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John KIOKO
1 The School for Field Studies, Center for Wildlife Management Studies, Nairobi 27743 – 00506, Kenya;, jkioko@fieldstudies.org

John Warui KIRINGE
1 The School for Field Studies, Center for Wildlife Management Studies, Nairobi 27743 – 00506, Kenya;

Simon Ole SENO
2 School of Natural Resources Management, Narok University College, Narok 861–20500, Kenya

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Impacts of livestock grazing on a savanna grassland in Kenya

John KIOKO[1*], John Warui KIRINGE[1], Simon Ole SENO[2]

[1] The School for Field Studies, Center for Wildlife Management Studies, Nairobi 27743 – 00506, Kenya;
[2] School of Natural Resources Management, Narok University College, Narok 861–20500, Kenya

Abstract: The dynamics of most rangelands in Kenya remain to be poorly understood. This paper provides baseline information on the response of a semiarid rangeland under different livestock grazing regimes on land inhabited by the Massai people in the east side of Amboseli National Park in Kenya. The data were collected from grasslands designated into four types: (1) grassland from previous Massai settlements that had been abandoned for over twenty years; (2) grassland excluded from livestock grazing for eight years; (3) a dry season grazing area; and (4) a continuous grazing area where grazing occurred throughout all seasons. Collected data included grass species composition, grass height, inter-tuft distance, standing grass biomass and soil characteristics. The results indicated that continuous grazing area in semiarid rangelands exhibited loss of vegetation with negative, long-term effects on grass functional qualities and forage production, whereas grassland that used traditional Maasai grazing methods showed efficiency and desirable effects on the rangelands. The results also showed that abandoned homestead sites, though degraded, were important nutrient reservoirs.

Keywords: dry season grazing; grass species composition; livestock grazing; soil nutrients; Kenya

Pastoralists such as the Maasai of East Africa adapted to life in arid lands by designating wet and dry season grazing areas (Berger, 1993). Their use of the rangelands was based on mobility, splitting and dispersing livestock over the landscape during wet and dry seasons (Oba *et al*., 2000), to ensure limited dry concentrated continuous grazing. The sphere of the Maasai in Kenya and Tanzania is continually experiencing dramatic changes in land tenure and land use, with broad consequences on the rangeland dynamics. The Maasai have progressively lost some of their grazing land to competitive use such as crop farming (Campbell *et al*., 2000) through the establishment of wildlife protection areas (Western and Wright, 1994). In Kenya, the Massai land was transformed from communal into group ranches in the 1960s (Graham, 1989). Group ranches are large parcels of land that were demarcated under the Land Adjudication Act of 1968 (Cap 284) and legally registered to one group duly constituted under the Land (Group Representatives) Act of 1968 (Cap 287). This further reduced the movement of Maasai livestock by largely confining them into group ranches. Under increased pressure from the group ranch members, who wanted to own individual parcels of land, the trend is now towards subdivision of the group ranches, further transforming the land use from extensive seasonal grazing to continuous grazing, and intensive livestock grazing (Burnsilver and Mwangi, 2007).

The savannahs, home of African rangelands, are highly dynamic systems due to factors such as rainfall, soil nutrient levels, fire and herbivory (Skarpe, 1992). Livestock herbivory can cause shifts in plant species composition by replacing highly palatable grasses with unpalatable species (Owen-Smith, 1999). In the semiarid savannas of East Africa, there is consistent evidence of change in species along grazing gradients, often characterized by a reduction in tuft size and replacement of perennial grasses by annual grasses (O'Connor and Pickett, 1999). The response of grass

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*Corresponding author: John KIOKO (E-mail: jkioko@fieldstudies.org)

species response to grazing is important in determining grazing capacity (the average number of animals that can be supported by an area) (Galt *et al*., 2000). Three categories of grasses, i.e. Decreaser, Increaser I and Increaser II describe the status of the rangeland (Trollope, 1990). Decreaser species dominate ranges in good condition and decrease with over or undergrazing. Increaser I species dominate in undergrazed or selectively utilized rangelands, and Increaser II species dominate in rangelands that are overgrazed. Under better management, heavily utilized rangelands that indicate overgrazing by the existence of Increaser II species can shift to a dominance of more palatable Decreaser species (Botha, 1999).

