GLOBAL JOURNAL OF BIOLOGY, AGRICULTURE & HEALTH SCIENCES
(*Published By*: Global Institute for Research & Education)

www.gifre.org

INFLUENCE OF GRAZING INTENSITY ON PLANT COMMUNITY DIVERSITY, STRUCTURE AND COMPOSITION IN DAMBO WETLANDS OF COMMUNAL ZIMBABWE

Dahwa, E.[1] Kativu, S.[2] Hungwe, T.[3] Mudzengi, C. P.[1] Poshiwa, X.[4] Murungweni, C.[5] & Shoko, M. D.[3]

[1]Department of Research and Specialist Services, Makoholi Research Institute, P. Bag 9182, Masvingo, Zimbabwe.
[2]University of Zimbabwe, Department of Biological Sciences, Box MP 167, Mount Pleasant, Harare, Zimbabwe.
[3]Great Zimbabwe University, Faculty of Agricultural Sciences, P. O. Box 1235 Masvingo, Zimbabwe.
[4] University of Zimbabwe, Marondera College of Agricultural Sciences, Box 35, Marondera, Zimbabwe.
[5]Chinhoyi University of Technology, Department of Animal Production and Technology, P. Bag 7724, Chinhoyi, Zimbabwe.

Abstract

A study was carried out to determine grazing impacts on dambo wetlands vegetation in Zimbabwe's arid communal lands. Results revealed that communal dambos were converting from floristically diverse wetlands of good grazing to communities dominated by low forage value grasses like *Eragrostis* species. Furthermore, changes in plant structural attributes like basal and litter cover that exposed soil to erosion were recorded. However, moderate grazing supported a diverse plant community with plant composition that supports a working wetland. Current management practices of dambos in the Zimbabwean communal areas are inadequate and needs regulation if sound conservation measures are to be adopted.

Key words: *dambos, wetlands, vegetation, overgrazing, diversity*.

Introduction

Southern Africa is plagued with numerous problems of environmental conservation and management of natural resources (Matiza and Crafter, 1994). Environmental deterioration is in the form of soil degradation and erosion, siltation of rivers and reservoirs, deforestation, desiccation of wetland ecosystems and consequently biodiversity loss (Booth *et al*., 1994). The deterioration is due to a variety of factors, such as unsustainable use and poor management of natural resources, unfair land distribution and poverty (Matiza and Crafter, 1994). Soil erosion and desiccation are products of a complex chain of events, amongst which overgrazing of dambo vegetation by livestock is a key component (Roberts, 1988).

In broad terms, dambos are depressions at the head of, or flanking watercourses, in which soils are saturated during the rainy season and remain so to within about 50cm or less from the surface for some considerable period thereafter (Thompson, 1972). Some 20% of these lie in Zimbabwean communal areas (Mharapara *et al*., 1997). Their presence is of great importance as they retain moisture during the dry season which supports a vigorous growth of grasses and sedges, and a high diversity of plant and animal species. The *in situ* decomposition of the vegetation cover leads to a buildup of organic matter, and the creation of a hydromorphic, sometimes peaty, upper soil horizon. Consequently, dambos act as an important food-producing buffer during the dry season through livestock rearing or small-scale agriculture tillage. They also provide important ecosystem services as wildlife habitats, water filters and flood protectors (Amanda *et al*., 2010; Whitlow, 1989). Dambo plant communities play a fundamental role in maintaining these functions, but their functional significance is rapidly being threatened by man's activities (Houlahan *et al*., 2006)

High livestock grazing pressure negatively affects the environment, but its effect on plant communities is highly variable from one site to another (Hayes and Holl, 2003; Baron *et al*., 2001). It has been shown that such changes to vegetative and reproductive output have the potential to alter species population dynamics and potentially change the vegetation community (Keddy *et al*., 2001; Marty, 2004; Pyke and Marty, 2004; Menard *et al*., 2002; Jones et al., 2010; Bullock *et al*., 2001; Middleton, 2002). Monitoring of grazing impacts is necessary for rangeland management to ensure that it is used sustainably. Dambo wetlands (commonly referred to as vleis or mapani, matoro, amaxaphozi in vernacular languages (Mharapara *et al*, 1997) are highly sensitive to grazing pressure. As such, they are considered as useful environmental indicators of environmental pressures (Limpitlaw and Rudigergens, 2006; Roberts, 1988).

In Zimbabwe, agro-rural watersheds have experienced serious environmental degradation in the recent past due to inappropriate land use practices (Scoones, 1991a). Land pressure has forced communities to concentrate on land and water availability irregardless of the state of these environmental resources (Mtetwa and Schutte, 2002). These communal watersheds used to contain typha and attract dozens of crowned crane, marsh harrier, stonechat and red bishop, however in recent years have progressively dried out and are now heavily eroded (Booth et al., 1994; Scoones, 1991b; Tooth and McCarthy, 2007).

