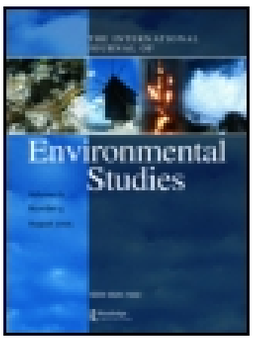

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EFFECTS OF LAND USE CHANGES ON HERBIVORES OF MASAI MARA ECOSYSTEM

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The Narok District has undergone rapid changes in land use patterns from nomadic pastoralism to a sedentary and farming lifestyle. In this study we describe wildlife and livestock numbers and past and present land-use patterns in three group ranches from 1975 to 1997. The purpose of this paper is to examine the effect of land-use changes on herbivore populations. Research methods included observation and interpretation of satellite imageries and aerial photographs, field checks, participant observation and secondary data. Results indicate that human settlement areas have increased significantly ($\chi^2_r = 11.475$, 3 df, $p = 0.001$), while natural vegetation area has decreased insignificantly ($\chi^2_r = 0.2$, 3 df, $p = 0.777$) between 1975 and 1997. Trend analysis indicated an increase in livestock numbers ($601100 + 843$ year; $r^2 = 0.127$; $P = 0.018$), a decrease in wildlife numbers ($953400 - 632$ year; $r^2 = 0.272$; $P = 0.036$) and an overall increase in large herbivore numbers ($155000 + 211$ year; $r^2 = 0.150$; $P = 0.043$). The information gained in this study can be used in the process of zoning the dispersal areas for different land uses. Also, if supported by a further study it can establish the optimum sustainable land use(s) around Masai Mara Reserve, that can assure the coexistence of man and wildlife.

Keywords: Cultivation; Group ranches; Herbivore populations; Land use changes; Masai Mara ecosystem; Kenya; Africa

1. INTRODUCTION

The Masai Mara National Reserve (MMNR), Kenya's leading tourist attraction area, supports the highest species richness, diversity, and

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densities of wildlife in sub-Saharan Africa [1]. It was estimated that MMNR represents between 30% and 60% of wild herbivores found in Kenya's protected areas [2]. However, the majority of its wild animals are found, or depend on the surrounding dispersal areas. These areas are in form of communally-owned group ranches which are inhabited by Masai nomadic pastoralists. Group ranches are production units on which a group of individuals collectively have freehold title to land [3]. Membership in the group is based on kinship and traditional land rights.

The Maasai pastoral lifestyle and communal ownership of land have enabled MMNR to support large numbers of wildlife. Amuyunzu [4] noted that for many centuries, the Maasai pastoralists have co-existed with wildlife in a state of equilibrium. However, this equilibrium is being destabilized by rapid change of land-use patterns in historical dispersal areas. The group ranches are being subdivided into privately-owned smaller holdings. Subdivision of land guarantees freehold title, which declares land a commodity in the market capable of being rented, sold or leased [5]. The land subdivision could lead to fencing and growth of the settlement frontier, which in turn would negatively affect seasonal wildlife migrations [6]. Their migratory nature enables wild ungulates to utilize the highly seasonal availability of grass end water. Fencing will prevent migrational movements, which is a favored strategy for animals in the rangelands. Without dispersal areas, only a fraction of the current migratory herbivore population could be expected to survive [7].

Wildlife dispersal areas are progressively becoming smaller due to the country's rapidly growing human population resulting in increased demand for land and food. Odongo [8] noted that in order to meet the country's food needs, Kenya will have to bring large areas of land under cultivation by the year 2000 and beyond. For example, in 1987 the government recommended expansion of wheat production land from less than 300,000 hectares to 500,000 hectares to meet domestic demands [8]. Karime [9] reported that maize and wheat planted in 1975 in Narok District covered 4,875 hectares of land and this increased to 43,313 hectares in 1987. The increase of cultivation encroaches areas that have traditionally been used as livestock and wildlife grazing lands and herbivore dispersal areas.

