Botany Research Journal 1 (1): 1-8, 2008
ISSN: 1995-4751

The Impact of Browsing and Grazing Pressure on Vegetation Community, Composition and Distribution Pattern in Ikona Wildlife Management Area, Western Serengeti, Tanzania

C. Mligo and H.V.M. Lyaruu
Department of Botany, University of Dares, P.O.Box 35060, Tanzania

Abstract: The study was carried out at Ikona WMA in the Western Serengeti National Park. It was aimed at assessing the impacts of grazing and browsing by both the domestic and wild animals including human activities on vegetation community structure, composition, diversity and association in Ikona WMA. The vegetation sampling followed Nested Quadrat Sampling Technique. It was found that three-vegetation community types separated based on the effects of browsing and grazing by wild animals, human activities and variation in environmental habitats. Community A dominated by *B. aegyptica* woodland and highly affected by bush fire, debarking and charcoal making with the lowest species diversity (T4, 1.057- T5, 1.393), B was that of open grassland and was highly affected by elephant browsing and knockdown of most woody species as well as overgrazed by domestic animals, having the lowest species diversity (T1, 1.0412- T2, 1.465) and C was of River Rine community dominated by *F. sycomorus* (with *A. African* epiphyte), *A. zanzibarica* and *P. maximum* showing healthier habitat with available ground water. C also had the highest plant species composition and diversity (T3, 2.56; T6, 2.5). There was significantly low plant species association between *P. Maximum* and *A. senegal*, *Acacia seyal*, *Acacia drepanolobium* and *B. aegyptica* due to effects of wild and domestic animals. It was concluded that, modification of woody community to open grasslands was due to the effects browsing and knockdown of woody species by elephants and grazing by wild and domestic animals as well as human activities in the WMA. Sharing of resources in the pastures is detrimental due to the lack of niche separation and resource partitioning between wild and domestic grazers and browsers.

Key words: Grazing, browsing, community, association, diversity, composition, distribution

INTRODUCTION

Ikona Wild life Management Area (WMA) is located at Serengeti District. It is found on the western part of Serengeti National Park one of the oldest African National Parks covered by the worlds' largest grassland community (Thomas *et al*., 2007). It boarders with Ikorongo Game Reserve to the East and Grumeti Reserve to the South-West, hence acting as a buffer zone to the Serengeti National Park and game reserves (Fig. 1). The area forms a part of the migratory corridors of wildlife between Serengeti and Masai Mara ecosystems. Ikona (WMA) with acreage of 311.4 km^2 was a jointly undertaking to be managed by the surrounding five villages, to include, Park Nyigoti, Makundusi, Nyichoka, Nata Mbiso and Robanda (Fig. 1). The main activities in these villages were pastoralism and agro-pastoralism where crops such as finger millet, maize, sorghum and livestock such as cattle, goats and sheep were common. However, each of the 5 villages contributed a substantial amount of land to the establishment of the WMA. The establishment of the WMA was in line with the Tanzanias' wildlife policy of 1998 whereby villagers residing close to wildlife sanctuaries have the right to benefit more from funds accrued from wildlife related activities through establishment of the WMAs.

Following the establishment of Ikona WMA, some of the activities which were illegally going on in the area (such as hunting and poaching) were suspended. This resulted into little movement of wild animals in the area and increased abundance of many of the animal species due to increased in security. Some of the animals which were vulnerable to poachers such as elephants (locally nick named VIP cattle) and other grazers and browsers increased in their populations. Such an increase in populations in the WMA has conservation implications because of their impact on the vegetation communities and plant species association. On the other hand, a wide range of grassland in Ikona WMA is encroached by cattle grazing, browsing and farming since there were no set restrictions on livestock husbandry and incompatible human activities on the boundaries and inside the WMA.