The inter-tuft distance can be used as an index of soil erosion potential (Trollope and Trollope, 1999). As vegetation cover declines, soil erosion increases, generating negative consequences on rangeland productivity (Oudtshoorn, 1992). Due to severe grazing, a reduction in plant biomass leads to soil loss that depletes the existing nutrients of soil, resulting in the reduction of soil fertility (Morgan, 1995).

A collapse of the traditional Maasai grazing system is hypothesized to have negative effects on the rangeland, likely leading to an increase in land degradation. This hypothesis was tested by comparing the vegetation functional characteristics in the areas grazed continuously, regardless of seasonality, with those in the areas excluded from livestock grazing for an eight-year period, grazed only during the dry season, and past Massai settlements that had been abandoned for over twenty years.

1 Study area and methods

The study area is in the southern Maasailand of Kenya (Fig. 1). It covers 251 km^2, and is located in 02°69′S–02°77′S and 37°41′E–37°38′E, to the east of Amboseli National Park. The area is semiarid, in agro-climate zone VI (Pratt and Gwynne, 1978). The rain seasons exhibited bimodal seasonality, with short, light rain in the dry season that occurred between November and December, and long, heavy rain in the wet season between March and May (Musembi, 1986). The rainfall was low (about 500 mm per year), often variable and poorly distributed. The temperatures for the area fluctuated between 14ºC and 30ºC (Katampoi *et al*., 1990). The soils were young and undeveloped black cotton soils that were poor in nutrients and susceptible to erosion (Katampoi *et al*., 1990). Black cotton soils dominated the flood plains, while the well-drained higher elevations had calcareous and sandy loams. The vegetation was classified as wooded and bushed grassland, grassland and dwarf shrub

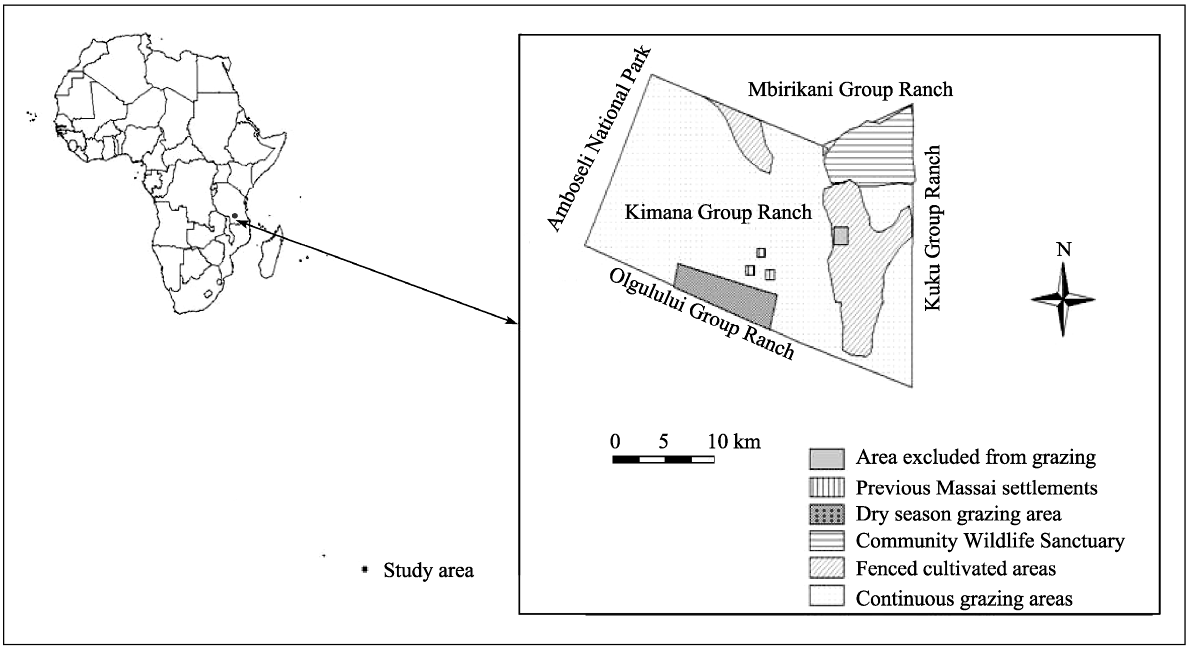

Fig. 1 Location of the study area in relation to Amboseli National Park

grassland (Pratt and Gwynne, 1978). The area is predominantly important for wildlife conservation and livestock grazing for the Maasai people.

