Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 4, No. 5, p. 296-302, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Impacts of grazing ungulates on vegetation and soils in areas closer to water holes in serengeti plains, Tanzania

M.B. Hagwet[1*], R.B. Senzota[2], M. Balakrishnan[3], A. Bekele[3]

[1] *National College of Tourism, P.O.Box 9181, Dar es Salaam, Tanzania*

[2] *Department of Zoology and Wildlife Conservation, Box 35064, Dar es Salaam, Tanzania*

[3] *Addis Ababa University, Department of Biology, P.O Box 1176, Addis Ababa, Ethiopia.*

Article published on May 20, 2014

Key words: Environmental degradation, grazing ungulates, Serengeti Plains, water holes

Abstract

Impacts of grazing ungulates on vegetation and soils in areas closer to water holes in Serengeti plains were studied between September 2004 and December 2004. Grass cover, percentage of grass grazed and soil characteristics closer to water holes and those as far as 4 km from water sources were evaluated. Grazing was found to be significantly more intense ($P=0.001$, $F=8.44$, $df=35$) closer to water holes than in areas away from water holes. Total grass cover and species diversity were significantly lower nearer water holes ($P=0.01$, $F= 5.32$, $df= 35$, $P<0.0001$, $F=10.00$, $df=35$). Percentage of clay, electrical conductivity and pH were significantly higher in areas close to the water holes and decreased with increasing distances from the water holes ($P=0.01$, $F=4.85$, $df=35$; $P=0.02$, $F=4.02$, $df=35$ and $P<0.0001$, $F=17.05$, $df=35$ respectively). Soil organic matter, total nitrogen and potassium were significantly lower ($P=0.03$, $F=3.89$, $df=35$; $P<0.0001$, $F=26.9$, $df=35$ and $P<0001$, $F=37.34$, $df=35$) in areas closer to the water holes. Park's management is recommended to install artificial waterholes and salt licks in different areas of the Park to encourage a more even distribution of animals over the park to reduce level of environmental degradation around the few existing water holes.

***Corresponding Author:** Hagwet ✉ mboay@yahoo.com.

Introduction

Land degradation caused by grazing and trampling is expected to be more pronounced in areas frequently visited by animals. In the Serengeti plains, during the dry season the resident grazers concentrate near the few water holes that retain water into the dry season (Bernhard and Michael, 1965). The concentration of water holes in few areas of the Park could result in land degradation due to the damage of vegetation and loosening of the soil as a result of trampling by large herbivores (Senzota, 1997). Grazing pressure may also exert profound influence on the community structure, diversity as well as soil characteristics of an area (Abrahamson 1989). Grazing either affects plant growth or seed production through reducing the vegetative growth required to support reproduction (Robert, 1990; Moore *et al.,* 2003). Wilson (1990) noted that the major impact of grazing resulted from removal of palatable shrubs by livestock close to water holes, thus exposing the soil to water and wind erosion. Grazing and trampling effects have been found to be inversely proportional to the distance from water sources and to be most obvious within 100 m of the water point ("sacrifice" zone) (Andrew and Lange, 1986; Senzota and Mtahko, 1990; Ntalwila, 2001 (Unpublished).

Soils in arid environments are generally nitrogen and phosphorous deficient. Most nitrogen that is available to plants is held in the top 10 cm of soil as a result of breakdown of organic matter and nitrogen fixing algae (Charley and Cowling, 1968). Heavy traffic by livestock breaks up the surface cryptogam crust (Crisp, 1975). As a result, the nitrogen-fixing action of the cryptogams is disrupted. Denudation by removal of surface vegetation and subsequent erosion is a major problem in many countries.

Rapp (1976) reported that grazing around artificial water sources in northern Sudan resulted in the denudation of vegetation and in soil compaction over areas of up to 100 km diameter. Soil compaction is prevalent in heavy stock-traffic areas such as those around water holes and along tracks (Crisp, 1975). Soil compaction reduces infiltration: areas of heavy grazing are known to show much lower infiltration rates than those of light grazing (William and Eric, 1989). Serengeti is famous for supporting large herds of ungulates. During the dry season, the Serengeti plains become very dry and the bulk of the ungulates migrate west and north where water and tree shade are much more available. Still the hundreds of resident ungulates that remain on the plains need drinking water which they get at the few water holes that keep water into the dry season. The impact that the ungulates might have on the waterholes in the plains has not been studied and the present study was carried out to try to partly fill the gap.