Corresponding Author: Cosmas Mligo, Department of Botany, University of Dares, P.O.Box 35060, Tanzania

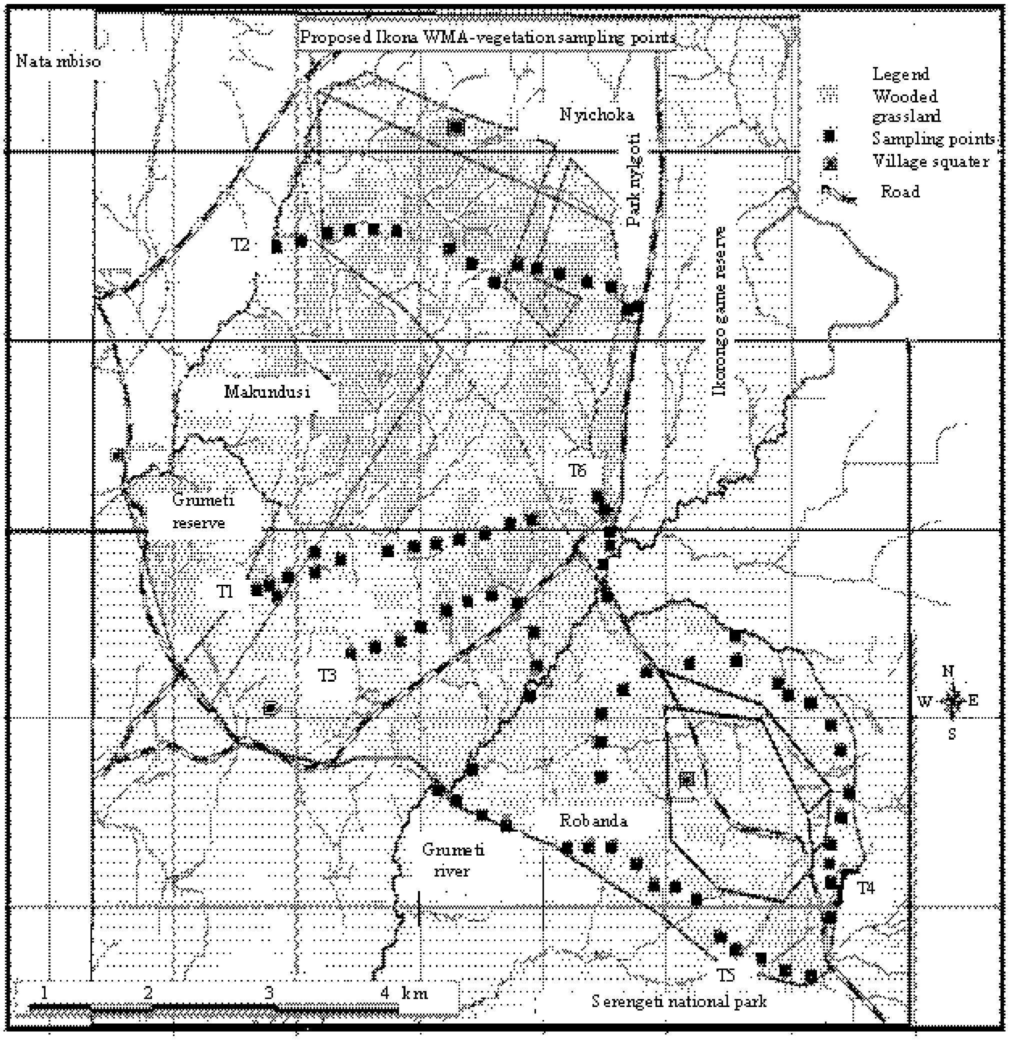

Fig. 1: Location sampling points in Ikona MWA at the Western Serengeti

This might have contributed to the variations in vegetation community structure and diversity in the Ikona WMA. Although, larger part of Serengeti grasslands have experienced a major vegetation changes due to effects of climatic changes (Gillson, 2006) but changes due to grazing and browsing by large mammals and other interferences caused by human was still unknown. The study aimed at assessing the impacts of grazing and browsing by both the domestic and wild animals including human activities on vegetation community structure, composition, diversity and association in Ikona WMA.