Dambo ecosystems are considered to be highly fertile, and as such are open to excessive exploitation. This is particularly so in areas where mean annual rainfall is below 1000 mm and soils are generally of low quality (Roberts, 1988). Sadly, these two conditions are often associated, and it is in climatically marginal environments where rainfed agriculture is least dependable and reliance on dambo cultivation and grazing is greatest. Being fragile ecosystems, the impact of such activities on dambo wetlands is severe. An understanding of the effects of agricultural pressure, particularly livestock grazing is necessary for the establishment of effective conservation measures (Roberts, 1988).

Efforts to conserve and properly manage wetlands in Zimbabwe date back to the 1950s (Matiza and Crafter, 1994; Thompson, 1972). Prior to this, dambo cultivation was a well-established practice. The post-1950 phase was one with increased pressure on land, with a growing human and livestock population. Dambos now supported a large number of cattle throughout the year, whilst efforts to curtail dambo cultivation were not well received by peasant farmers (Matiza and Crafter, 1994). Consequently, the state of the wetland ecosystem changed from the natural to modified state. Biodiversity was subsequently lost, with consequential shortage of pastures and water.

In this study, dambos are introduced as an effective environmental indicator to monitor livestock grazing activities in communal dambos in Zimbabwe. The objective of this study was to determine the impacts of grazing on wetland plant community structure, diversity and composition in rural Zimbabwe. It is hypothesized that continuous grazing of dambo vegetation results in changes in structure, diversity and composition of herbaceous vegetation.

Materials and Methods

Description of experimental site

The study area is located to the north of Masvingo town (Fig 1), in Zimbabwe. The area falls within Natural Region IV (NR4) of the Zimbabwean ecological classification system (Vincent and Thomas, 1961) Altitude is 1204m above sea level on latitude $19^0 50'$ S and longitude 30^0 46'E. NR4 is highly suitable for extensive farming, and receives an annual rainfall of 450 to 650 mm. Mean maximum temperature is during summer and it is about 28^0C, and the minimum temperature is during winter and it is about 6^0C. It is characterised by sandy soils with low organic matter and humus content, and consequently low fertility. Farming activities in the area are considered risky because of highly variable rainfall that affects biomass production, fluctuating nitrogen fertiliser and farm output marketing prices and unreliable yields (Mharapara *et al*., 1997).

Dambo wetland selection

Three categories of wetlands from contrasting land use history were identified based on frequency and severity of defoliation. Two sites per category were selected and were the continuously grazed (CG), moderately grazed (MG) and ungrazed (UG). The control (UG) sites were selected from the commercial land, MG was selected from small scale commercial land while the CG was selected from the communal land. All dambos were cutting across similar soil type with major differences in use. Aerial photographic maps and a Global Positioning Satellite (GPS) altitude-measuring unit were used as aids for selection. Using mileage, a motorbike was run along and across dambos to estimate their varying sizes.