1.1 Data collection

Four types of sites were chosen. They included: (1) previous Maasai settlement areas (about 3 km^2) that had been abandoned for over twenty years; (2) an area excluded from livestock grazing for eight years (about 5 km^2); (3) a dry season/calf grazing area (about 4 km^2) and (4) a livestock area under continuous grazing (6 km^2). The sites experienced similar rainfall and soil conditions.

The Descending Step Point Method (Mentis, 1981; Trollope and Trollope, 1999) was used to assess vegetation functional characteristics. In each site, five transects in 200-m length with varying widths were established. The data of soil erosion potential, grass biomass, grass species composition and grass height were collected along each transect, with an interval of two meters. The soil erosion potential was determined by measuring the distance from transect to the base of the nearest grass species. To estimate the grass biomass, the Disc Pasture Meter Method (Bransby and Tainton, 1977) was used.

The ability of each grass in producing forage for livestock grazing was assigned a forage score ranging from 0 to 10. The forage potential was determined using the method by Trollope and Trollope (1999).

The status of soil nutrients was determined in each study site. Soil samples were collected at 10-cm intervals, in 30-cm depth from six random locations within each site. Analysis of soil pH, Ca, Mg, K, C and N was undertaken at the International Centre for Research in Agro-Forestry (ICRAF) Laboratories, Nairobi, Kenya.

1.2 Data analyses

A Chi-Square Goodness of Fit test was used to determine differences in the occurrence of grass species, forage scores and total bare ground among the study sites. A one-way analysis of variance (ANOVA) test was used to compare the mean inter-tuft distances and mean grass heights among the study sites. A Tukey's HSD test was then carried out to determine which sites differed significantly from the others. The mean disc pasture meter height for each site was used to calculate the site's grass biomass based on:

$$Y = -3340 + 2323\sqrt{X}\ .$$

Where Y is the weight of grass (kg/hm^2), and X is the disc pasture meter height (cm). The values come from work undertaken in similar rangelands in northern Kenya (Botha, 1999). The Kruskal-Wallis test was used to test whether there were variations in the amounts of soil parameters across the sites.

2 Results

2.1 Species composition and grass ecological status

Fifteen grass species were found in the study area (Table 1). The area was mostly dominated by Increaser I grass species–*Pennisetum stramenium* and *Pennisetum mezianum* and Increaser II grass species–*Cynodon dactylon. Cenchrus ciliaris, Panicum maximum* and *Themenda triandra* were the only three Decreaser species recorded.

There were significant differences in the occurrences of the three ecological grass categories in each of the study sites (Table 2). Most of the study sites were dominated by Increaser I and Increaser II grass species.

2.2 Grass height, inter-tuft distance and standing biomass

The grass height differed significantly among the study sites (P<0.001). The average grass height was 40.68±1.24 cm (mean±SE) in the site that excluded from grazing for an eight-year period, 1.17±0.15 cm in the sites previously settled by the Maasai people over twenty years ago, 31.53±0.74 cm in the dry season grazing area and 4.29±0.16 cm in the continuous grazing area.

The mean inter-tuft distance varied across the study sites (P<0.001). The continuous grazing area had the highest inter-tuft distance (69.11±0.62 cm), while the area excluded from livestock grazing for eight years had the least inter-tuft distance (22.53±0.86 cm). The total occurrence of bare ground was significantly different between the four sites (P<0.001). The dry season grazing area and the continuous grazing area had the largest bare ground, 35.43±0.37 cm and 49.81±21 cm, respectively, compared to the area previously settled by the Maasai people (1.84±18 cm), and the areas excluded from livestock grazing for at least eight years (12.33±49 cm).

The total grass biomass differed significantly between the dry season grazing area, the area excluded from livestock grazing and the previously settled Maasai areas (P<0.001), but was not significantly different between the dry season grazing area (5,639.94 kg/hm^2) and the area excluded from livestock grazing (5,350.00 kg/hm^2) (P=1.00). The previous Maasai settlements had 108.62 kg/hm^2. Since most of the continuous grazing areas were bare ground, the disc height value (0.74±0.20 cm) was not considered in grass biomass calculation.

2.3 Forage potential

The scores for total forage biomass were different between the four study sites (P<0.001). However, the dry season grazing area and the area excluded from livestock grazing had similar grazing values, 467 and 444, respectively (P=0.446). The sites with the lowest forage potential were the previous Maasai settlements and the continuous grazing area, with values of 224 and 48, respectively.