MATERIALS AND METHODS

Vegetation sampling: Reconnaissance Survey was carried out in a period of 2 days to characterize the vegetation types found in the Ikona WMA. The idea of doing the reconnaissance survey was to know the details of the vegetation segments in the project area which was relatively heterogeneous in order to come up with a sound sampling protocol of the vegetation communities present in the ecosystem. The vegetation of the study area was then sampled using the standard Nested Quadrat Sampling Technique (Stohlgren *et al*., 1995). This method entails the use of rectangular quadrats as it combines the advantage of minimizing edge effect as well as increasing the chances of including most species in the study area. Three level sampling was done with trees sampled in 20×25 m^2 quadrats. Shrubs and saplings were sampled in 5×2 m^2 quadrats nested in the bigger quadrat and finally grasses and herbs were sampled in smaller quadrats measuring 2×0.5 m^2 nested in the 5×2 m^2 quadrats. The information collected included tree identity, shrubs and juvenile trees, grasses and herbaceous species and the levels of browsing and grazing pressure was assessed by using a 6-point scale (Rulangaranga, 2000). During this study, plant species were identified in the field and those species that proved difficult to identify in the field were collected and transported to Dares Salaam herbarium where they were identified using the available floras, manuals and also matched with preserved dried herbarium specimens.

Vegetation analysis using the Two Way Indicator Species Analysis (TWINSPAN): The vegetation communities from Ikona WMA were classified by the use of (TWINSPAN) (Hill *et al*., 1975). TWINSPAN tested the significance community structural differences among vegetation samples collected from different parts of the area as actually represented due to the effects of grazing pressure and other anthropogenic activities.

Plant species diversity: The Ikona WMA was divided into 6 major study sites where species diversity was calculated from the raw data obtained from each study site, using Shannon's diversity index (Shannon and Weiner, 1948) as shown:

$$\text{Deversity index (H!)} = -\sum_{i}^{\infty} \text{pi In pi}$$

Where,

pi = ni/N, the number of individuals found in the ith species as a proportion of total number of individuals found in all the species.

In = Natural logarithms to base *e*.

The variation in species diversity between transect was compared by using repeated measures analysis of variance (Zar, 1984). And the plant species association was assessed by using Chi-square (X^2) (Henderson and Seaby, 1999).

RESULTS

Vegetation community analysis using TWINSPAN: TWISPAN dendrogram shows hierarchical separation of samples into 3 vegetation community groups denoted as A, B and C (Fig. 2). The 3-vegetation community types separated based on the effects of browsing and grazing by wild animals, human activities and variation in environmental habitats. Samples first separated into two broad dichotomies i.e., A and BC on the basis of *Panicum maximum* as indicator species of fertile soil and shaded or moist habitat (Fig. 2). Vegetation community type A (T4 and T5), separated as woodland vegetation dominated by *Balanites aegyptica* which provides sufficient forage in all the year round as it is evergreen in all seasons of the

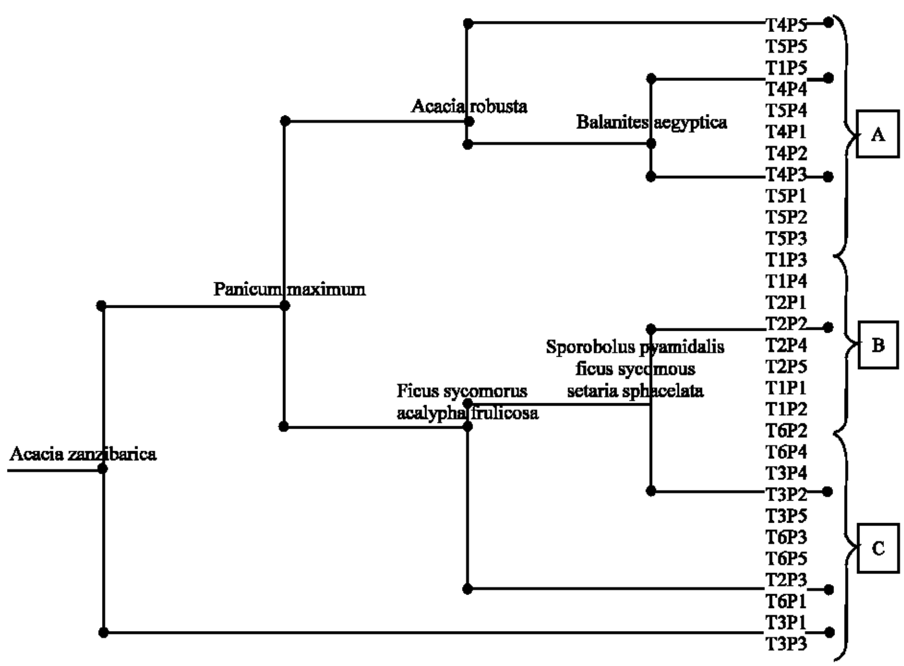

Fig. 2: TWINSPAN showing the three vegetation communities from Ikona WMA

year. This vegetation community types were located at Robanda village and this side of the ecosystem was also highly affected by bush fire and human activities such as debarking of *Balanites aegyptica* and charcoal burning.