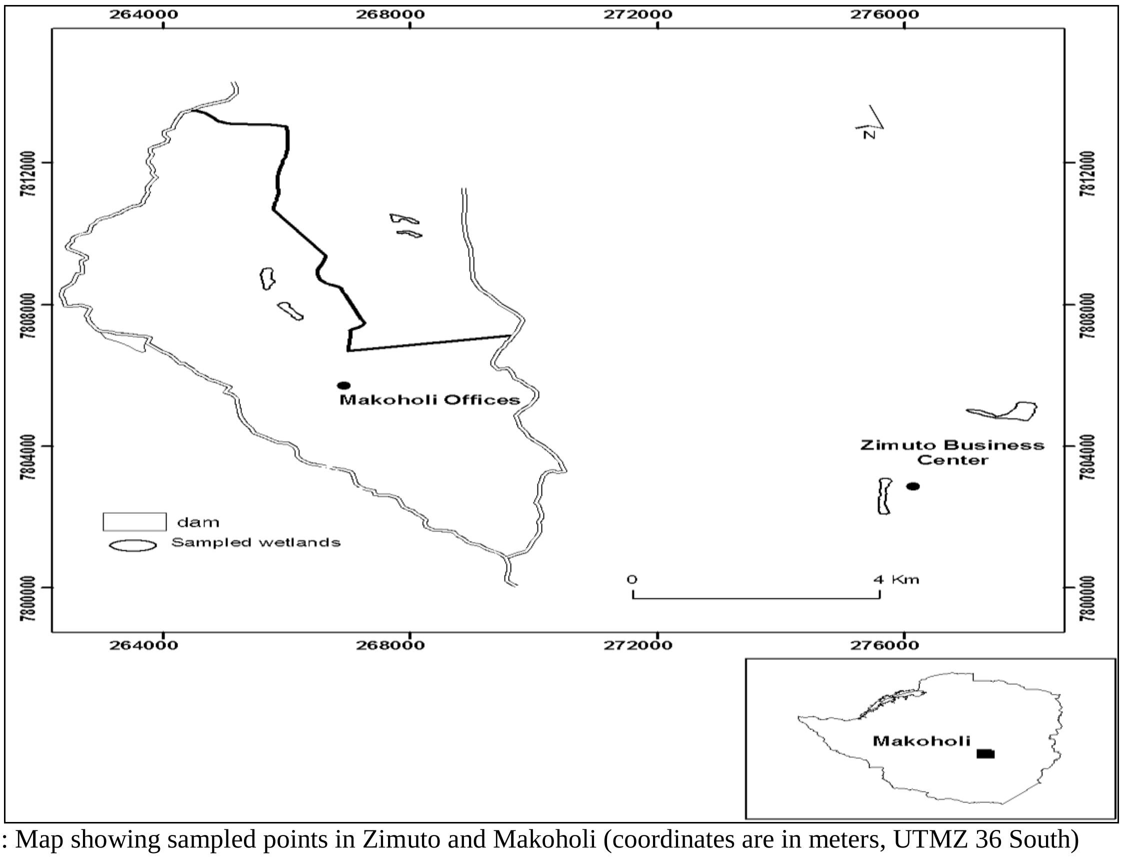

Figure 1: Map showing sampled points in Zimuto and Makoholi (coordinates are in meters, UTMZ 36 South)

Vegetation sampling

Within each wetland, vegetation was sampled from 0.5 m^2 quadrats systematically laid along transects (Curtis and McIntosh, 1950), starting at the center and transverssing to the edge of the wetland. Edges of dambos were determined by sampling until the vegetation cover was >90% pasture grass cover (Boughton *et al*., 2010). At least three transects measuring 100 m or less were laid in each wetland, this depending on size of the dambo sampled (dambos ranged in size from 0.9–4.5ha). All transects were laid perpendicular to the general wetland hydrologic gradient to capture any variations due to moisture gradient (Jones *et al*., 2010). Transects were also laid at least 30 m from roads to minimise border effects. A GPS unit was used to measure altitude and coordinate points within each sampling unit (quadrat). Variables recorded from each quadrat to determine species composition, diversity and structure were: name of species (nomenclature followed Wild, 1972), Basal cover, litter cover, plant height, erosion, plant vigour and plant density.

Data analysis

All diversity calculations were done in PAST version 2.07. Diversity indices for different samples were tested for significant differences using t-test (Amanda *et al*., 2010). To quantify the degree of overlap between species in different wetland communities and explore the floristic composition, Jaccard's similarity index was computed using PAST version 2.07 (Mueller-Dombois and Ellenberg, 1974;Braak and Verdonschot, 1995) using species presence absence data. To classify wetlands into groups or levels, hierarchical cluster analysis was also used (Amanda *et al*., 2010). One way analysis of variance from SPSS ver. 13 was then used to check for significant differences in vegetation structural attributes.

Results

Herbaceous plant species diversity

Diversity indices for the three grazing intensities show that Taxa_S varied significantly ($P < 0.05$) between sites (Table 1). The moderately grazed sites and continuously grazed sites had relatively higher taxa as compared to the ungrazed sites. Moderately grazed (MG) sites were more diverse while the ungrazed (UG) sites were least diverse ($P < 0.05$). All the sites exhibited less species evenness. Ungrazed sites had higher dominance values due to abundances of *Loudetia simplex* and *Aristida junciformis* hence significantly lower plant species diversity than other sites. A total of 65 herbaceous plant species were identified in the six dambo wetlands during this study (Appendix 1).

Table 1: Plant species diversity indices for three different grazing intensities. Means in rows with different superscripts are significantly different (P<0.05).

Diversity index	Ungrazed	Grazing intensity Moderate	Continuous
Taxa_S	24.5^c	35^a	32.5^b
Individuals	255.5^c	453^a	494.5^b
Dominance_D	0.11^b	0.07^a	0.09^a
Shannon_H	2.64^b	3.05^a	2.88^b
Simpson_1-D	0.90^b	0.94^a	0.92^a
Evenness_e^H/S	0.58^b	0.63^a	0.55^b

Plant species composition

A pairwise comparison of grazed and ungrazed sites (Table 2) revealed that the continuously grazed sites show a different floristic composition from the moderate and ungrazed sites as shown by a low index value of less than 25% similarity. Using presence absence data (Appendix 1), Hierarchical Cluster analysis was used to illustrate how communities can be grouped or separated based on species composition (Figure 2). Ungrazed sites formed the first cluster indicating their similarity in terms of species composition. Moderately grazed sites also clustered with one overgrazed site indicating some degree of similarity as well. One overgrazed site failed to cluster due to differences brought about by compositional shift of species.