Materials and methods

Study area description

The study was conducted in Serengeti National Park which is located in the northern part of Tanzania, at coordinates between 1°30′ – 3°20′ S and 34° 00′ - 35° 15′ E. It covers an area of about 14,763 km^2. It lies on altitude from 920 m in the west to 1850 m in the east. Temperature is relatively constant with mean monthly maximum ranging from 27°C to 28°C and minimum from 13 °C to 16°C. Annual rainfall is bimodal with heavy rains during March to May and short rains during November to December. Rainfall varies from 1200 mm in the north to less than 400 mm in the southeastern plains and in the Rift Valley (Sinclair, 1995). Vegetation is predominantly treeless grassland within the south eastern plains and woodland in the north western part of the Park. Soils of the Park are highly saline and shallow in the eastern plains due to their being of volcanic origin, but progressively deeper and less alkaline towards the northwestern plains (McNaughton and Banyikwa, 1995). The Serengeti National Park supports the largest herds of migrating ungulates in the world (Sinclair and Arcese, 1995). It is estimated that there are migratory species of 1.6 million wildebeest (*Connochaetes taurinus,* Burchell, 1823), 200,000 zebra (*Equus quagga quagga,* Boddaert, 1785) and 440,000 Thomson's gazelle (*Eudorcus thomsonii,* Günther, 1884) (Campbell and Borner, 1995)

Site selection

Three water holes were identified and constituted the study sites. They were chosen on the basis of their being known to hold water deep into the dry season in previous years. The first site was on a tributary of Seronera River, the second on the Ngare Nanyuki River and the third on the tributary of the Mbalageti River. These sites were subsequently named Seronera River (site A), Ndiakarta River (site B) and Loyangalani River (site C) (Fig. 1).

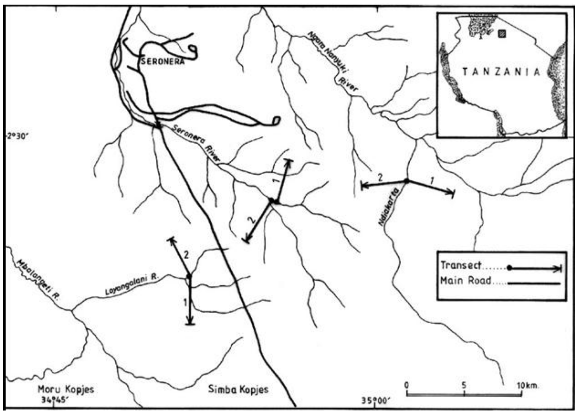

Fig. 1. Map of the study area in the Serengeti plains, showing transects at the three sites: Seronera (Site A), Ndiakarta (Site B) and Loyangalani (Site C) Rivers.

Methods

Transects and sample plots/quadrats

A total of six transects, each of 4 km long were established during the study, two at each study site. Transects were divided into three zones; zone 1 (0-500 m), zone 2 (1000 – 2000 m) and zone 3 (3000-4000 m) from the water holes. A total of 36 quadrats, each of 1 × 1 m^2 were selected randomly and marked using sticks; 12 quadrats in each zone. The measurements taken in these zones were compared to determine the impact of grazers on the vegetation on the basis of the assumption that grazing intensity differs between zones.

Vegetation and soil sampling

Grass cover was measured using pin frame method as described by Kent and Coker (1992). The grazing intensity in terms of grass cut was visually estimated and the measurements were recorded as percentages. From the 36 quadrats, soil samples were collected at the depth of 0-20 cm at the centre of each quadrat using a soil auger, kept in polythene bags, sealed to prevent contamination and moisture loss and taken to the Laboratory of Botany of the University of Dar es Salaam for determination of soil physical and chemical properties.

Data analysis

Shannon-Weaver Index of Diversity, (H′) was used to calculate the species diversity (Kent and Coker, 1992) and species evenness were calculated using the Shannon's evenness index. Variation in plant species diversity between the two seasons was tested using t-test, and that among the three zones was tested using Analysis of Variance (ANOVA). Soil parameters in the three zones were also tested using One-Way ANOVA. All probabilities were two tailed and the results were recorded as significant at $P < 0.05$.

Results

Vegetation cover and species diversity

Grass cover was significantly lower in areas nearer to the water hole than those away from water holes ($P=0.01, F= 5.32, df= 35$). Grazing intensity was significantly higher nearer to the water holes than in areas away from the water hole ($P=0.001, F=8.44, df =35$). During the short rainy season, total cover differed significantly between zones ($P= 0.002, F=7.95, df=35$), being lowest in zone 1 and highest in zone 3. However, grazing intensity did not vary significantly between zones ($P=0.1, F=2.43, df =35$).