BC separated further to bring about two important communities where *Ficus sycomorus* as indicator species of possible availability of ground water and long term seasonal moist habitat. On the other hand *Setaria sphacelata* and *Sporobolus pyramidalis* were indicator species of open grassland since woody species were heavily grazed and browsed as well as being knocked down by elephants. The vegetation community B (T1 and T2) was dominated by *Themeda triandra* and some *Acacia* sp. forming open *Themeda grassland* and *Acacia-Themeda* wooded grasslands (Fig. 2). On the other hand community C (T3 and T6) was located along Grumeti River (which only a seasonal river) forming River Rine vegetation community types dominated by *Ficus sycomorus* (with *Anselia africana* an epiphyte), *Acacia zanzibarica* and *Panicum maximum* showing the presence of high soil nutrient contents, moist and healthy habitat.

Similarity in floristic composition among transects from Ikona WMA: The similarities in species composition using Sorensen similarity coefficient (S_c) was the highest between transect 4 and 5 (T4 and T5, ($S_{c=}$ 0.875) than with other sets (Table 1). These have suffered similar level of environmental influence and hence similar in plant species composition. Also species composition in Transect 1 (T1) was to some extent similar to that from T2 (Sc = 0.531) and was slightly higher than that between T1:T6, T2:T6 and T3:T6 (Table 1).

Effects of grazing and browsing pressure on plant species diversity between transects: Plant species diversity varied from one transect to the other depending on the intensity of grazing and browsing as well as the distribution of herbivores populations in the WMA. It was observed that, the third (T3) and sixth (T6) transects recorded the highest species diversity (T3 = 2.56±0.13 and T6 = 2.505±0.179 than T1 (1.0412±0.098); T2 (1.465± 0.169); T4 (1.057±0.183) and T5 (1.393±0.176) (Fig. 3). The Analysis of Variance (ANOVA) showed significant difference between transects (F = 18.722, p<0.0001). However, plant species diversity was significantly higher at T3 than T1 (LSD = 1.523, F = 9.539, p<0.001); T2 (LSD = 1.099, F = 6.884, p<0.001); T4 (LSD = 1.508, F = 9.442, p<0.001) and at T1 (LSD = 172, F = 7.33, p<0.001). Also diversity was significantly higher at T6 than T1, (LSD = 1.46, F = 9.164, p<0.001); T2 (LSD = 1.039, F = 6.509, p<0.001); T4 (LSD = 1.448, F = 9.06, p<0.001) and T5 (LSD = 1.112, F = 6.964, p<0.001) in that order. The grazing and browsing pressure at T3 and T6 were at the lowest scale values.

Effects of Browsing and grazing on plant species association in Ikona WMA: There was a siginificnat association between *Panicum maximum* and the *Acacia mellifera* (X^2 = 3.8, p<0.05), *Acacia zanzibarica* (X^2 = 3.03, p<0.05) and *Ficus sycomorus* (X^2 = 5.03, p<0.05) (Table 2)

Table 1: Sorensen similarities between Transect from the sampling area

Transects	T1	T2	T3	T4	T5	T6
T1	1					
T2	0.5316	1				
T3	0.3673	0.3294	1			
T4	0.3333	0.3729	0.3333	1		
T5	0.3235	0.3636	0.2973	0.875	1	
T6	0.4696	0.451	0.4463	0.3579	0.3297	1