Table 2: Jaccard's similarity indices of pairwise comparisons between the grazed and ungrazed sites using species presence absence data

	MG1	***MG2***	***CG3***	***CG4***	***UG_5***	***UG_6***
MG_1	1	0.45	0.22	0.28	0.28	0.32
MG_2	0.45	1	0.40	0.50	0.40	0.43
CG_3	0.22	0.40	1	0.50	0.21	0.24
CG_4	0.28	0.50	0.50	1	0.48	0.47
UG_5	0.28	0.40	0.21	0.48	1	0.61
UG_6	0.32	0.43	0.24	0.47	0.61	1

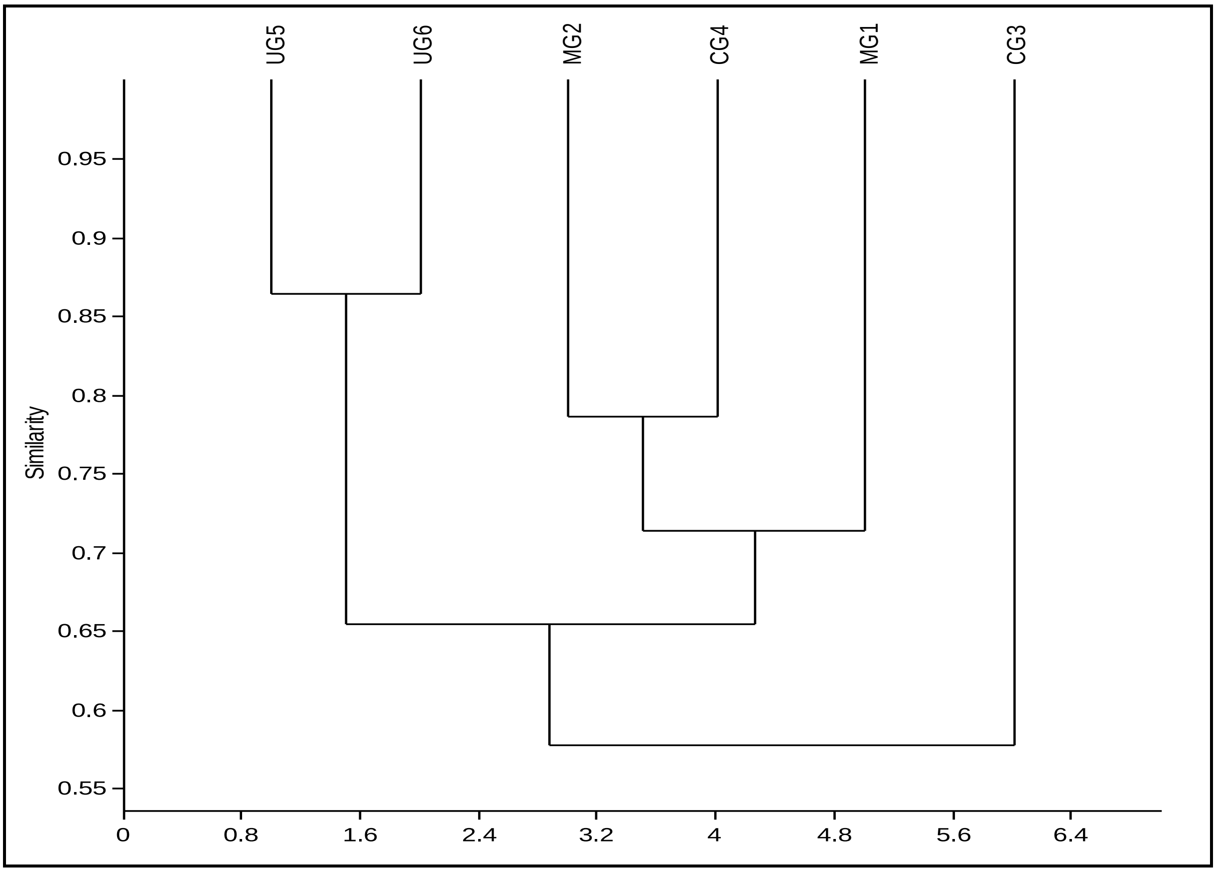

Figure 2: HCA Dendrogram to illustrate resemblance and differences in species composition by sites under different grazing intensities.