Capone [10] noted that the major cause of wildlife depletion has been habitat loss due to expanding agriculture related to Kenya's

rapidly growing population. A recent study by Norton-Griffiths [2] found that 37% of the total decline in wild herbivore numbers in Kenya detected between 1970 and 1990 occurred in the Narok District, which is undergoing rapid changes in land-use patterns from nomadic pastoralism to a sedentary and farming lifestyle.

This study was aimed at determining the extent of the changing land-use patterns and their effect on herbivore population numbers over the past 20 years in three group ranches. Specific objectives included: (a) to identify and document the past and present land use patterns in the group ranches adjacent to Masai Mara National Reserve; (b) to determine the rate of change in livestock and wildlife numbers in the group ranches; and (c) to determine how changes in livestock and wildlife numbers relate to land use patterns in the group ranches.

2. STUDY AREA

The study area is in Narok District in southwest Kenya. It lies between 1° 15′ and 1° 50′ S, and 35° 15′ and 35° 50′ E. The study area occupied an area of 2064 km^2 and was composed of three group ranches (Siana, Naikara and Maji-Moto), which border Masai Mara National Reserve (MMNR) to the east.

The Mara area was of exceptional diversity due to the variety of vegetation zones – open grasslands alternating with riverine forest, islands of bush and trees, dense natural forests, open plains, rocky hills and drylands [11]. About 2 million wild ungulates exist, many of which move freely back and forth across the border into the Serengeti Plains in Tanzania. In the dry season (July–October), the Mara area is a concentration area for a great number of migratory herbivores including approximately 250,000 zebras (*Equus* spp) and 1.3 million wildebeest (*Connochaetes taurinus*) [12].

3. METHODS

3.1. Change in Land Use

The terms land use and land cover are often used almost interchangeably, but this is really quite improper [13]. Land cover describes

the vegetational and artificial coverings of the land surface [14], and thus, forms an attribute of land or terrain. It includes vegetation, permanent snow and ice fields, water bodies or structures. In contrast, land use includes man's activities on land, which are directly related to the land [3]. For example, land use may include agriculture, forestry, range, urban and communication corridors [15]. One or more uses may take place concurrently on the same piece of land.

Data on land use changes were gathered using landsat images, aerial photographs and field checks. Images and photographs were obtained from the Department of Remote Sensing and Resource Surveys (DRSRS), Kenya. Two 1984 landsat images were visually interpreted whereas 49 aerial photographs of 1975 were interpreted using a stereoscope. After interpretations, 3 land use base maps for 1975, 1984 and 1991 were prepared.

Field checks were conducted in 1997 to verify accuracy of imagery and photograph interpretation, and aid in further identification of doubtful cases marked during interpretation. Field checks involved selecting various sites at random from the latest land use base map and then visiting each site to verify whether land use or cover on the ground was what was indicated on the base map. Also, all doubtful cases marked during interpretation were searched, located and identified. All corrections were recorded on the base maps and used to prepare the 1997 base map.

Updated land use or land cover base maps were digitized into the Geographical Information System (GIS) using ARC/INFO (ESRI, Redlands, CA USA) computer software, which also calculated the area of each land use type. Four computer-generated land use, or land cover maps were produced containing nine major classes that included agriculture, abandoned farms, bare or rocky grounds, and 6 natural vegetation types, as well as physical structures and infrastructural facilities.

3.2. Herbivore Populations

Data on domestic and large wild herbivores were obtained from the Department of Resource Surveys and Remote Sensing (DRSRS) censuses from 1977 to 1996. The DRSRS method of censusing animal populations follows that of Norton-Griffiths [16], which used

systematic reconnaissance flights (systematic transect sampling) Flight lines followed UTM grid lines and were generally oriented in a parallel east to west direction.

During survey flights, observers photographed animal herds that included more than 10 animals to improve the accuracy of counting large groups. For each observer, a linear regression was used to predict the corrected count (photo count) from the visual count. Regressions were used to adjust every visual count even if a matching photograph was not taken. Visual counts were used with herds with less than 10 animals.