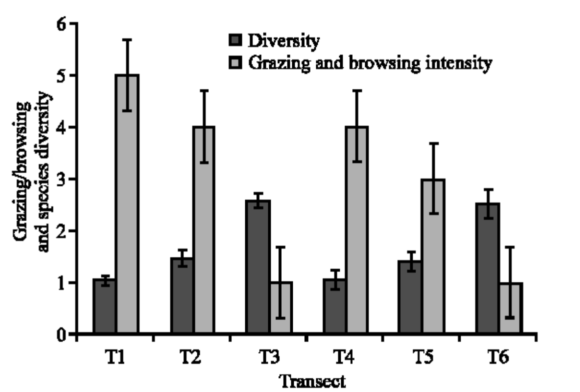

Fig. 3: Variation in plant species diversity between transects

Table 2: Effects of elephant browsing on plant species association

	A.me.	A. sn.	A.sy	Ac.d	A. z	B.ae.	F. sy.	H. f.	P. m.
A.me.	0								
A. sn.	2.25	0							
A.sy	0.03	0.16	0						
Ac. d	0.03	-0.01	-4.84	0					
A. z	-0.11	-0.20	-0.07	0.40	0				
B.ae.	0.03	0.68	0.82	-0.57	-0.69	0			
F. sy.	-0.11	0.20	0.07	-0.40	1.16	-0.40	0		
H. f.	-4.53	-0.45	-0.82	-2.23	-0.40	0.00	-0.40	0	
P. m.	3.8	0.01	0.23	0.08	3.03	0.08	5.03	0.38	0

A.me = Acacia melifera, A.sn = Acacia senegal, A.sey = Acacia seyal, Ac.d = Acacia drepanolobium, A.z = Acacia zanzibarica, B.ae = Balanites aegyptica, F.sy = Ficus sycomorus, H.f = Hyperrenia fillipendula, P.m = Panicum maximum (X^2 = 2.20, p<0.05) with little effects from grazing and browsing as well as human influence. However, the lowest association between *Panicum maximum* with *Acacia senegal*, *Acacia seyal*, *Acacia drepanolobium* and *Balanites aegyptica* ($p>0.05$). Also significantly negative association between *Hyperrhenia filipendula* with *Acacia mellifera* ($X^2 = -4.53$, $p<0.05$) and *Acacia drepanolobiun* ($X^2 = -2.23$, $p<0.05$) (Table 2) where such plant species grow in different habitats.

DISCUSSION

Vegetation community and distribution patterns in Ikona WMA: The vegetation of the Ikona WMA was heterogeneous community types with very patchy, without any defined distribution pattern. A very important and critical habitat along Grumeti River (T3 and T6 in Fig. 2) which was characterized by *Acacia zanzibarica*, *Albizia* sp. *Trichilia roka* and *Ficus sycomorus* which is an indicative feature of availability of groundwater. The presence of orchid *Ansellia africana* was an indication that this vegetation community was rather healthy and has suffered little effects of browsing and grazing. The community had also high cover abundance of *P. maximum* which was an indicator of soil fertility and favourable humid zones. This grass species (*P. maximum)* performs well in the present of high soil moisture content, shaded habitats. i.e., grows well under the canopy of woody species. Therefore, the decrease in canopy of woody plant species due to grazing and browsing pressure decreases the abundance of this grass species.

Although, in other areas *P. maximum* were in a mixture with *Sporobolus panycoides, Heteropogon contortus* and *Hyparrhenia filipendula* but the *P. maximum* was the dominant species in all the shaded habitats. On the other hand, *Themeda triandra* dominates the open areas forming a *Themeda triandra* grassland vegetation community and sometimes mixed with scattered woody plant species making a scattered *Acacia-Themeda*-wooded grassland community in a rangeland. In water lodged areas, *T. triandra* failed to grow well, however it grew well in dry areas and in black cotton soil. The luxuriant growth and high performance of *T. triandra* were highly activated by frequently set in bush fire and grazing pressure by the numerous residential wild herbivores translocating themselves in the Ikona rangelands. However the grass species was exhausted completely in areas intruded by domestic livestock due to its palatability (Mligo, 2006).

Vegetation community type A is *Balanites aegyptica* was a typical woodland vegetation which provides sufficient forage in all the year round as it is evergreen in all seasons of the year. This vegetation community types were located at Robanda village and this side of the ecosystem was also highly affected by bush fire and human activities and charcoal burning (Fig. 4 a and d). *B. aegyptica* has been targeted in the area by business smugglers for pharmaceutical industries in the neighbouring country and hence debarked and killed many individual trees in many parts in the WMA (Fig. 4b). The illegal harvesting of medicinal plant parts and killing of the whole individual plants have resulted into poor distribution patterns of *B. aegyptica* and affected the association with other species in the WMA. This is due to the fact that, harvesting entails total uprooting of the whole plant, threatening the total disappearance from the area.