Herbaceous plant species structure

Vegetation structure varied significantly across different grazing intensities (*P<0.05*). Basal cover and litter cover were significantly lower under continuous grazing than in moderate and ungrazed sites (*P<0.05*). Sites which are moderately and continuously grazed supported significantly (*P<0.05*) higher taxa and plant density as compared to the ungrazed sites (Table 3).

Table 3: Vegetation structural attributes for different dambo grazing intensities

		Grazing intensity	
Parameter	**Ungrazed**	**Moderate**	**Continuous**
Basal cover	7.9^{c}(0.30)	6.44^{a}(0.29)*	5.42^{b}(0.17)
litter cover	2.14^{c}(0.25)	3.07^{a}(0.32)	1.27^{b}(0.15)
Plant vigour	6.58^{b}(0.34)	4.79^{a}(0.68)	5.75^{b}(0.23)
Erosion	0.78^{c}(0.12)	1.83^{a}(0.22)	1.22^{b}(0.13)
Top hamper	2.88^{c}(0.22)	1.78^{a}(0.26)	1.60^{b}(0.12)
Species richness	2.62^{c}(0.17)	7.13^{a}(0.31)	4.90^{b}(0.21)
Plant density	44.84^{c}(2.57)	69.27^{a}(3.29)	57.34^{b}(3.19)

* Means in rows with different superscripts are significantly different (P<0.05)
*Standard error of mean shown in brackets at the end of each value

Discussion and Conclusion

Plant species diversity and composition

Explaining and predicting species diversity and composition in ecological communities presents challenges (Geho *et al*., 2007). The compositional changes normally associated with grazing suggest that impacts of grazing are largely mediated by plant's structural design, with tall stature and tussock-forming plants more vulnerable to grazing while species favoured by grazing are generally perennial, short, prostrate and stoloniferous or rosette plants (Price *et al*., 2010)

Results from this study indicate that characteristics of the community composition, species abundance, diversity levels and floristic composition between the grazed and ungrazed sites show some similarities. A number of same species were found across all grazing intensities though abundance and frequency varied. Contrary to this, there are apparent vegetation changes underway within and among sites. Under continuous grazing, changes suggest that the communities are converting from floristically diverse dambo wetlands of good grazing to communities dominated by ruderal and more competitive species like *Eragrostis species*. *Eragrostis species* are perennial grasses common on sand veld, often found on disturbed ground and predominantly of poor forage value (Wild, 1972). Species of low palatability dominate pastures that are heavily and continuously grazed (Thurow and Hussein, 1989). The Jaccard's indices in table 2 indicated the loss of resemblance in floristic composition by sites under different grazing intensities. All sites under moderate grazing clustered with a single site under continuous grazing indicating some degree of similarity while the other CG site is not clustered (Figure 2). This may indicate a negative compositional shift under the continuous grazing system. Contrary to these findings (Pyke and Mart, 2004) working in ephemeral wetlands in Central California reported continuous grazing to be beneficial on plant species diversity. However it is important to specify the need for managing grazing inorder for it to be beneficial.

The abundance and distribution of *Eragrostis enamoena*, *Eragrostis plana* and *Eragrostis stapfii* in continuously grazed dambos reflects their great tolerance to heavy grazing. Of the 115 subplots sampled in CG4, *Eragrostis enamoena* and *Eragrostis plana* took up 82% and 62% of the subplots respectively. When compared to ungrazed site UG5, 99 subplots were sampled and the two *Eragrostis* species took up 35% and 10% respectively while *Loudetia simplex* took up 77% of the subplots in this category. This compositional shift due to grazing may probably be irreversible if ecological thresholds for recovery have been crossed. Recently, state and transition models have highlighted that grazing-induced changes may be irreversible if these thresholds for recovery have been crossed (Price *et al*., 2010).

High grazing intensities should be avoided as other studies have shown that these have resulted in monotonous stands of species resistant to grazing (Price *et al*., 2010). This may help explain the lower species diversity, low litter cover and basal cover, in continuous grazing when compared to moderate grazing. Several studies, have indicated that changes to vegetative and reproductive output due to grazing have the potential to alter species population dynamics and potentially change the vegetation community (Keddy *et al*., 2001; Pyke and Marty, 2004; Marty, 2004; Menard *et al*., 2002). If desirable species are eventually eliminated from the seed bank, this is deleterious to the ecosystem (Middleton, 2002). However if correctly practiced, grazing has the important role of maintaining biodiversity (Keddy *et al*., 2001; Pyke and Marty, 2004).