Mean diversity shows that zone 1 was the least diverse in both dry and short rain seasons; zone 2 was the most diverse (Fig. 2). Species diversity in zone 1 was significantly lower than those of zones 2 and 3 ($P<0.0001, F=10.00, df =35$) while there was no significant difference ($P>0.05$; Fig. 2) in species diversity between zones 2 and 3.

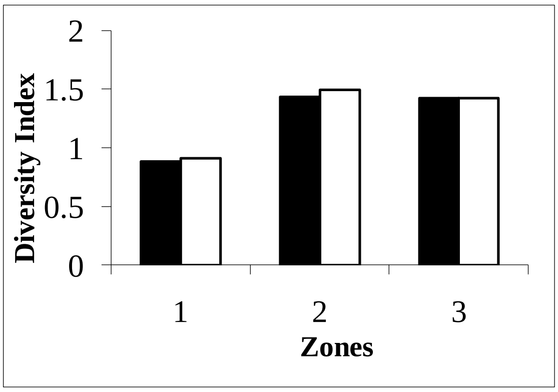

Fig. 2. Mean diversity for plant species among zones 1, 2 and 3 in Serengeti plains, Tanzania, September-December 2004. Closed bar=dry season, open bar =short rain season.

Soil characteristics

(a) Physical parameters

There was a decline in soil bulk density (Bd) and percent soil moisture content (MC) away from the water holes even though the declines were not statistically significant (Bd, P=0.33, F=1.13, df=35) and (MC, P=0.44,F=0.83,df=35; Table 1). The percentage of clay was significantly higher in areas around the waterholes (P=0.01, F=4.85, df=35); and decreased away from the holes. Percentage of silt and sand increased with distance from the water hole; the increase was not statistically significant (Table 1).

Table 1. Analysis of Variance (ANOVA) results for variation of soil physical parameters between zones 1-3 around water holes in Serengeti Plains, Tanzania.

Variables	Sum of Squares	F	Sig ($p \leq 0.05$)
Bd	2.26	1.13	0.33
MC	1290.53	0.83	0.44
% Sand	2033.77	1.66	0.21
% Silt	3017.39	1.92	0.16
% Clay	4338.54	4.85	0.01

(b) Chemical parameters

Organic matter content (OM), potassium (K) and total nitrogen (TN) increased as the distance from the water hole increased whereas, pH and electro conductivity (EC) decreased as distance from the water hole increased; all these varied significantly between zones (Fig. 3; Table 2).

Table 2. Analysis of Variance (ANOVA) results for variation of the soil chemical characteristics between zones 1-3 around water holes in the Serengeti plains, Tanzania. September-December 2004.

Variables	Sum of square	F	Sig ($p \leq 0.05$)
OM	235.135	3.89	0.030
K	1199.86	37.34	0.000
pH	48.80	17.05	0.000
EC	49683200	4.02	0.027
TN	0.54	26.91	0.000

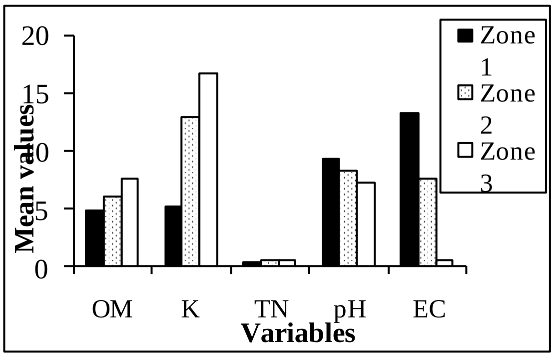

Fig. 3. Soil chemical properties in the study area at Serengeti plains Tanzania, September- December 2004. **Note:** EC values are to be multiplied by 10^2

Discussion

Vegetation cover and species diversity

Land-use by large hoofed animals often damage vegetation thus reducing cover and increasing the potential for soil erosion (Burrows 2000). In the present study, total grass cover was low in quadrats located around the water holes. Closer to water holes animal trails were conspicuous and formed networks of trails. The low grass cover would have been contributed by the high grazing intensity in areas around water holes. Burrows (2000) and Hagwet (2005 (Unpublished) showed that, during the dry seasons, animals spent more time and utilize vegetation in areas close to water points.

Areas close to water holes (zone 1) were found to have low diversity of plant species. This can be explained by the larger extent of disturbances exerted in these areas. Highly disturbed areas and completely undisturbed areas tend to have low species diversity compared to moderately disturbed areas (Humphrey and Patterson, 2000). Crawley (1997) noted that moderate levels of disturbance prevent dominance of one or few species in a particular habitat.