2.4 Soil properties

The measured values for soil properties showed that there were significant differences between the study sites (Table 3). The mean contents of exchangeable calcium, total carbon, total nitrogen, exchangeable magnesium and exchangeable potassium were highest in the previous Maasai settlements. The continuous grazing area had the lowest mean contents of exchangeable calcium, total nitrogen, and a lower pH value, while the area excluded from grazing had a higher pH value.

3 Discussion

The results showed that continuous grazing had undesirable effects on the rangeland, impairing functional characteristics of plants. The savannahs are dynamic systems where spatio-temporal variability of abiotic

Table 1 Frequency of occurrence of grass species across study sites

Species	Grass ecological category	Exclosure area (n = 704)	Maasai settlements (n = 784)	Dry season grazing area (Olopololi) (n = 960)	Continuous grazing area (n = 96)
		(%)			
Panicum maximum	Decreaser	0.15	0.00	0.00	0.00
Themeda triandra	Decreaser	0.15	0.00	0.15	0.00
Cenchrus ciliaris	Decreaser	20.37	0.00	1.12	1.34
Pennisetum stramenium	Increaser 1	36.88	5.06	63.13	56.70
Pennisetum mezianum	Increaser 1	0.28	0.23	4.44	12.46
Cynodon dactylon	Increaser 11	35.31	93.99	22.25	20.31
Digitaria scalarum	Increaser 11	3.00	0.00	1.42	2.24
Chloris roxburghiana	Increaser 11	0.57	0.00	0.00	0.13
Aristida kenyensis	Increaser 11	1.00	0.00	0.48	5.40
Brachiaria sp.	Increaser 11	0.72	0.59	2.38	0.26
Harpachne schimperii	Increaser 11	0.43	0.00	0.63	0.48
Setaria verticilata	Increaser 11	0.43	0.00	0.00	0.00
Dactyloctenium aegyptium	Increaser 11	0.28	0.00	0.00	0.27
Eragrostis tenuifolia	Increaser 11	0.28	0.00	3.35	0.42
Sporobolus fimbriatus	Increaser 11	0.14	0.12	0.63	0.00

Table 2 Occurrence of different grass species in different study sites

Grass ecological category	Area excluded from livestock grazing	Previous Maasai settlement area	Dry season/calf grazing area	Continuous grazing area
Decreaser	143	0	11	1
Increaser 1	262	46	651	65
Increaser 11	298	743	299	28
χ^2 test	χ^2=56.16, df =2, P<0.001	χ^2 =631.17, P<0.001	χ^2=641.46, df=2, P<0.001	χ^2=65.89, df=2, P<0.001

Table 3 Kruskal-Wallis H test results for soil parameters in different study sites

Study sites	pH	Exchangeable acidity (me/100g soil)	Exchangeable calcium (me/100g soil)	Exchangeable magnesium (me/100g soil)	Exchangeable potassium (me/100g soil)	Total carbon (%)	Total nitrogen (%)
Area excluded from livestock grazing for eight years	8.24	0.10	17.33	7.56	0.59	2.05	0.20
Continuous grazing area	7.70	0.10	11.8	5.2	0.90	0.10	0.10
Dry season/calf grazing	6.81	0.14	10.26	5.01	0.49	2.09	0.17
Previous Maasai settlements abandoned for twenty years	7.35	0.23	19.88	9.05	0.98	7.35	0.72
Kruskal-Wallis *H* test results	$H(3)=13.52$, $P=0.004$	$H(3)=11.23$, $P=0.010$	$H(3)=12.03$, $P=0.007$	$H(3)=9.80$, $P=0.020$	$H(3)=9.37$ $P=0.024$	$H(3)=13.60$ $P=0.003$	$H(3)=14.84$ $P=0.001$