Previous studies have shown that accumulation of plant litter generally reduces species richness in most plant communities (Xiong *et al*, 2003). Factors such as grazing that removes litter may therefore be important in maintaining a species-rich flora in productive communities where litter usually accumulates (Reeves and Champion, 2004). This may explain why the ungrazed sites were less diverse than both the continuously and moderately grazed sites. Several lines of evidence are taken to support these interpretations. Unhampered natural selection in new salt marshes has been reported (Milotic *et al*., 2010) often leading to a dominance of clonal species such as *E. athericus*, eventually leading to species poor vegetation with low floral and faunal diversity. Introduction of grazing seemed to be a useful management tool to control the expansion of *E. athericus* and to increase plant diversity. However, reduced quantity of litter favours the growth of annual weeds (Heitschmidt *et al*., 1982). Annuals are of low grazing value to livestock due to their low leaf producing ability.

Vegetation structure and grazing interaction

The evidence produced in this study show that traditional continuous grazing is negatively affecting elements of vegetation structure in the communal set up. The principal elements of structure are growth form, stratification and coverage (Mueller-Dombois and Ellenberg, 1974). Measured variables exhibited significant differences among the sites. These included basal cover, litter cover, top hamper, plant densities and plant vigour. The influence of livestock grazing brought about apparent differences in plant structure across the dambos. Basal cover, litter cover and top hamper decreased with increasing grazing intensity. The importance of plant litter has probably been underestimated (Xiong *et al*, 2003), because production is often measured as above-ground biomass including both live and dead material. Studies have stressed the importance of leaf litter for the structuring of plant communities (Xiong *et al*, 2003).

Although it is sometimes difficult to draw generalizations from the many studies, due in part to differences in methodology and environmental variability among study sites, most scientific studies document that livestock grazing continues to be detrimental to stream and wetland ecosystems (Belsky *et al*., 1999; Bullock and Pakeman, 1997; Bullock *et al*., 2001). Some individual factors may have a minor influence, for example the effects of erosion and litter cover and total species richness, but their interactions with each other or with other factors, such as litter accumulation, may have a substantial influence on total species diversity and composition. Consequently, knowledge about the role of individual factors only, and ignorance of their interactions, may lead to false predictions about community structure and function.

Conclusion

Current management practices of dambos in the communal setup of Zimbabwe are inadequate and needs regulation if sound conservation measures are to be adopted. Moderate grazing should be considered one of a variety of important tools for land managers interested in the maintenance of biodiversity. Continuous grazing has negative effects on vegetation diversity and structural attributes. There is an apparent compositional shift of plant species in dambo wetlands with a probable consequence in loss of wetland important function.

Acknowledgements

The authors gratefully acknowledge the field assistance of Chiuta T, Mutata L, Muraza I and Madokudya A of Makoholi. Anthony Mapaura from the National Botanic Gardens, Harare helped with the identification of some plants and Mr. Mutsambiwa from the Soils and Chemistry Laboratory of the University of Zimbabwe carried out the soil analyses. We would like to thank Proffesor CHD Magadza for his input and comments earlier on. Project went well with partial financial assistance from the Ministry of Agriculture mechanisation and Irrigation Development.

References

Amanda, M. L. Glenn, R. G. Allen, T. F. H. (2010). Conceptual Hierarchical Modelling to Describe Wetland Plant Community Organization, *Wetlands,* 30, pp. 55–65.

Baron, V. S. Dick, A. C. Mapfumo, E. Malhi, S. S. (2001). Grazing impacts on soil nitrogen and phosphorus under Parkland pastures, *Journal of Range Management,* 54, pp. 704 - 710.

Belsky, J. Matzke, A. Uselman, S. (1999). Survey of livestock influences on stream and riparian ecosystems in the western *United States Journal of Soil and Water Conservation*, 54 (1), pp. 419-431.

Booth, J. McCullum, J. Mpinga, M. Mukute, (1994). The state of the environment in Southern Africa, Report by Southern African Research and Documentation Center with IUCN and SADC.

Boughton, E. H. Quintana, A. Bohlen, P. J. Jenkins, D. G. Pickert, R. (2010). Land use and isolation interact to affect wetland plant assemblages, *Ecogeography,* 33(3), pp. 461- 470.

Braak, T. C. J. F. Verdonschot, P. F. M (1995). Canonical correspondence analysis and related multivariate methods in aquatic ecology, *Aquatic Sciences,* 57 (6), pp. 255-289.

Bullock, J. M. Franklin, J. Stevenson, M. J. Silvertown, J. Coulson, S. Gregory, S. J. Tofts, R. (2001). A plant trait analysis of responses to grazing in a long term experiment, *Journal of Applied Ecology,* 38, pp. 253- 267.

Bullock, J. M. Pakeman, R. J. (1997). Grazing of lowland heath in England: Management methods and their effects on heathland vegetation, *Biological Conservation*, 79 (1), pp. 1- 13.