Variation in plant species composition and diversity in different parts of the WMA: Plant species composition and diversity were affected by many factors to include, wildlife and livestock grazing and browsing as well as other environmental factors. T3 and T6 had high significant similarity species composition and recorded the highest plant species diversity than other transects. These were together classified as vegetation community C which was bushy and was of River Rine vegetation community type. With high species composition, the bushy community functions as potential area where carnivores like lions and leopards hide. Therefore, high plant species composition and diversity at T3 and T6 might have been contributed by the avoidance of many of the grazing and browsing ungulates to forage this area on the fear of carnivores that preferred to rest in these bushed areas. However, with the decrease in forage in open woodlands during the dry seasons, herbivores have no option than seeking for green forage everywhere in the rangelands in such a way that carnivores do not starve in this seasons. Similarly the favourable habitats of the area due to its fertility and long lasting moisture made most plant species to flourish contributing to evergreen foliage, high species composition and diversity. On the other hand the lowest plant species diversity at T1 T2 T4 and T5 was contributed by grazing and browsing by both wild and domestic livestock, frequently set in bushfire and human activities such as charcoal making. At Robanda (T4 and T5) were area where charcoal making and frequently set in bush fire and wind erosions affected the area resulting into low plant species diversity (Fig. 4d). Most of the woody species in the areas seem to be fire intolerant and are disappearing rapidly from the area due to frequently burning and hence the grassland community is being threatened by invasive and weedy plant species that were emerging in most parts. Diversity is likely to

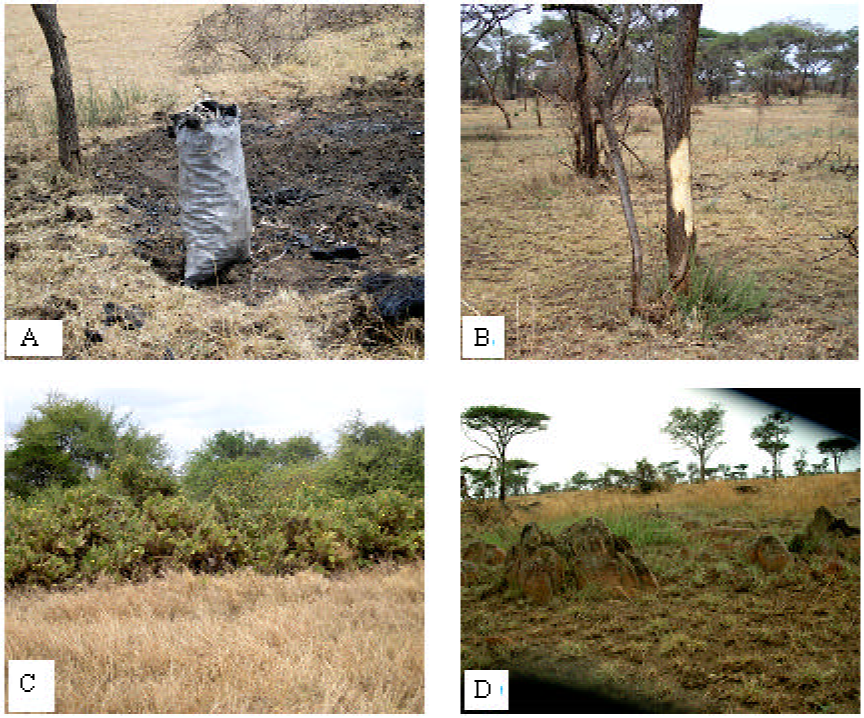

Fig. 4: A- Charcoal making at Ikona WMA a threat to the ecosystem, B- Debarking of *Balanites aegyptica* for medicinal purpose, C- The invasion of *Opuntia vulgaris* in Ikona WMA , D- Exposed stones due wind erosion as result of recurrent bush fire

continue decreasing and plant species composition will continue changing due to disappearance of native plant species and replacement bythe invasive species (Fig. 4c).