3.3. Statistical Methods

Friedman's analysis [17] was used to test for changes in areas of land-use/cover types overtime. Its test statistic is:

$$X_r^2 = \frac{12}{ba\,(a+1)} \Sigma R_i^2 - 3b(a+1)$$

where, **b** is the number of blocks of data, **a** is the number of groups in each block, and **R** is the Sum of values in row i.

Simple regression analysis [17] was used to test the null hypothesis that "the rates of change of various animal groups (*i.e.*, wildlife, livestock and herbivores) were the same for the past 20 years", that is, regression of number of animals (dependent variable) against time in years (Independent variable).

Correlation analysis [17] was performed to test the null hypothesis that "there was no association between change in wild herbivore density (dependent variable) and change in other dependent variables such as habitat areas and livestock density".

4. RESULTS

4.1. Land-use or Cover Patterns

Land use patterns identified included agriculture, settlement, and physical structures such as schools, market centres, dispensaries,

church mission centres, airstrips, lodges and campsites. The area covered by these land uses has increased significantly over the past 20 years ($\chi_r^2 = 11.475$; 3 df; $P = 0.001$). This increase was the primary reason for decrease in available habitat for wildlife and livestock. The habitat was classified into various land cover types: forest, riverine vegetation, open grassland, wooded grassland, shrubby grassland, shrubland and bare ground. There were changes in percent cover of the various land use or cover types between 1975 and 1997 (Tab. I). There was decrease in land under natural vegetation but it was not statistically significant ($\chi_r^2 = 1.097$; 3 df; $P = 0.777$). A negative correction occurred between land under natural vegetation and land under human settlement and structures ($r = -0.995$; 2 df; $P = 0.005$). Also, there was a negative correlation between agriculture and natural vegetation areas ($r = -0.999$; 2 df; $P = 0.001$).

4.2. Herbivore Populations

Regression analysis indicated an increase in livestock, a decrease in wildlife, and an overall increase in large herbivore numbers over the years. The estimated rate of change in livestock (601100+843 year, $r^2 = 0.127$; $P = 0.018$) was much higher than that of wildlife (953400−632 year, $r^2 = 0.272$; $P = 0.036$) and large herbivores (155000+211 year; $r^2 = 0.150$; $P = 0.043$). This analysis predicted an increase in livestock numbers (843 animals per year), a decrease in wildlife numbers (632 animals per year) and an overall increase in large herbivore numbers (211 animals per year).

Evaluation of livestock population estimates within the 1970s–1980s–1990s data sets showed no significant change in any of the analysis periods (Tab. II). However, in the 1970–90 interval, cattle, sheep and goats indicated insignificant increases whereas donkey indicated an insignificant decline. During the 1980–90 interval, elephant (*Loxodonta africana*) showed a significant increase, whereas the following wildlife species showed a significant decline: giraffe (*Giraffa camelopardalis*), buffalo (*Syncerus caffer caffer*), kongoni (*Alcelaphus buselaphus*), warthog (*Phacochoerus aethiopicus*) and waterbuck (*Kobus deffassa*). Also, during the 1970–90 interval, 3 species (giraffe, kongoni and warthog) showed a significant decline whereas elephants still showed a significant increase.

TABLE I Land-use and land cover area estimates in Siana, Naikara and Maji-Moto group ranches in Narok district of southwest Kenya (1° 15′ and 1° 50′ S, and 35° 15′ and 35° 50′ E) between 1975 and 1997

