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*Full Length Research Paper*

# Land use cover and environmental changes in a semi-arid rangeland, Southern Kenya

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**To understand the environmental changes within the Amboseli ecosystem, satellite image based analysis of land use cover changes and interviews with landowners were conducted. Satellite imageries for 1976 - 2007 were analyzed for change in land use cover. Interviews focused on the changes and trends in range condition, their causes and consequences. Wetlands used for dry season grazing by for both wildlife and livestock have significantly reduced in the last 30 years due to irrigated cash crop farming. The majority of landowners had noticed a downward trend in rangeland health. To read sustainable management of the rangelands, there is need for active involvement of the local community in resolving the rangeland degradation problem. This should be coupled with regional land use planning with the local people as the key custodian.**

**Key words:** Land use change, pastures, satellite imagery, range condition.

## INTRODUCTION

Pastoralism within dry lands has coexisted with wildlife for decades (Berger, 1993). The Maasai adapted to life in arid and semi-arid rangelands by shifting between wet and dry season grazing areas and by maintaining multiple species of livestock (Seno and Shaw 2002).

The movement of livestock between wet and dry season grazing areas is undertaken to cope with forage availability as determined by spatially and temporally variable and unpredictable rainfall patterns and grazing pressure (Oba et al., 2000). Similarly, wildlife from the adjacent protected areas use these areas to maximize their daily and seasonal forage requirements (Western and Lindsay, 1987).

In 1970s, the grazing area for the Maasai of Kenya declined through establishment of wildlife protected areas (Western and Wright, 1994) and land fragmentation. The formation of group ranches in 1960s reduced the movement of Maasai livestock into smaller regions (Graham, 1989).

This resulted in reduced livestock mobility within much of Maasailand leading to an all season grazing regime, while livestock numbers were not actively reduced. This has led to overstocking and decline in the general health of the rangelands and the land's ability to recover from stochastic events such as droughts (Milton et al., 1994; Robertson, 1996).

In the Amboseli Ecosystem, recent influx of immigrant farmers and adoption of crop farming by the Maasai has additionally contributed to habitat loss and degradation (Berger, 1993; Campbell et al., 2000; Kioko et al., 2006). By 2005, 44.64% of the households in the Amboseli Ecosystem were non-Maasai, mainly engaged in crop cultivation and agro-business (Kioko, 2005). Due to increasing demand for cropland land by the immigrants and the changing lifestyle of the Maasai, high potential areas such as the slopes of Mountain Kilimanjaro and most of the wetlands got apportioned for crop cultivation (Berger, 1993).

The Maasai now cultivate or lease to newcomers (Kioko et al., 2006). The foregoing land transformation from communal ownership to private ownership has had undesirable effects on the environment in terms of land cover and quality, with profound effects on wildlife, livestock and resident livelihoods.

In this study, we explore the changes in land use cover, knowledge of landowners on rangeland changes and the implycations for viability of the rangelands as grazing areas for both wildlife and livestock. The specific objectives were to; identify and classify land use cover changes and to assess the community views on rangeland health and management.

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## STUDY AREA

The focus of this study is the section of the Amboseli Ecosystem that lies between Amboseli, Tsavo West and Chyulu National Parks in Kenya. The area is semi- arid (agro-climatic zone VI), characterised by a warm and dry climate (Pratt and Gwynne, 1977). There are two rain seasons; short rains occur between October and December, and long rain between March and May (Katampoi et al., 1990; Awere-Gyekye, 1996). The rains are low (about 500 mm per year), erratic and unpredictable (Republic of Kenya, 1990) . The soils vary depending on terrain and altitude. In the floodplains, the soils are dominated by poorly drained black cotton soils, while at higher elevations the soils are dominated by calcareous loam and sandy soils (Katampoi et al., 1990). The area has high wildlife diversity (Berger, 1993) and is one of the top tourist destinations in Kenya (Okello, 2005). While the area was historically settled by the Maasai, the population is now composed of a mixture of Maasai and tribes from other parts of Kenya and Tanzania. The immigrants mostly engage in crop cultivation mostly within the wetlands that were used by the livestock and wildlife as dry season foraging area.

### METHODS

#### Land use cover changes

LANDSAT imagery scenes for 1976, 1987 and 2007 for the Eastern range of Amboseli elephants were analyzed to identify and classify land use cover changes. This period corresponds with the start of immigration into Maasailand (Campbell, 2000). Use of remote sensing to describe ecosystem changes has been increasingly applied (Karime, 1990; Ottichilo, 1992; Hepinstall et al., 1996; Petit et al., 2001). LANDSAT Multispectral Scanner (MSS) and Thematic Mapper (TM) and Aster scenes for the area were acquired from the Regional Center for Mapping of Resources for Development (RCMRD) Nairobi. Multi-temporal Landsat data processing and classification was done using the procedure by (Yang and Lo, 2002). Six land use classes; forest, irrigated agriculture, perennial swamp, riverine vegetation, rain-fed agriculture, seasonal swamp and rangeland were delineated as the major land use cover types. Satellite imagery maps were overlaid in Arcview GIS® (Esri, 2002), to determine the area covered by each land use cover type. Additional information on land use was gathered by asking the farmers (N = 217) within the main irrigated areas the number of years they have been farming and the acreage under cultivation.

