rooted, woody, self-supporting, and multistemmed or single-stemmed plants greater than 1 m but < 3 m in height were classified as shrubs [16]. Herbaceous vegetation (forbs and herbs) species richness per plot was also recorded. A total of 60 plots (30 × 20 m<sup>2</sup>) were sampled in the study sites, that is, 30 plots in northern GNP and 15 plots each in CCA and CRA (Figure 1). A 6 m graduated pole was used for measuring woody plant height, and a handheld Global Positioning System (GPS) was used to mark the location of each sampling plot.

2.3. Data Analyses. Collected data were summarised and tested for normality using the Kolmogorov-Smirnov test, and data for tree density, shrub density, sapling density, and tree height were found to be not normally distributed; hence, data were normalised using log<sub>10</sub>(x + 1) transformation [18]. Species diversity in different land use areas was determined by calculating the Shannon-Weiner (H') diversity index [19]. Differences in vegetation structure and composition were tested using One-way Analysis of Variance (ANOVA), at 5% level of significance using the Statistical Package for Social Sciences (SPSS) version 19 for Windows (SPSS Inc., Chicago, IL, USA). Post hoc analysis for variables with significant differences was carried out using Tukey’s Honestly Significant Difference (HSD). Furthermore, we performed a Principal Component Analysis (PCA) to determine the underlying patterns of the vegetation data using the 60 sample plots in CANOCO version 4.5 for Windows [20].

3. Results

3.1. Woody Vegetation Structure and Composition across Land Use. A total of 3670 woody plants (61% trees and 39% shrubs) were assessed, and 136 vegetation species were identified across all land uses. About 51% of the vegetation species were woody plant species whereas 49% were grass species. Vegetation structure and composition significantly differed across land use, particularly in the following variables: tree density, sapling density, tree height, woody species diversity, and grass species richness (Table 1). In contrast, there were no significant differences in densities of shrubs, dead trees, and shrub height. Woody vegetation community in the study area was dominated by Colophospermum mopane, Acacia nigrescens, Combretum apiculatum, Dichrostachys cinerea, Kirkia acuminata, Spirostachys Africana, and Terminalia sericea.

3.2. Patterns in Woody Vegetation Structure and Composition. Figure 2 shows a PCA biplot of sample plots and measured variables in the study area. Axis 1 explained 91.7% of the variance in vegetation data and defined a gradient from areas with taller trees and higher grass species richness to areas with a higher density of saplings, shrubs and higher woody vegetation diversity. Accordingly, the CCA, and CRA correlated negatively with Axis 1 whereas GNP correlated positively with Axis 1. Moreover, Axis 2 explained 7.9% of the vegetation data and defined a gradient from areas characterised with taller trees and higher grass species richness to areas with higher
densities of shrubs and diversity of woody plants. GNP, CRA and CCA had a negative correlation with Axis 2 whereas mostly GNP and, to a lesser extend, CCA were positively correlated with Axis 2.

4. Discussion

The three land use areas examined in this study showed significant differences in structural and compositional attributes of vegetation. We find it interesting that tree species diversity was higher in CCA than in the protected area, that is, GNP. This finding is contrary to the widely accepted perception that diversity is poorly managed in areas settled by people. However, the perception is supported by our results on grass species richness where diversity was higher in the GNP than in CCA. This finding suggests that disturbance factors may have a significant effect on certain plant communities, their composition and functioning are important factors to consider when studying biodiversity [21, 22], and anthropogenic disturbances may be more pronounced outside protected areas [23, 24]. Similarities across the land use strata were in shrub height, shrub density, and dead tree density.

The vegetation structure and composition across different land uses suggest that the role of anthropogenic disturbance can have long-term effect in influencing habitat loss [11]. Despite topography, edaphic and moisture variation which is known to affect structure and composition in savannas [25, 26], the loss of woody vegetation due to herbivory, fires, droughts, frost, diseases, and human disturbances remains important in semiarid savanna ecosystem [27–29]. Our study confirms this finding and further suggests that human disturbance is likely to be a key factor in shaping woody vegetation communities in the southeastern Zimbabwe. This has implications on CAMPFIRE areas surrounding protected areas in Zimbabwe, as habitat availability affects distribution of wildlife [30]. Moreover, vegetation provides local communities with basic subsistence and economic resources [31]. Recent evidence of cattle grazing in the different land uses, including GNP, presents some important insights of habitat overlaps between wild and domesticated herbivores [32], which also leads to herbaceous layer changes due to human and livestock encroachments into protected areas.

Most communal areas in southeastern Zimbabwe are associated with human population increase, encroachments into wildlife areas, and increased dependency on natural resources for livelihood, which often results in habitat loss and degradation, thus influencing wildlife abundances and their distribution [32–35]. In the unprotected areas, vegetation losses can be a result of selective extraction of forest/woodland resources for purposes such as fuel wood, construction materials, and other nontimber forest products [36]. The varying levels of disturbance in the different land use categories have an effect on plant biodiversity. It has been reported that the structural complexity of an ecological community is positively correlated with the diversity of plant life [37]. Fully protected areas are often assumed to be the best way to conserve plant diversity and maintain intact woodland/forest composition and structure [38], that ultimately determines biodiversity at various scales, providing habitat for unique wildlife species that require unique and variable forage and cover opportunities or “niches” for survival and reproduction.

5. Conclusions

Our study provides some evidence that the protected areas are a more effective way to conserve diversity in grasses compared to nonprotected areas. However, how to improve diversity of trees inside protected areas or understanding what is causing less diversity of trees in these areas remains a puzzle. This study provides a reference baseline for monitoring changes in vegetation species diversity, which has, undoubtedly, important conservation implications requiring appropriate and timely management interventions if the direction of change is not desirable according to conservation objectives being pursued in the area. We, therefore, recommend regular monitoring of vegetation structure and composition in all areas surrounding protected areas and not restricting ecological monitoring effort within boundaries of protected areas. There is also a need for tapping into local ecological knowledge to understand the sociocultural issues surrounding the survival of some woody plant species in unprotected areas dominated by human activities.

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