	1975[a]		1984[b]		1991[b]		1997[c]	
Land-use	*Area* (km^2)	*Relative cover* (%)	*Area* (km^2)	*Relative cover* (%)	*Area* (km^2)	*Relative cover* (%)	*Area* (km^2)	*Relative cover* (%)
Abandoned farms	0	0	5.32	0.25	63.43	3.02	63.43	3.01
Agriculture	0.08	0	17.24	0.82	70.24	3.34	86.98	4.12
Maasai "Manyattas"	0.12	0.01	0.68	0.03	2.23	0.11	3.25	0.15
Physical structures	0.42	0.02	0.91	0.04	1.97	0.09	2.25	0.11
Human occupied area[d]	**0.62**	**0.03**	**18.83**	**0.89**	**74.44**	**3.54**	**92.48**	**4.39**
Rocky/bare ground	3.83	0.18	8.05	0.38	9.87	0.47	10.91	0.52
Forest	16.22	0.77	60.01	2.85	66.23	3.15	71.38	3.39
Riverine vegetation	50.65	2.4	24.15	1.15	77.52	3.69	68.71	3.26
Wooded grassland	85.54	4.06	106.75	5.07	81.38	3.87	92.84	4.4
Open grassland	560.18	26.59	585.97	27.83	735.32	34.99	739.63	35.07
Shrubland	647.19	30.72	628.64	29.86	559.73	26.64	539.97	25.61
Surubby grassland	742.86	35.26	668.35	31.74	435.47	20.73	429.36	20.36
Natural vegetation[e]	**2102.64**	**99.79**	**2073.87**	**98.51**	**1955.65**	**93.07**	**1941.89**	**92.09**

[a] Determined from aerial photographs.
[b] Determined from satellite images.
[c] Determined from field checks.
[d] Human occupied area consists of area under agriculture, "Manyattas" and physical structures.
[e] Natural vegetation consists of area under open grassland, shrubby grassland, wooded grassland, shrubland, forest and riverine vegetation.

TABLE II Population size, population change, relative population change, and flag values of wildlife and livestock in Siana, Naikara and Maji-Moto group ranches in Narok district of southwest Kenya, between the 1970s and 1990s

	Population size			*Population change*			*Relative population change*			*Flag values*[a]		
Year	1970	1980	1990	1970–80	1980–90	1970–90	1970–80%	1980–90%	1970–90%	f_1	f_2	f_3
Cattle (*Bos indicus*)	76,485	61,204	58,915	−15,281	−2,289	−17,570	−20	−4	−23			
Donkey (*Equus asinus asinus*)	1,093	1,886	720	793	−1,166	−373	73	−62	−34			
Sheep (*Ovis aris*) and goats (*Capra hircus*)	51,043	38,859	43,094	−12,184	4,235	−7,949	−24	11	−16			
Buffalo (*Syncerus caffer caffer*)	2,593	1,316	414	1,057	−902	155	408	−69	60		−	
Eland (*Taurotragus oryx*)	533	251	305	−282	54	−228	−53	22	−43			
Elephant (*Loxodonta africana*)	0	0	166	0	166	166	0	Undefined	Undefined		+	+
Grant' Gazelle (*Gazella granti*)	4,100	1,990	2,551	−2,110	561	−1,549	−51	28	−38			
Thomson's Gazelle (*Gazella thomson*)	9,170	7,955	5,516	−1,215	−2,439	−3,654	−13	−31	−40			
Giraffe (*Giraffa camelopardalis*)	910	771	527	−139	−244	−383	−15	−32	−42		−	−
Impala (*Aepyceros melampus*)	15,002	14,374	9,982	−628	−4,392	−5,020	−4	−31	−33			
Kongoni (*Alcelapus buselaphus*)	851	917	514	66	−403	−337	8	−44	−40		−	−
Ostrich (*Struthio camelus*)	27	72	79	45	7	52	167	10	193			
Topi (*Damaliscus Korrigum*)	477	605	325	128	−280	−152	27	−46	−32			
Warthog (*Phacocherus aethiopicus*)	242	290	82	48	−208	−160	20	−72	−66		−	−
Waterbuck (*Kobus deffassa*)	38	160	2	122	−158	−36	321	−99	−95		−	
Wildebeest (*Connochaetes taurinus*)	10,094	6,970	5,886	−3,124	−1,084	−4,208	−31	−16	−42			
Zebra (*Equus spp*)	4,508	6,326	5,659	1,818	−667	1,151	40	−11	26			

[a]The three flag values represent the significance of change in each of the analysis periods: $f_1 = 1970-1980$, $f_2 = 1980-1990$ and $f_3 = 1970-1990$. The item flag identifies significant change (for 90% confidence limit) between the 1970s and 1990s populations estimate, that is, decline(−), increase(+) or no significant change (0).