#### Community perceptions on rangeland health

Interviews were conducted in the three main human settlement clusters. In each cluster, households to be interviewed were randomly selected by generating random numbers assigned after homestead mapping. A questionnaire containing both open-ended and closed-ended questions was administered to one hundred and fifty-seven household heads. In each household, the household head was interviewed by the authors with the help of translators fluent in Maa (Maasai language). The male household head was interviewed except in cases when he was not available, then the female household head would be interviewed. The interviews primarily focused on the respondent's household socio-economic characteristics, indicators of range degradation, perceptions on the extent and causes of range condition changes and the measures that the community felt can help mitigate rangeland degradation.

#### Data analyses

The area of land under different land uses was used to calculate percent changes in land use cover. Chi- square goodness of fit test was used to test if there was significant change in land use cover. Pearson correlation coefficient was used to determine changes in the number of farmers within the main wetland in the area over the last 18 years. One-way Analysis of Variance (ANOVA) was used to determine variability in acreage under cultivation. Data from the household interviews was summarized into frequencies of responses and chi-square goodness of fit used to test for significance in the responses.

## RESULTS

### Changes in land use

Within the last 30 years (1976 - 2007), the extent of land under irrigated agriculture, perennial swamps and riverine vegetation has changed significantly (Table 1). The extent of irrigated agriculture within the swamps almost doubled within the first 10 years since 1987. Within Kimana basin, the largest swamp area, the number of farmers has increased significantly over an 18 year period ($r = -5.75$, $p = 0.032$). Consequently, the land covered by perennial swamps declined by 89% (Table 1). Land cover classified as rangeland, forest land and seasonal swamps did not change significantly within the same period. It was however observed that much of the forest is now under exotic trees.

### Livelihood dynamics

Livestock keeping was the main form of livelihood among the household heads in the marginal areas (43% of the respondents), 31% practiced both livestock keeping and crop cultivation, 22% practiced crop farming only, 2% were employed and 1% relied on small scale business. Most respondents (50%) stated that their dependency on livestock had decreased, 31% stated that their dependency on livestock had increased, while 15% claimed that their dependency has not changed ( $^2 = 41.12$, $df = 2$, $p < 0.001$). Agriculture was seen as an alternative livelihood strategy to livestock keeping by most of the respondents(62%), 21% said that running small scale business had become an alternative livelihood strategy while 12% reported that employment was their alternative livelihood strategy, 6% stated that they had no other option for their livelihood (6%). Agriculture in the irrigated areas was undertaken by newcomers from other parts of the country and Tanzania, only 22.6% of those undertaking crop farming were Maasai and the majority of

**Table 1.** Land use cover changes ($km^2$) in the Amboseli Ecosystem between 1976 and 2007.

| Land cover type | 1976 | 1987 | 2007 | % change in land use cover | $^2$ goodness of fit test |
|---|---|---|---|---|---|
| Forest | 41.74 | 37.73 | 36.53 | -12 | $^2$ = 0.483, df =2 p= 0.786, |
| Irrigated Agriculture | 2.16 | 25.57 | 50.18 | 2217 | $_2$ = 45.59, df =2 p = 0.001 |
| Perennial Swamp | 68.52 | 47.26 | 7.45 | -89 | $_2$ = 46.09, df = 2, p = 0.001 |
| Riverine vegetation cover | 16.12 | 9.58 | 4.73 | -71 | $_2$ = 5.80, df = 2, p = 0.050 |
| Rainfed Agriculture | 134.36 | 202.99 | 262.88 | 96 | $_2$ = 40.94, df = 2, p = 0.001 |
| Seasonal Swamps | 156.51 | 159.59 | 166.43 | 6 | $_2$ = 0.385, df = 2, p = 0.825 |
| Rangeland | 3738.33 | 3675.03 | 3631.49 | -3 | $_2$ = 1.544, df = 2, p = 0.462 |

the farmers (59.4%) were leasing the farmland or co-operating in farming with the Maasai who owned the land.

### Perceptions on pasture availability and trends in livestock numbers

Most of the respondents (43%) stated that agriculture had caused a decline in pasture availability, while 13% said that pasture availability had increased due to agriculture. Most respondents (40%) stated that agriculture had no effect on pasture availability, 4% did not know if pasture availability had been affected by agriculture. Whether or not agriculture had effect on wildlife habitat; 50% said that agriculture had no effect on wildlife habitat, 33% stated that agriculture had decreased wildlife habitat, 13% reported that agriculture increased wildlife pasture and 4% did not know if agriculture had affected wildlife habitat. Interestingly, majority (72%) of respondents said that subdivision had not affected wildlife pasture availability.