On the other hand the lowest plant species diversity at T1 and T2 was because of the effects of increased elephant populations that heavily browsed the area and knocked down most of the woody plant species and their associates on the Nothern-Western part of the Ikona WMA. On the other hand domestic animals shared the pastures with wild animals which caused the effects more severe in the WMA. An encroachment by domestic livestock made the area heavily grazed and browsed and therefore, resulted into the lowest in plant specie diversity. There were potential pastoralists from the bounding villages such as Park Nyigoti, Makundusi, Nyichoka which still use the areas as grazing land. It seems that, protection offered within the Ikona WMA was not an effective management strategy for wildlife conservation. Although, regulations were in place regarding wildlife management, but there were no restrictions on livestock husbandry and incompatible human activities on the boundaries of the WMA. It has beeen reported (Wiseman *et al.*, 2004), that livestock encroachment has an adverse effect on wild mammals. It causes direct grazing and browsing competition between livestock and wildlife and the vegetation gets depleted fastly. The plant species diversity in the areas has been consequently decreased due to lack of niche separation and resource partitioning between wild and domestic grazers and browsers in the Ikona WMA.

Variation in plant species association and distribution pattern in the IKONA WMA: The elephants (locally known as the VIP cattle) in the western Serengeti area have increased in numbers due to protection and conservation measures seriously taken. However, they account for several trees die backs in the WMA they area heavily browsed and knocked down in the process. There were serious effects of the increased population of elephats on plant species association which was found detrimental to the ecosystem. Although, there was a significant association between *Panicum maximum* and the *Acacia mellifera*, *Acacia zanzibarica* and *Ficus sycomorus* these woody plant species were not preferred by elephants. On the other hand, *A. mellifera* has hooked thorns which make elephants feel uncomfortable when browsing. The lowest association between *Panicum maximum* with *Acacia senegal, Acacia seyal, Acacia drepanolobium* and *Balanites aegyptica.* Such species were preferred by browsers and were highly browsed and knocked down by elephants through out the sampling areas where the effects were more serious at T1 and T2 resulting to decreased level of associations as well the diversity (Fig. 3 and Table 2).

The negative association between *Hyparrhenia filipendula* with *Acacia mellifera* and *Acacia drepanolobiun* (Table 2) was due to the fact that such species grew in different habitats and hence grazing and browsing effects could not be accorded in this case. The browsing pressure affected plant species association in a short time as most part of the WMA was converted to grasslands. Although, *Acacia drepanolobium* and *Balanites aegyptica* could survive in waterlogged areas, however, the tremendous die-backs of *Acacia drepanolobium* in the floodplain grassland successionally resulted into vegetation conversion from woodlands and wooded grasslands into grassland due to failure of root establishment and the effects of browsing particularly knock down by elephants. On the other hand, the rampant die back of *Acacia drepanolobium* trees in the water logged floodplain grassland could probably be explained by other factors as well such as cracking and shrinking property of the heavy black cotton soils killed the trees by cutting tree roots. Apart from the above species, other highly affected woody plant species were the *Acacia Senegal*, *Acacia seyal* and *Acacia nilotica* which are shallow rooted species in the ecosystem and also the association with grass species such as *Panicum maximum* and *Hyparrhenia fillipendula* was low.

As it has been reported (MacGregor and Conor, 2004; Mapaure and Mahlanga, 1998) that, elephants apart from other browser of the rangelands they are known to destroy individual trees. This reduces the survival interaction of native plants species that are historically favoured by the habitats in this ecosystem. The density of such selectively browsed species decreases and also may provide opportunities to other species (invasive and succession species) with exponential reproductive rate to thrive inside the WMA as was seen at Robanda with high abundance of (e.g., invasive *Opuntia vulgaris, Grevillea robusta*, *Senna siamea*, *Tagetes minuta*, *Lantana camara* and *Lantana trifolia*). Of these species, *Opuntia vulgaris* is a threat to the WMA as it quickly replaces the native grass, thereby bringing about rangeland deterioration (Fig. 4c). Since *P. Maximum* grows in association with woody plant species in the rangelands, any changes in the environment that is accompanied by the removal of shades through elephant browsing and knockdown of trees in the WMA (*Acacis* sp. and *Balanites aegypica*) leads to the reduction in the density of such woody species and the associated grass species *P. maximum* as well. It has been reported that, woody plant species canopies acts as sunlight attenuators. Hence their presence help such grass species to capture the necessary frequency it requires for its metabolic reactions and hence its best performance in the shaded habitats. On the other hand *P. maximum* has the ability to maintain high water potential and is adapted to water stress in shaded habitats (Mapaure and Mhlanga, 1998). Since, the canopy trees close to elephant reach have been removed through knock down and browsing, the life of the species occurring under the shades of such trees like *P. maximum* has been threatened and the distribution of this grass species varied from place to place in relation to the distribution of the canopy trees. The canopy trees create microenvironments that improve the water status of the plants growing beneath their canopies and therefore, favouring the abundance of *P. maximum* in the shaded habitats.