5. DISCUSSION

The changes in land-use and land cover are attributed to a rapid increase in the human population, increases in livestock and the subsequent overgrazing, fluctuations in elephant numbers and change in Maasai diet. Human population pressures encourage people to engage in land uses that generate high short-term benefits regardless of their negative impacts to the environment and the future generation. Cultivation has higher returns per hectare than livestock production or tourism. It has been estimated that one hectare of land under agriculture, livestock production and tourism can earn the Maasai land owners a net revenue of US $ 6.25, US $ 1.99 and US $ 0.35, respectively [11, 18]. Western [19] reported that, unmanaged land of a few years ago was now under active food production and the pressure to bring more land under cultivation was threatening marginal lands in the arid and semi-arid zones.

Another factor encouraging farming is the gradual change in traditional Maasai diet from total dependence on livestock blood, milk and meat to a wider diet including cereals and vegetables. This factor, combined with the effect of interaction with other non-Maasai farming communities, encourage the Maasai people to start growing food crops for subsistence instead of selling livestock to buy food which is an expensive and unsustainable process.

Increase of livestock density leads to over-browsing and over-grazing [20]. This in turn suppresses growth of tree and shrub plants and promotes growth of grasses. Our results support this pattern by documenting an increase in open grassland and decrease in shrubland and shrubby grassland. Because the increase in livestock was insignificant, overgrazing could have been caused by an increase in livestock density, (*i.e.*, same number of livestock on less hectares) because of increased agriculture.

In the past, the absence of elephants in the study area, allowed an increase in forests. Elephants have been identified as the species most responsible in destroying forests [12]. Douglas-Hamilton *et al.* [11] noted that as a result of the absence of elephants there was no fuel for serious fires in the group ranches, and subsequently encroachment of forest and bush prevailed in the 1980s. Today, elephants are found in the group ranches and the trend is changing. However, inside the

protected boundaries of the Mara Reserve the opposite trend occurred. Dublin [21] noted that, in the Mara, an unprecedented numbers of elephants seeking refuge from the heavy poaching pressures continued to reduce woody vegetation. This contributed to the prevalence of grasslands in the Reserve. Similar observations by International Union for Conservation of Nature [12] indicated that the combination of uncontrolled fires and elephant destruction of riverine forest and bushland resulted in a reduction in plant diversity and conversion to open grassland.

In the past, Maasai pastoralists were able to co-exist with wildlife due to lack of capital, technology, and low human population densities [2]. Today the human population is increasing rapidly. The Maasai economy relies almost entirely on livestock, and the Maasai refer to livestock as their "living bank accounts". With an increase in Maasai family sizes, their basic needs increase. For this reason, the Maasai have to increase their livestock numbers in order to meet family needs.

The decline of wildlife in the group ranches can be attributed to several factors: livestock increase, drought, poaching, and land use changes. Increased livestock population may have out-competed and displaced the wildlife in the group ranches. That is, the group ranch with highest density of livestock will have the lowest density of wildlife. However, we did not detect an association between change in livestock numbers and change in wildlife numbers.

Droughts, which occurred in 1979, 1984, 1992 and 1993 could have caused declines in wildlife numbers. Our results partly support this concept by indicating major declines in wildlife during 1980, 1986, 1990, 1992 and 1993. Wargute *et al.* [22] asserted that one of the causes of the drastic declines of wildlife populations on Kenyan rangelands are the occasional droughts.