The majority of informants (60%) said that land subdivision had reduced availability of livestock pasture, 10% thought that land subdivision had caused an increase in livestock pasture availability, while 28% thought that land subdivision had no effect on livestock pasture availability and 3% did not know whether or not subdivision had an effect on livestock pasture availability.

### Perceptions on rangeland quality and measures for mitigating range condition deterioration

The majority of the household heads (84%) stated that they had noticed changes within the rangelands, while 16% stated that they had not noticed any changes ( $^2$ = 72.92, $p < 0.001$). The major changes that had been observed were increase in frequency of droughts, soil erosion, human population, conflicts over livestock pasture and water. The amount of rainfall, number of livestock, land available for grazing, amount of woody vegetation cover, herbaceous cover, the grasses that livestock prefer and the quantity of forage available for livestock were reported to have declined.

The major factors reported to have caused deterioration of the range condition were insufficient rainfall (46%), loss of vegetation (17%), agriculture (11%). The other factors reported were land subdivision (6%), wildlife grazing (5%), religious factors (5%), lifestyle changes (4%), increased human population (2%), deteriorating soil fertility (2%) and overstocking of livestock (1%).

When community members were asked to state what they thought needed to be done to prevent further range condition deterioration; maintaining vegetation cover by minimizing tree felling and planting trees was the most common response. 49% and 33% of the respondents felt that group ranch officials and the government respectively were responsible for minimizing range condition deterioration, while 18% of the respondents did not know who was responsible for managing the rangelands. Most respondents (89%) said that they would take care of the environment if they were apportioned individual parcels of land ( $^2$ = 132.92, df = 1, $p < 0.001$).

## DISCUSSION

Maasai pastoral grazing is less harmful to the environment when compared to other form of land use such as agriculture; however its success is limited by a number of factors among them quality and availability of forage. Increase in rain-fed and irrigated agriculture and sedentarization of Maasai are important factors in explaining wildlife habitat size and quality in the Amboseli Ecosystem. The Amboseli Ecosystem was historically managed by the Maasai through a regulatory livestock communal grazing system managed by village elders and enforced through the Morans (Ogolla and Mugabe, 1996). Wetlands and hillside were grazed during the dry season, thus allowing the lowland to recover from livestock pressure. A similar range utilization pattern is followed by most wildlife species, which move from the dry plains to high moisture areas (Estes, 1991) . This forage utilization system gave the rangelands time to re-cover from the stress of droughts and grazing. In the last few decades, human immigration into wetlands within rangelands has led to increased environmental de-gradation, as newcomers scramble for the high potential farming areas

(Campbell et al., 2000).

The fact that the community perceived rangeland deterioration to be as a result of a myriad of natural and anthropogenic causes emphasizes the fact that management of rangelands cannot be confined to the scientific approach only which assumes that the local communities are not aware of the rangeland problems (Abel and Blaikie, 1989). The community views may differ from those of scientists and the state (Dejene et al., 1997), for instance some of the community members did not associate increase of agricultural activities with decline in pasture availability and others blamed it on deity. A large majority of respondents felt that agriculture had no effect on wildlife pasture. This view differs from the general understanding that among conservationists that crop farming is a major threat to the area as a wildlife dispersal area (Okello and Kioko, 2010).

The overriding cause of decline in livestock numbers was perceived as insufficient rainfall in contrast to other studies which show that heavy grazing may have greatly contributed to the rangeland degradation (Kioko et al., 2010). In line with their thinking, the amount of rainfall is correlated with herbivore biomass (Coe et al., 1976; East, 1984). It is important to understand that the local community may interpret the environmental interrelatedness differently; droughts that usually result to large livestock mortalities are often viewed in isolation.

Most land owners do not feel there was a need for any action to deal with the overall rangeland deterioration situation and were indifferent on whether they were responsible for managing the rangelands. The government and the community leaders are seen as the ones responsible for managing the rangelands. An interesting contradiction is that the land owners were willing to manage their own land if they individually owned the land. This shows that the rangelands may be currently suffering from the tragedy of the common syndrome, where the long term viability of the rangelands is ignored (Hardin, 1968).

## Conclusion

Changing social-economic circumstances have led to loss of wildlife and livestock pasture land through increased agriculture. Increased dependency on agriculture led to loss of dry season grazing reserves, leading. Management intervention should focus on raising awareness to the landowners about implications of the foregoing land use changes to their future livelihoods. Education should aim to enlighten the community of on the interrelatedness between land use and environmental degradation.

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