Hindawi Publishing Corporation
International Journal of Biodiversity
Volume 2013, Article ID 692564, 5 pages
http://dx.doi.org/10.1155/2013/692564

Research Article

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

Patience Zisadza-Gandiwa,[1] Cheryl T. Mabika,[2] Olga L. Kupika,[2] Edson Gandiwa,[1] and Chrispen Murungweni[3]

[1] *Scientific Services, Gonarezhou National Park, Parks and Wildlife Management Authority, Private Bag 7003, Chiredzi, Zimbabwe*
[2] *Department of Wildlife and Safari Management, Chinhoyi University of Technology, Private Bag 7724, Chinhoyi, Zimbabwe*
[3] *Department of Animal Production and Technology, Chinhoyi University of Technology, Private Bag 7724, Chinhoyi, Zimbabwe*

Correspondence should be addressed to Patience Zisadza-Gandiwa; patience.gandiwa@gmail.com

Received 11 January 2013; Revised 10 March 2013; Accepted 25 March 2013

Academic Editor: Antonio Terlizzi

We compared the structure and composition of vegetation communities across different land uses in the northern Gonarezhou National Park and adjacent areas, southeast Zimbabwe. Vegetation data were collected from 60 sample plots using a stratified random sampling technique from April to May 2012. Stratification was by land use, and sample plots in all three strata occurred on predominantly siallitic soils. Our results show that the communal area had higher woody plant species diversity ($H' = 2.66$) than the protected area ($H' = 1.78$). However, the protected area had higher grass species richness per plot than the communal area and resettlement area. Overall, the protected area had more structural and compositional diversity than the other land use areas. These findings suggest that the areas adjacent to protected areas contribute to plant diversity in the greater ecosystem; hence conservation efforts should extend beyond the boundaries of protected areas. We recommend that protected area management should engage community-based institutions in neighbouring areas for effective monitoring of woody vegetation structure and composition.

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].

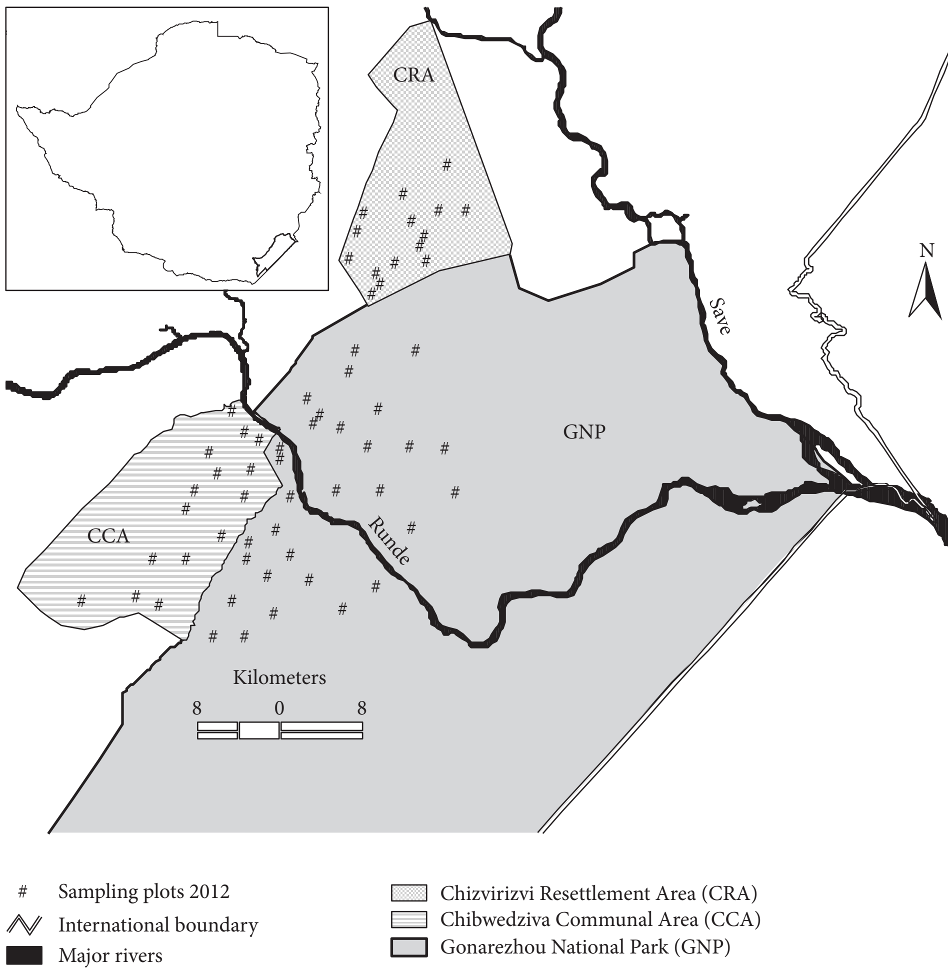


Figure 1: Location of study sites and sample plots in northern Gonarezhou National Park and adjacent areas in southern Zimbabwe.