During the mid and late 1970s and in 1980s poaching was so rampant in Kenya that populations of most wildlife species declined drastically, particularly for elephants and rhinos (*Diceros* spp.) [22]. This is why elephants were absent from the study area until 1991. Enactment of a ban in 1977 may have reduced poaching, but other factors continued to negatively impact wild animals. Poor management by the Wildlife Conservation and Management Department (WCMD) during the 1970s and 1980s due to inadequate resources to implement wildlife management programs [23], may have escalated

poaching, especially for elephants and rhinos. However, poaching did not account for the decline of various wildlife species, which were not poached during the 1980s and 1990s. This suggests that other factors were responsible for their declines.

The main factor related to declines of most wildlife species during the 1970s and 1980s was apparently land use changes. During this period, the government introduced a new land tenure system in the Narok District. In an effort to commercialize livestock production in the semi-arid and arid areas, the government initiated the creation of group ranches in order to give the rights and responsibilities of land ownership to the specified pastoral communities [24]. This decision was prompted by human and livestock population growth, combined with finite range resources and increasing land and environmental degradation [25].

Impacts of group ranches and individual land holdings occurred though exclusion of wildlife from properties to minimise competition between livestock and wildlife (Wargute *et al.* [22]). This was further aggravated by the fact that wildlife was not directly benefiting private land owners economically. Thus, Land owners, perceived little economic incentive to allow wildlife access to their private land. Norton-Griffiths [2] asserted that a ranch or farm with less wildlife was more efficient and profitable than one with abundant wildlife. In addition, due to increasing land use pressure and conflicts in the group ranches, the government has been forced to allow further subdivision of ranches into individual farms, which are being fenced to exclude wildlife. The Kenya Wildlife Service [26] acknowledged the role of land use changes in the decline of wildlife species by pointing out that land use agencies have failed to integrate, harmonize, and enforce land use legislation and policies that would have enhanced conservation and the competitive value of wildlife.

Modification of wildlife habitats has played a vital role in the decline of some wildlife species. Drying of marshes and some rivers due to increased drought [5], as well as farming along rivers (*e.g.*, Maji-Moto River), likely contributed to the decline of waterbucks. The rising population of elephants in the study area have caused massive destruction of acacia (*Acacia* spp.) and other trees, which are preferred by giraffes [5]. This could be a possible reason for significant decline of the giraffe (browsers) population.

In conclusion, in the Mara area there are socio-economic and political forces at work that are essentially beyond the control of the wildlife authorities. These include conversion of communal dry season grazing areas into fenced, cultivated, private land, or the transition from communally used land to ranches and to private rangeland ownership.

6. MANAGEMENT RECOMMENDATIONS

There is an urgent need for the supporters of wildlife conservation to initiate cooperation between different sectors or ministries that affect conservation in any way. These Ministries should work in concert to establish land use policies that are suitable to wildlife conservation, human economic development, and sustainable production of natural resources.

Also, Kenya should intensify international cooperation with Tanzania to standardize land-use and conservation policies in the two countries because they share migratory wild animals such as wildebeest and zebras in the Mara-Serengeti ecosystem.

Dispersal areas around MMNR should be zoned into 2 categories – inner group ranches and outer group ranches. Inner group ranches should be those bordering or very close to the reserve. These will be the ranches that receive 19% of the annual gate entry fee as a Group Ranch Fund (GRF) from the reserve. No farming should be done on the inner group ranches that are included in the revenue sharing scheme. If farming is done, it should be in small fields that are properly fenced and located within the homestead. No game animals should be killed to protect crops in this area. Also, cultivated crops should be unattractive (or less preferred) to wild herbivores (*e.g.*, onions, kales and cabbages); maize and beans, which attract wild herbivores, should not be grown here. This area should be left mainly for livestock and multi-use wildlife utilization, such as sport hunting, game viewing, lodges, campsites, nature trails and cultural villages. Cultivation should be strictly and cautiously conducted in the high potential land in the outer ranches. Farms should be protected with electric fences and game should not be killed to protect crops, except by the reserve authorities where necessary.

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