Curtis, J.T. McIntosh, R. P. (1950). The interrelations of certain analytic and synthetic phytosociological characters, *Ecology,* 31, pp. 434-455.

Eijkelkamp, The double ring infiltrometer, product manual, 2nd edition, 1983.

Geho, E. M. Campbell, D. Keddy, P. A. (2007). Quantifying ecological filters: the relative impact of herbivory, neighbours, and sediment on an oligohaline marsh, *Oikos*, 116, pp. 1006- 1016.

Hayes, G. F. Holl, K. D. (2003). Cattle Grazing Impacts on Annual Forbs and Vegetation Composition of Mesic Grasslands in California, *Conservation Biology,* 17, pp. 1694–1702.

Heitschmidt, R.K. Price, D.L Gordon, R.A. Fraser, J.R. (1982). Short duration grazing at the Texas Experimental Ranch: Effects on above ground net primary production and seasonal growth patterns, *Journal of Range Management,* 35(3), pp. 367-371.

Houlahan, J. E. Keddy, P. A. Makkay, K. Findlay, C. S. (2006). The effects of adjacent land use on wetland species richness and community composition, *The Society of Wetland Scientists,* 26 (1), pp. 79–96.

Jones, W. M. Fraser, L. H. Curtis, J. (2010). Plant community functional shifts in response to livestock grazing in intermountain depressional wetlands in British Columbia, Canada, *Biological Conservation,* 144 (1), pp. 511- 517.

Keddy, P. A. Fraser, L. H. Keogh, T. A. (2001). Responses of 21 wetland species to shortages of light, nitrogen and phosphorus, Bulletin of the *Geobotanical Institute ETH*, 67, pp. 13- 25.

Limpitlaw, D. Rudigergens, M. (2006). Dambo mapping for environmental monitoring using Landsat TM and SAR imagery: Case study in the Zambian Copperbelt, *International Journal of Remote Sensing,* 27 (21), pp. 4839–4845.

Marty, J. T. (2004). Effects of Cattle Grazing on Diversity in Ephemeral Wetlands, *Conservation Biology*, pp. 1626–1632.

Matiza, T. Crafter, S. A. (1994, January). Wetlands ecology and priorities for conservation in Zimbabwe: proceedings of a Seminar on Wetlands of Zimbabwe held in Harare, Zimbabwe

Menard, C. Duncan, P. Fleurance, G. Georges, J. Y. Lila, M. (2002). Comparative foraging and nutrition of horses and cattle in European wetlands, *Journal of Applied Ecology,* 39, pp. 120–133.

Mharapara, M. Munema, M. D. Mkwanda, R. (1997). Wetland characterization and classification for sustainable agricultural development, FAO, Zimbabwe country paper, Experiences on wetland characterisation, classification, management and utilization for agricultural development in Zimbabwe: a case for wetland research, FAO.

Middleton, T. (2002). Winter burning and the reduction of Cornus serecia in sedge meadows n southern Wisconsin, *Journal for the Society for Ecological Restoration,* 10 (4), pp. 723- 730.

Milotic, T. Erfanzadeh, R. Petillon, J.. Maelfait, J. P Hoffmann, M. (2010). Short term impact of grazing sheep on vegetation dynamics in a newly created salt marsh site, *Grass and Forage Science,* 65 (1), pp. 121- 132.

Mtetwa, S. Schutte, C. F. (2002). An interactive and participative approach to water quality management in agro-rural watersheds, *Water SA,* 28(3).

Mueller-Dombois, Ellenberg, H. (1974). Aims and Methods of Vegetation Ecology, John Wiley and Sons, New York.

Price, J. N. Wong, N. K. Morgan, J. W. (2010). Recovery of understorey vegetation after release from a long history of sheep grazing in a herb-rich woodland, *Austral Ecology,* 35, pp. 505–514.

Pyke, R. Marty, J. T. (2004). Cattle Grazing Mediates Climate Change Impacts on Ephemeral Wetlands, *Conservation Biology,* 36, pp. 1619–1625.

Reeves, P. N. Champion, P. D. (2004). Effects of livestock grazing on wetlands. National Institute of Water and Atmospheric Research Ltd, Client Report, Project EVW04273.

Roberts, N. (1988) Dambos in development of a fragile ecological resource, *Journal of Biogeography,* 15, pp. 141-148.

Scoones, I. (1991a). Wetlands in drylands: the agroecology of savanna systems in Africa, International of Institute of Environment and Development. Drylands programme, Scoones, I. (1991b). Wetlands in Drylands: Key Resources for Agricultural and Pastoral Production in Africa, *Ambio*, 20 (8), pp. 366-371.