In Zimbabwe, the assumption that the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) surrounding mostly protected areas expands the habitat of the core wildlife area, forming a buffer around the protected area [14], needs to be continuously investigated. Such assumptions assume a land use gradient exists for biodiversity protection [15]. Therefore, the aim of this study was to investigate the current vegetation status in and around a large state protected area in a semiarid savanna landscape of southeast Zimbabwe. Our main objective was to determine the structure and composition of plant species across different land uses adjacent to a state protected area.

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 km^2 in extent whereas CCA and CRA are 315 km^2 and 240 km^2 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 $\geq$ 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.

Variable	Land use category GNP	CRA	CCA	$F_{2,57}$	P value
Tree density ha^{-1}	842.78 ± 110.11^{a}	416.67 ± 93.59^{b}	407.78 ± 185.25^{b}	5.41	**0.007**
Shrub density ha^{-1}	240.00 ± 56.73^{a}	80.00 ± 17.68^{a}	111.11 ± 48.87^{a}	2.71	0.075
Sapling density ha^{-1}	694.44 ± 152.25^{a}	204.44 ± 54.44^{b}	147.78 ± 61.18^{b}	5.36	**0.007**
Dead tree density ha^{-1}	27.77 ± 7.84^{a}	28.88 ± 11.21^{a}	42.22 ± 17.66^{a}	0.44	0.647
Tree height (m)	4.56 ± 0.16^{a}	5.63 ± 0.38^{b}	7.42 ± 0.87^{a}	11.13	**0.000**
Shrub height (m)	1.44 ± 0.15^{a}	1.51 ± 0.22^{a}	1.08 ± 0.25^{a}	1.11	0.335
Woody species diversity (H')	1.78 ± 0.16^{a}	1.54 ± 0.26^{b}	2.66 ± 0.24^{a}	6.37	**0.003**
Grass species richness per plot	11.27 ± 0.88^{a}	6.80 ± 0.85^{b}	7.47 ± 0.8^{b}	7.68	**0.001**

GNP represents Gonarezhou National Park, CRA represents Chizvirizvi Resettlement Area, and CCA represents Chibwedziva Communal Area. Significant values are indicted 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^2) 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 $\log_{10}(x+1)$ 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*.

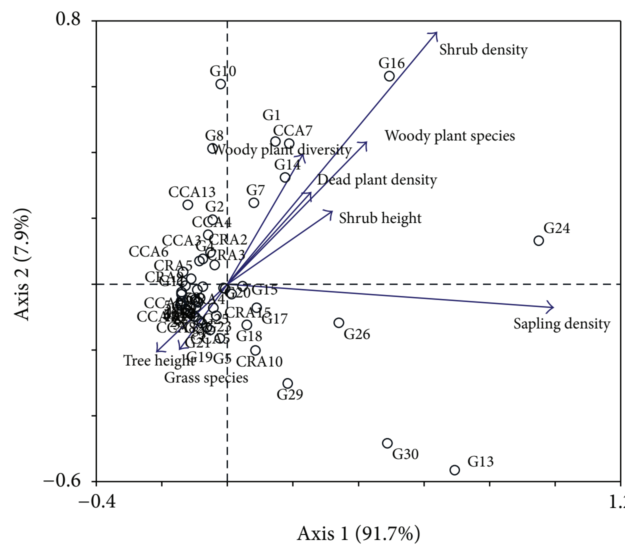


Figure 2: Principal Component Analysis biplot of measured vegetation variables from the 60 sample plots in northern Gonarezhou National Park and adjacent areas, southern Zimbabwe. G represents Gonarezhou National Park, CCA represents Chibwedziva Communal Area, and CRA represents Chizvirizvi Resettlement Area.

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, CCA and CRA 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.

Acknowledgments

This research was supported by the Gonarezhou Conservation Project, a conservation partnership between the Zimbabwe Parks and Wildlife Management Authority and Frankfurt Zoological Society. The authors are grateful to Hillary Madzikanda, Evious Mpofu, Daphine Madhlamoto, Tendai Chinho, Patience Nyabawa, and Gonarezhou National Park staff for rendering invaluable assistance during this study. Comments and suggestions from two anonymous reviewers helped improve this paper.