factors shapes the biotic life (Westoby *et al.*, 1989). While grazing alone does not determine the overall vegetation structure in rangelands, its effects can be adverse when rangelands are not well planned or managed. The dominance of Increaser I and Increaser II grass species (Tables 1 and 2) indicates that the rangeland has been under long-term stress from grazing. After eight years of exclusion from grazing, the rangeland has not fully recovered, showing only 21% Decreaser species, mostly *Cenchrus ciliaris*. Under heavy grazing, the species that are less resistant to grazing diminished, leaving more adaptable species that are less palatable to grazers. *Cynodon dactylon*, the dominant grass species, is associated with disturbed areas and is able to withstand heavy grazing through propagation by means of rhizomes and stolons (Oudtshoorn, 1992). *Pennisetum* sp. is relatively palatable during the wet season and progressively becomes hard and fibrous during the dry season, and is thus likely to have been avoided by grazers. The effects of continuous grazing in the continuous grazing area were evident due to the significantly lower frequencies and counts of perennial grasses and the exceptionally high proportion of bare ground. Similarly, the study of Allen *et al*. (1995) showed an increase in perennial species after six years of grazing exclusion in semiarid rangelands of Central Otago New Zealand.

The area excluded from grazing and that under seasonal grazing had higher grass biomass than those continually grazed ones. The grass height was 8–10 times more in the area excluded from grazing and in the dry season livestock grazing area than in the continuous grazing area. By comparison, after sixteen years of exclusion from grazing, the amount of standing aboveground biomass doubled in the steep seasonally-dry pastoral lands of Southern Island, New Zealand (McIntosh and Allen, 1998).

As expected, the sites under continuous grazing conditions had the highest soil erosion potential, and the area excluded from grazing for eight years had the lowest. The percentage of bare ground on a site increased with grazing pressure (Milton *et al*., 1994; Robertson, 1996). Continuous grazing within the Maasai rangelands has led to loss of vegetation, with long-term implications for the health of the rangelands. The forage potential of the continuous grazing area was about 10 times less than that in both the area excluded from grazing for eight years and the dry season grazing area. As grazing pressure increased, the Decreaser grass species declined, leaving Increaser I and Increaser II species of low forage. The results from Yeo (2005) showed that plant composition, indicators of soil erosion, ground cover and vegetation cover improved in the enclosure site, compared to adjacent unenclosed sites.

There were different values for soil properties across the different treatments. The previously settled Maasai area and the area excluded from grazing for eight years tended to have the highest levels of soil nutrients, pH and exchangeable calcium. Changes in soil properties might arise from the indirect effects of grazing, such as soil erosion (McIntosh and Allen, 1998), nutrient accumulation through livestock dung in areas settled by pastoralists (Augustine, 2003) and soil enrichment by litter accumulation and subsequent decomposition (Berliner and Kioko, 2000). The lack of differences among soil properties between sites could be due to the slow rates of change in soil properties over time (Marrs *et al*., 1989). The chemical composition and rate of decomposition of plant residues are important determinants of nitrogen and calcium accumulation in the soil (Whalen *et al*., 2003).

The area excluded from grazing may have gained nutrients from leaf decomposition, as there was minimal removal through large herbivore defoliation and minimal soil loss through erosion due to high vegetation cover. Similar studies showed that extremely degraded lands in Eastern Cape, South Africa had less organic carbon and organic matter than moderately degraded areas (Neary *et al*., 1999; Oluwole and Sikhalazo, 2008). Under heavy grazing, rangelands showed declines in soil carbon and nitrogen (He *et al*., 2011).

Calcium, which declined in the continuous grazing area, is one of the important exchangeable cations in semiarid soils for stabilizing soil pH (Berliner and Kioko, 2000). The soil pH was high in the area excluded from grazing for eight years and the previously settled Maasai areas, which was likely due to the high calcium level from decomposed plant organic matter. In the previous Maasai settlements, the calcium level might have been enriched by ash deposits from fire used within the settlements. Shifting livestock enclosures (Bomas) within the landscape has an important role in restructuring vegetation management through nutrient concentration (Muchiru *et al*., 2003).

4 Conclusion and recommendations

Excluding an area from grazing for eight years did not significantly change the grass biomass relative to the dry season grazing area. These findings emphasize the role of regulated grazing in maintaining productivity of semiarid rangelands. The decline in soil erosion potential, the increase in grass biomass, forage potential and soil nutrients in the site excluded from grazing showed the potential of enclosure plots in the rehabilitation of highly degraded rangelands. It is likely that most of the areas have enough seed bank and would gradually recover with minimal or no grazing pressure. Previous homestead settlements are important nutrient concentration areas, so they should be taken into account when planning rangeland grazing strategies within rangelands. In the face of diminishing extensive grazing systems, as well as changing land tenure and land use, adaptive measures should be adopted to mitigate rangeland degradation.

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