Thompson, J. G. (1972). Utilisation of vleis: Water in agriculture, *Rhodesian Agricultural Journal* 15.

Thurow, T. L. Hussein, A. J. (1989). Observations on vegetation responses to improved grazing systems in Somalia, *Journal of Range Management*, 42 (1), pp. 16 -19.

Tooth, S., McCarthy, T. S. (2007). Wetlands in drylands: geomorphological and sedimentological characteristics, with emphasis on examples from southern Africa, *Progress in Physical Geography*, 31(3).

Vincent, V. Thomas, R. G (1961). An Agricultural Survey of Southern Rhodesia, Part 1: Agro-Ecological Survey

Whitlow, R. (1989). A review of dambo gullying in south-central Africa. *Zambezia*, XVI Department of Geography, University of Zimbabwe,.

Wild, H.A. (1972). Rhodesian Botanical Dictionary of African and English Plant names, National herbarium, Department of Research and Services, Ministry of Agriculture. Government printer, Salisbury, Rhodesia.

Xiong, S. Johansson, M. E. Hughes, F. M. R. Hayes, A. Richards, K. S. Nilsson, C (2003). Interactive effects of soil moisture, vegetation canopy, plant litter and seed addition on plant diversity in a wetland community, *Journal of Ecology*, 91, pp. 976–986.

List of Appendices

Appendix 1: List of herbaceous plant species found at sites under all the grazing intensities

	GRAZED				UNGRAZED	
SPECIES	**MG1**	**MG2**	**CG3**	**CG4**	**UG5**	**UG6**
Andropogon eucomus	1	1	0	1	1	1
Andropogon gayanus	0	0	0	0	1	0
Aristida spp.	0	0	0	0	1	0
Aristida junciformis	1	1	0	1	1	1
Aristida melidonalis	1	0	0	0	0	0
Brachiaria brizantha	0	0	0	1	1	0
Bricaria nigropedata	0	0	0	0	0	1
Bricharia spp	0	1	1	0	0	0
Commelina benghalensis	1	0	0	0	0	0
Corchorus tridens	1	0	0	0	0	0
Cynodon dactylon	1	1	1	1	1	0
Cyperus angolensis	1	1	1	1	0	0
Cyperus esculentus	1	1	1	0	1	1
Cyperus obtusiflorus	1	1	1	1	0	0
Cyperus rotundus	1	1	1	1	1	1
Cyperus spp 1	0	1	1	1	1	1
Fuirena pubescens	1	0	0	0	0	0
Fuirena ciliaris var. angolensis	1	1	0	1	1	1
Bulbostylis spp	0	1	1	1	0	0
Cyperus spp 7	1	0	1	0	0	0
Cyperus spp 9	1	0	0	0	0	0
Digitaria penzaii	0	0	1	1	1	1
Paspalum scrobiculatum.	0	0	0	1	0	0
Eragrostis bicola	0	0	1	0	0	0
Eragrostis chapelieri	1	1	0	1	0	1
Eragrostis inamoena	1	1	1	1	1	1
Eragrostis plana	1	1	1	1	1	1
Eragrostis stapfii	1	1	0	1	1	1
Eragrostis trichofolia	1	0	1	1	1	1
Fimbristylis dichotoma	1	0	0	0	0	0
Heteropogon contortus	1	1	1	1	1	0
Hibiscus museei	1	1	0	0	0	0

Hyparrhenia filipendula	1	1	1	1	1	1
Hyparrhenia nyassae	0	0	0	0	1	1
Hyperthelia dissoluta	0	0	0	1	1	0
Leucas martinicensis	1	0	0	0	0	0
Loudetia simplex	1	0	0	0	1	1
Macrochloa kunthii	0	0	1	1	1	1
Oxalis latifolia	1	0	0	0	0	0
Panicum dregeanum	0	0	0	0	1	0
Pelargonium luridum	0	1	0	0	0	0
Perotis patens	0	0	1	1	0	0
Pogonathria squarosa	1	0	1	0	0	0
Rhynchelytrum repens	0	0	0	0	0	1
Richardia scabra	1	1	1	1	0	0
S. palidifusca	0	1	0	1	1	1
Schkuhria pinnata	1	0	1	0	0	0
Sida alba	0	1	0	0	1	0
Sporobolus pyramidalis	1	0	1	1	0	0
Stereochlaena cameronii	0	0	0	0	1	1
Stylo	1	1	1	1	0	1
Gerbera piloselloides	1	1	0	1	0	0
Geigeria filifolia	1	0	0	0	0	0
Craterostigma plantagineum	0	0	1	0	0	0
Gomphrena celosioides	0	0	1	0	0	0
Unknown runner grass	0	0	1	0	0	0
Urochloa mozambicensis	0	0	1	1	0	0