References

[1] N. Clerici, A. Bodini, H. Eva, J. M. Grégoire, D. Dulieu, and C. Paolini, "Increased isolation of two Biosphere Reserves and surrounding protected areas (WAP ecological complex, West Africa)," *Journal for Nature Conservation*, vol. 15, no. 1, pp. 26–40, 2007.

[2] R. DeFries, A. Hansen, A. C. Newton, and M. C. Hansen, "Increasing isolation of protected areas in tropical forests over the past twenty years," *Ecological Applications*, vol. 15, no. 1, pp. 19–26, 2005.

[3] International Union for Conservation of Nature, "1993 United Nations list of national parks and protected areas," WCMC and CNPPA. IUCN, Gland, Switzerland, 1994.

[4] L. Naughton-Treves, M. B. Holland, and K. Brandon, "The role of protected areas in conserving biodiversity and sustaining local livelihoods," *Annual Review of Environment and Resources*, vol. 30, pp. 219–252, 2005.

[5] K. J. Gaston, K. Charman, S. F. Jackson et al., "The ecological effectiveness of protected areas: the United Kingdom," *Biological Conservation*, vol. 132, no. 1, pp. 76–87, 2006.

[6] K. A. Brown, J. C. Ingram, D. F. B. Flynn, R. Razafindrazaka, and V. Jeannoda, "Protected area safeguard tree and shrub communities from degradation and invasion: a case study in eastern madagascar," *Environmental Management*, vol. 44, no. 1, pp. 136–148, 2009.

[7] R. Watson, K. H. Fitzgerald, and N. Gitahi, "Expanding options for habitat conservation outside protected areas in Kenya: the use of environmental easements," Technical Paper no. 2, African Wildlife Foundation, Kenya, 2010.

[8] M. Anyonge-Bashir and P. Udoto, "Beyond philanthropy: community nature-based enterprises as a basis for wildlife conservation," *The George Wright Forum*, vol. 29, no. 1, pp. 67–73, 2012.

[9] P. F. Langhammer, M. I. Bakarr, L. A. Bennun et al., *Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems*, The World Conservation Union-IUCN, Gland, Switzerland, 2007.

[10] M. Niamir-Fuller, C. Kerven, R. Reid, and E. Milner-Gulland, "Co-existence of wildlife and pastoralism on extensive rangelands: competition or compatibility?" *Pastoralism: Research, Policy and Practice*, vol. 2, no. 8, 2012.

[11] A. J. Hansen, R. Rasker, B. Maxwell et al., "Ecological causes and consequences of demographic change in the new west," *BioScience*, vol. 52, no. 2, pp. 151–162, 2002.

[12] H. H. T. Prins, "The patoral road to extinction: competition between wildlife and traditional pastoralism in East Africa," *Environmental Conservation*, vol. 19, no. 2, pp. 117–123, 1992.

[13] W. D. Newmark, "Isolation of African protected areas," *Frontiers in Ecology and the Environment*, vol. 6, no. 6, pp. 321–328, 2008.

[14] P. G. H. Frost and I. Bond, "The CAMPFIRE programme in Zimbabwe: payments for wildlife services," *Ecological Economics*, vol. 65, no. 4, pp. 776–787, 2008.

[15] J. D. Maestas, R. L. Knight, and W. C. Gilgert, "Biodiversity across a Rural Land-Use gradient," *Conservation Biology*, vol. 17, no. 5, pp. 1425–1434, 2003.

[16] E. Gandiwa and S. Kativu, "Influence of fire frequency on *Colophospermum mopane* and *Combretum apiculatum* woodland structure and composition in northern Gonarezhou National Park, Zimbabwe," *Koedoe*, vol. 51, no. 1, 2009.

[17] Zimbabwe Parks and Wildlife Management Authority, "Gonarezhou National Park Management Plan: 2011–2021," Zimbabwe Parks and Wildlife Management Authority, Harare, Zimbabwe, 2011.

[18] J. H. McDonald, *Handbook of Biological Statistics*, Sparky House, Baltimore, Md, USA, 2nd edition, 2009.

[19] J. A. Ludwig and J. F. Reynolds, *Statistical Ecology: A Primer on Methods and Computing*, John Wiley & Sons, New York, NY, USA, 1988.