In our study area, zone 2 had the highest diversity of herbaceous plant species likely due to its experiencing a moderate level of grazing pressure. The present study has also revealed that areas around water holes were highly trampled by grazing ungulates resulting in their being bare. These observations agree with the findings of Ntalwila (2001) and Senzota (1997) in their studies of patterns of plant species diversity around Lake Manyara in Northern Tanzania and Mikumi National Park (Central Tanzania) respectively. The high grazing effect around water holes results from higher densities of animals closer to the waterholes; as one moves closer to holes the relative density of animals increase as the same number of animals ends up utilizing a smaller area (Senzota, 1997, Hagwet, 2005). Overgrazing and trampling, likely contribute to the low diversity of plants around water holes. Ground cover and species richness are known to decrease as a consequence of increasing grazing pressure (Zerihun, 1985 (Unpublished). Salt is another factor that could contribute to the low herbaceous diversity in areas close to water holes (de Wit 1977).

Soil characteristics

Soils in areas close to water holes were found to have higher salt levels possibly because of their being deficient in exchangeable bases such as potassium. Closer to water holes there was higher erosion levels that left mostly the subsurface horizons in which the accumulation of material by illuviation has taken place (Brady and Weil, 1999). Similarly, the high EC and PH close to water holes would have resulted from erosion which exposes the lower horizon, where there is always accumulation of salts (Brady and Weil, 1999) and loss of organic matter (Fig.3). The lower organic matter around the water holes likely resulted from loss of surface A-horizons, primarily caused by erosion during the rainy season. The erosion of top-soil (A- horizon) around the water holes would also be enhanced by animal trampling that may have occurred during the dry season as the animals congregated at the few remaining water holes (Hagwet, 2005). It has been demonstrated that organic matters are reservoirs of K^+ minerals (Brady and Weil, 1999). Hence, lack of organic matter might have contributed to low K^+ in areas near water holes.

Our study found higher bulk densities in areas around the water holes than in outer areas. In principle, the soil bulk density is higher when the soil is dominated by coarser texture (sand) and it is lower when fine particles dominate (clay) because the fine-textured soils are normally organized, a condition which assures high total pore space and low bulk density (Brady and Weil, 1999). However, the higher bulk density around the water holes, where fine particles dominated, suggests soil compaction, brought about by animal trampling, or due to low soil organic matter.

Soil total Nitrogen tended to increase with increase in distance from the water hole (Fig. 3). Total nitrogen was highly correlated to percentage of organic matter. One may expect to have higher percentage of total nitrogen in areas close to water holes because of addition through animal urine as ammonium, but the present study showed a different trend. This discrepancy could possibly be due to the influence of low organic matter in those areas close to the water holes due to the fact that the level of grazing was high hence less vegetation.

Conclusion

The impacts presented in this paper are likely the result of frequent use of the areas around waterholes by grazing ungulates. The situation might be worse in places where water holes are situated in one or only a few areas. Previous studies have suggested that the concentration of waterholes in few locations of the wildlife areas could result in land degradation due to the damage of vegetation and loosening of the soil as a result of trampling by large herbivores.

Management actions

Studies by Burrows (2000) and Agouridis *et al* (2005) suggested several management practices including fencing, installation of artificial watering points and salt licks away from watershed areas as mechanisms to reduce impacts around water sources. However, fencing is practical mostly in grazing land for livestock whereas in wildlife areas the most effective management practice might be establishing artificial watering points and salt licks. Hence, we recommend installation of more artificial water holes and salt licks so as to more evenly distribute the grazers and reduce impact on vegetation and soil around the few natural water holes in the Serengeti Plains.

Acknowledgements

The authors thank the Research Programme on Sustainable Utilization of Dryland Biodiversity (RPSUD) for funding this study and Tanzania Wildlife Research Institute (TAWIRI) and Tanzania National Parks (TANAPA) for giving us permit and support during the study. Part of this article was presented to a RPSUD workshop in Arusha workshop. We thank RPSUD for funding our (first author) attendance to this workshop.

References

Abrahamson GW. ed. 1989. Plant-Animal Interactions. McGraw-Hill Inc., New York.

Agouridis CT, Edwards DR, Workman SR, Bicudo JR, Koostra BK, Vanzant ES, Taraba JL. 2005. Stream bank erosion associated with grazing practices in the humid region. American Society of Agricultural Engineers **48 (1)**, 181 -190.

Andrew MH, Lange RT. 1986. Development of new biosphere in arid chenopod shrubland grazed by sheep: changes to the vegetation. Australian Journal of Ecology **11**, 411- 424.