CONCLUSION

Conclusively, modifications of vegetation community stratifications were due to the influences of environmental variations operating within the Ikona rangelands. Such influences were due to the combinations of wild and domestic grazing and browsing animals as well as human activities taking place in the WMA. These resulted into variation in vegetation communities as they were encountered during this study. Elephants found to affect much woody plant species in the area due to knockdown of many trees and severe browsing, where woody plant species density and canopies decreased which affected plant species associations in the rangeland. The feeding habits of the both wild and domestic animals in the area resulted into the ecosystem transformation from intact woodlands into grasslands in many parts of the area. It was then recommended that, there is a need of intensive scientific study on elephant population dynamics in the WMA in order to control the population of elephants in particular so as to prevent rapid modification of the ecosystem to open grasslands. On the other hand, regular hunting as one of the avenues of income from the WMA should be planned to minimize populations of both grazers and browsers so that the plant-animals interaction can result into stable communities in Ikona ecosystem. Also the prickly *Opuntia* should be seen as a very potential environmental threat. Since the invasion of

Opuntia vulgaris reduces the quality of the rangeland and replaces the palatable native grass species, it needs to be eliminated using biological control measures. Sharing of the pasture between the wild and domestic livestock should be abandoned so as to avoid competition between livestock and wildlife that could lead to vegetation depletion fast. Also the interference of wild populations has potential spread of disease from livestock to wild populations which is likely to cause difficulties in wildlife management.

ACKNOWLEDGEMENT

We highly acknowledge Grumeti Fund for financial support.

REFERENCES

Gillson, L., 2006. A large infrequency disturbance' in an East African Savanna. Afr. J. Ecol., 44: 458-467.

Henderson, P.A. and R.H.M. Seaby, 1999. Community Analysis Package. Pisces conservation Limited, Pemington, Lymington, UK.

Hill, M.O., R.G.H. Bunce and M.W. Shaw, 1975. Indicator Species Analysis. A divisive polythetic method of classification and its application to a survey of native pine woodlands in Scotland. J. Ecol., 63: 597-614.

MacGregor, S.D. and T.G. O'Conor, 2004. Response of Acacia tortilis to utilization by elephants in a semi-arid African savanna. South Afr. J. Wildlife Res., 34: 55-66.

Mapaure, I. and L. Mhlanga, 1998. The impacts of Elephant damage to Colophosperma mopane on Namembere Island, Lake Kariba, Zimbabwe. The Zimbabwe Science News, 32: 15-19.

Mligo, C., 2006. Effects of grazing Pressure on plant specie Composition and Diversity in the Semi-arid Rangelands of Mbulu D istrict, Tanzania. Agric. J., 1: 277-283.

Rulangaranga, Z.K., 2000. Obstacles to the sustainable utilization of the vegetations of the semi-arid area of Mbulu District for animal husbandry. The current initiatives in sustainable management of dryland Biodiversity, Arusha, Tanzania.

Shannon, C.F. and W. Weiner, 1948. The mathematical theory of Communication. University of Illinois Press, Urbana: In: Razida, A., Joshi, S.P. and M.M. Srivastava (1980) Composition and Vegetation Diversity in Alpine Grasslands in the Garhnal Himalaya. Trop. Ecol., 39: 133-141.

Stohlgren, T.J., M.B. Falker and L.D. Schell, 1995. A modified Whittaker nested vegetation sampling method. Vegetatio, 17: 113-121.

Thomas, K., E. Gottschalk Klemens and A. Bairlein, 2007. Relationship between vegetation and birds Composition in grasslands of Serengeti. Afr. J. Ecol., 45: 557-565.

Wiseman, R., B.R. Page and T.G. O'Conor, 2004. Woody vegetation changes in response to browsing in Ithala Game reserve, South Africa. South Afr. J. Wildlife Res., 34: 25-37.

Zar, J.H., 1984. Biostatistical Analysis. 2nd Edn. Prentice-Hall, Inc. Englewood cliff's, New Jersey.