[20] C. J. F. Ter Braak and P. Šmilauer, "CANOCO reference manual and CanoDraw for Windows user's guide: software for Canonical Community Ordination," version 4.5, Microcomputer Power, Ithaca, NY, USA, 2002.

[21] J. P. Grime, *Plant Strategies and Vegetation Processes*, Wiley, Chichester, UK, 1979.

[22] P. Zisadza-Gandiwa, L. Mango, E. Gandiwa et al., "Variation in woody vegetation structure and composition in a semi-arid savanna of Southern Zimbabwe," *International Journal of Biodiversity and Conservation*, vol. 5, no. 2, pp. 71–77, 2013.

[23] E. F. Lambin, B. L. Turner, H. J. Geist et al., "The causes of land-use and land-cover change: moving beyond the myths," *Global Environmental Change*, vol. 11, no. 4, pp. 261–269, 2001.

[24] W. Kperkouma, Y. W. Agbélessessi, B. Wiyao et al., "Assessment of vegetation structure and human impacts in the protected area of Alédjo, Togo," *African Journal of Ecology*, vol. 50, pp. 355–366, 2012.

[25] E. T. F. Witkowski and T. G. O'Connor, "Topo-edaphic, floristic and physiognomic gradients of woody plants in a semi-arid African savanna woodland," *Vegetatio*, vol. 124, no. 1, pp. 9–23, 1996.

[26] R. J. Williams, G. A. Duff, D. M. J. S. Bowman, and G. D. Cook, "Variation in the composition and structure of tropical savannas as a function of rainfall and soil texture along a large-scale climatic gradient in the Northern Territory, Australia," *Journal of Biogeography*, vol. 23, no. 6, pp. 747–756, 1996.

[27] C. D. Allen, A. K. Macalady, H. Chenchouni et al., "A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests," *Forest Ecology and Management*, vol. 259, no. 4, pp. 660–684, 2010.

[28] E. Gandiwa, T. Magwati, P. Zisadza, T. Chinuwo, and C. Tafangenyasha, "The impact of African elephants on *Acacia tortilis* woodland in northern Gonarezhou National Park, Zimbabwe," *Journal of Arid Environments*, vol. 75, no. 9, pp. 809–814, 2011.

[29] C. Tafangenyasha, "Decline of the mountain acacia, *Brachystegia glaucescens* in Gonarezhou National Park, southeast Zimbabwe," *Journal of Environmental Management*, vol. 63, no. 1, pp. 37–50, 2001.

[30] M. Waltert, B. Meyer, and C. Kiffner, "Habitat availability, hunting or poaching: what affects distribution and density of large mammals in western Tanzanian woodlands?" *African Journal of Ecology*, vol. 47, no. 4, pp. 737–746, 2009.

[31] E. Gandiwa, "Importance of dry savanna woodlands in rural livelihoods and wildlife conservation in southeastern Zimbabwe," *Nature & Faune*, vol. 26, no. 1, pp. 60–66, 2011.

[32] E. Gandiwa, I. M. A. Heitkönig, P. Gandiwa, W. Matsvayi, H. Van Der Westhuizen, and M. M. Ngwenya, "Large herbivore dynamics in northern Gonarezhou National Park, Zimbabwe," *Tropical Ecology*, vol. 54, no. 3, pp. 343–352, 2013.

[33] P. Gandiwa, M. Matsvayi, M. M. Ngwenya, and E. Gandiwa, "Assessment of livestock and human settlement encroachment into northern Gonarezhou National Park, Zimbabwe," *Journal of Sustainable Development in Africa*, vol. 13, no. 5, pp. 19–33, 2011.