Bernhard G, Michael G. 1965. Serengeti Shall Not Die. Hamis Hamilton Ltd., London.

Brady NC, Weil RR. 1999. The Nature and the Properties of Soils. 12th edition. Prentice Hall, Upper Saddle River.

Burrows DW. 2000. Literature Review of the Potential Impacts of grazing on Aquatic and Riparian Ecosystems in the Australian Dry Tropical Rangelands. Australian Centre for Tropical Freshwater Research. Report No. 00/01.

Campbell K, Borner M. 1995. Population trends and distribution of Serengeti herbivores: implications for management. In: Sinclair ARE, Arcese P, eds. Serengeti II*:* Dynamics, Management and Conservation of an Ecosystem, University of Chicago Press, Chicago, 117-145.

Charley RR, Cowling SW. 1968. Changes in the soil nutrient status resulting from overgrazing and their consequences in plant communities of semi arid areas. Proceeding of Ecological Society of Australia **3**, 28–38.

Crawley MJ. 1997. Plant Ecology. 2nd Edition, Blackwell Sciences, Cambridge.

Crisp DJ. 1975. Grazing in Terrestrial and Marine Environments. Blackwell Scientific Publication, London.

de Wit H. 1977. Soil Map of the Serengeti Plain. Appendix: Soils and Grassland types of the Serengeti Plain (Tanzania). PhD Thesis, Wageningen Agricultural University, Wageningen.

Gereta EJ. 2004. The Importance of Water Quality and Quantity in the Tropical Ecosystem, Tanzania. Ph.D. Thesis, Norwegian University of Science and Technology (NTNU), Trondheim.

Hagwet MB. 2005. Distribution of Grazing Ungulates in Relation to Water Holes, its Consequences on Vegetation and Soil in the Serengeti Plains, Tanzania. M.Sc Thesis, Addis Ababa University, Addis Ababa.

Humphrey JW, **Patterson GS.** 2000. Effects of late summer cattle grazing on the diversity of riparian pasture vegetation in an Upland Conifer Forest. Journal of Applied Ecology **37**, 986-996.

Kent M, Coker P. 1992. Vegetation Description and Analysis: A Practical Approach, CRC Press, Boca Raton.

McNaughton SJ, Banyikwa FF. 1995. Plant communities and herbivory. In: Sinclair ARE, Arcese P, eds. Serengeti: Research, Management, and Conservation of an Ecosystem, University of Chicago Press, Chicago, 49-70.

Moore JP, Taylor JE, Paul ND, Whittaker JB. 2003. Reduced leaf expansion as a cost of systematic induced resistance to herbivory. Functional Ecology **17**, 75-81.

Ntalwila J. 2001. An Ecological Study of the Pattern of Plant Species Diversity around Lake Manyara, Northern Tanzania. M.Sc. thesis, Addis Ababa University, Addis Ababa.

Rapp A. 1976. Sudan: Can Desert Encroachment be stopped? A Study with Emphasis on Africa. In: Rapp A, Le Houérou HN, Lundholm B, eds. Ecological Bulletin, No.24. U.N. Environment Programme & Secretariat for International Ecology, Stockholm,155-164.

Robert ER. 1990. Ecology. 3rd Edition. W. H. Freeman and Company, New York.

Senzota RBM. 1997. Water Dynamics in Mikumi National Park, Tanzania. Research Report. Biannual Newsletter of Research Programmeme on Sustainable Use of Dryland Biodiversity **3**, 22.

Senzota RBM, Mtahko G. 1990. Effect on wildlife of a water-hole in Mikumi National Park, Tanzania. African Journal of Ecology **28**, 147-151.

Sinclair ARE. 1995. Serengeti. Past and Present. In: Sinclair ARE, Arcese P, eds. Serengeti II. Dynamics, Management and Conservation of an Ecosystem, University of Chicago Press, Chicago, 3- 30.

Sinclair ARE, Arcese P. (eds.), 1995. Serengeti II: Dynamics, Management and Conservation of an Ecosystem. Chicago University Press, Chicago.

William LR, Eric B. 1989. Wildlife Ecology and Management, 2nd Edition. Collier Macmillan Publishers, London.

Wilson AD. 1990. The effects of grazing on Australian ecosystems. Proceeding of Ecological Society of Australia **16**, 235-244.

Zerihun W. 1985. Variation in grassland vegetation on the central plateau of Shewa, Ethiopia in relation to Edaphic Factors and Grazing Conditions. PhD Thesis, Uppsala University, Sweden. PhD Dissertationes Botanecea **84,** 1-114.