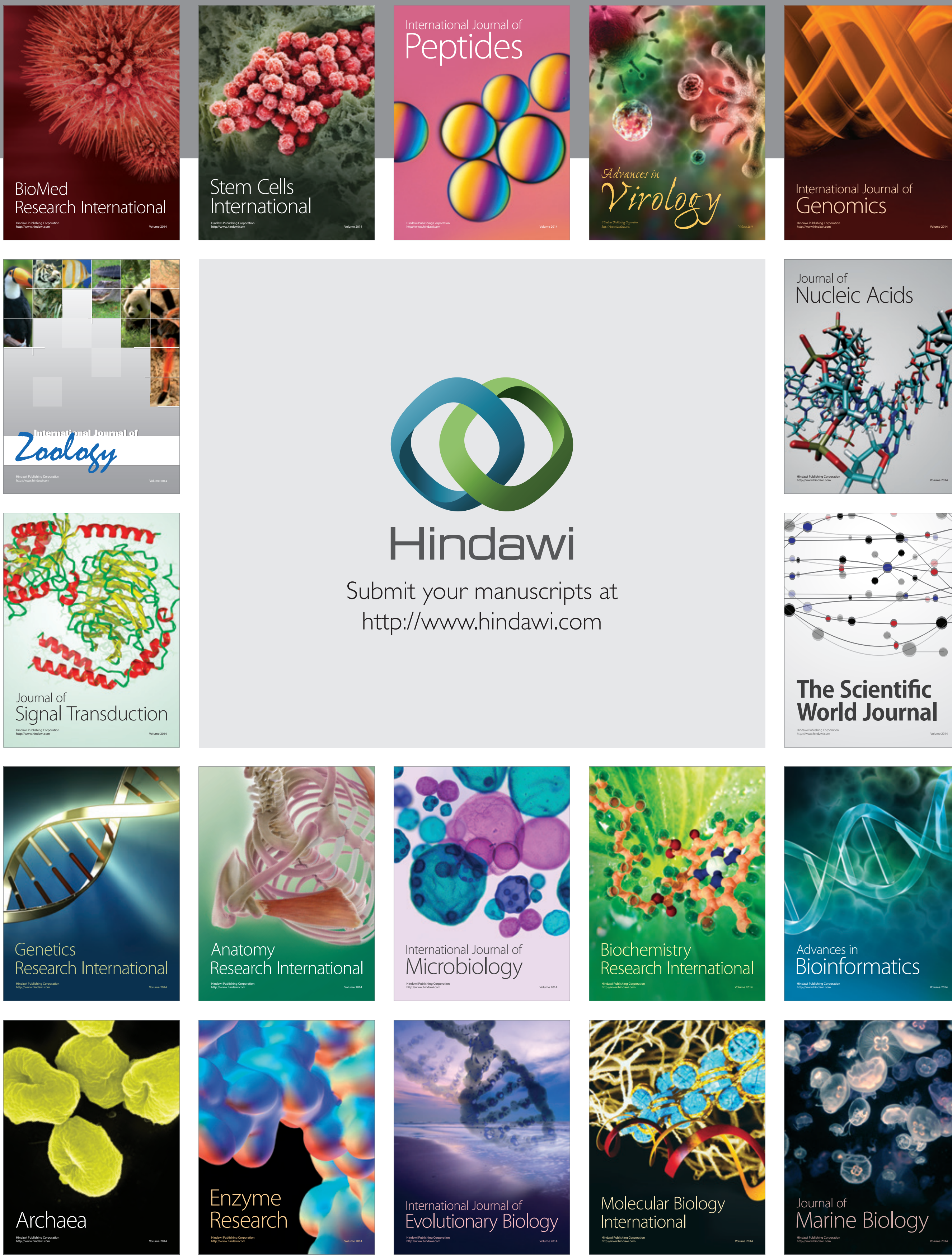
[34] W. Wolmer, J. Chaumba, and I. Scoones, "Wildlife management and land reform in southeastern Zimbabwe: a compatible pairing or a contradiction in terms?" *Geoforum*, vol. 35, no. 1, pp. 87–98, 2004.

[35] W. Wolmer, "Wilderness gained, wilderness lost: wildlife management and land occupations in Zimbabwe's southeast lowveld," *Journal of Historical Geography*, vol. 31, no. 2, pp. 260–280, 2005.

[36] K. A. Brown, S. Spector, and W. Wu, "Multi-scale analysis of species introductions: combining landscape and demographic models to improve management decisions about non-native species," *Journal of Applied Ecology*, vol. 45, no. 6, pp. 1639–1648, 2008.

[37] M. A. Huston, *Biological Diversity: The Coexistence of Species on Changing Landscapes*, Cambridge University Press, New York, NY, USA, 1996.

[38] T. Banda, M. W. Schwartz, and T. Caro, "Woody vegetation structure and composition along a protection gradient in a miombo ecosystem of western Tanzania," *Forest Ecology and Management*, vol. 230, no. 1-3, pp. 179–185, 2006.


BioMed Research International
Stem Cells International
International Journal of Peptides
Advances in Virology
International Journal of Genomics
International Journal of Zoology
Journal of Nucleic Acids
Hindawi
Submit your manuscripts at
http://www.hindawi.com
Journal of Signal Transduction
The Scientific World Journal
Genetics Research International
Anatomy Research International
International Journal of Microbiology
Biochemistry Research International
Advances in Bioinformatics
Archaea
Enzyme Research
International Journal of Evolutionary Biology
Molecular Biology International
Journal of Marine Biology