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Full Length Research Paper

Land use and cover changes and their effects on elephant home ranges and distribution in Mara landscape, Narok County, Kenya

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The Maasai Mara Landscape (MML) supports one of the richest wildlife populations remaining on earth but over the last century, has experienced transformation notably through conversion of former rangelands into croplands. Elephants have both temporal and spatial requirements, which if not provided, render them vulnerable to the land-use practices. The study assessed land use and vegetation cover changes that have occurred and their effects on the elephant movements and distribution within the MML using an integrated methodological approach. The analysis revealed changes in land use and land cover classes over a period of 20 years for the three epochs, from 1997, 2007 and 2017. Elephant's distribution has been restricted to areas of high vegetation densities within specific habitats hence accelerating the rate of habitat destruction and degradation due to their high densities. These changes have drastically reduced forage for elephants necessitating them to travel longer distances out of their home range in search for food. Human beings have caused land use and cover changes which have detrimental impacts on the ecosystem and ecosystem services.

Keywords: land use change, land cover changes, Maasai Mara Landscape, elephant distribution, home range.

INTRODUCTION

The combination of rich biodiversity and intensely rapid land use and cover changes within a single system provides an ideal opportunity for examining the impact on elephant ranges and distribution status. Land use change is the result of a complex web of interactions between bio-physical and socio-economic forces over space and time (Briassoulis, 2006). Land use change is a major driving force of habitat modification and has important implications for the distribution of wildlife species and ecological systems. The human environmental impacts are widely recognized as major driving forces of habitat modification and hence their influence on the distribution of elephant species and ecological systems (Western, 2001). Land use change is driven by synergetic factors of resource scarcity leading to an increased pressure of production on resources, changing opportunities created by markets, outside policy intervention, loss of adaptive capacity, and changes in social organization and attitudes (Lambin et al., 2003). Changes in land use and land tenure systems affect utilization of the range by elephants and restrict their home ranges (Doughlas-Hamilton et al., 2005). The increase in human population and changes in lifestyle have led to changes in land with mushrooming of human infrastructure (such as, roads, human settlements, fences and crop fields) within elephant ranges.

Today, Kenya's largest remaining elephant populations live in conservation areas in the Tsavo and Mara ecosystems,

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and the Laikipia-Samburu complex (KWS, 2019 and Mara Conservancies, 2017). The African elephant is an intelligent animal since it can remember its old home range even back to 50 years ago. An elephant is a gregarious animal, lives and moves in herds of 10-50 animals spending about 16 hours a day feeding, according to AWF, (2019). Elephants have a life expectancy of about 60 years. Males may weigh as much as 6 tons (6,000 kg), and females 2.7 tons (2,700 kg). The gestation period is 20-22 months. They are generalized herbivores (mixed feeders) relying on widely distributed resources (PBS, 1997, Bradford, 2019). Elephants require a large home range to satisfy their huge nutritional demands (Galant et al., 2006; Jackson and Erasmus, 2005; Whitehouse and Schoeman, 2003). According to Bradford (2019), elephants spend over 16 hours in a day eating, and consume about 75-150 kg of foliage. They eat a variety of vegetation to satiate their nutritional needs, from grasses, fruits, roots, leaves and the barks of trees. They thus thrive in woodlands, forests, wooded shrubland, and wooded grassland habitats (Simberloff, 1998). Elephants play an important ecological role in savannahs and forest ecosystems in maintaining suitable habitats for numerous animal species (Stephenson, 2007). Their habit of stripping bark from trees and pulling down trees to access fodder modifies vegetation dynamics and plays a fundamental role in the creation of savannah-woodland mosaics (Richmond, 2006).

As pointed out by Osborne (2012), the loss of elephant habitat and subsequent home range in priority areas is a cause for concern and is caused by agricultural expansion into elephant habitat. The latter is negatively impacting forests, woodlands, wetlands and open grasslands. Other contributing factors include expanding agriculture into elephant migratory pathways and corridors, unsustainable and unregulated land use practices, limited awareness and knowledge on elephant conservation and associated benefits and to some extent climate variability resulting in extreme droughts and floods. In their entirety these factors result in a serious challenge for the Maasai Mara National Reserve, where land is host to huge numbers of elephants, carrying about 60% of the MML elephant population (Mara Conservancies, 2017 and KWS, 2019). These changes impede wildlife movement and fragment prime elephant habitats (BurnSilver et al., 2008). The fragmented landscape negatively impacts elephant home ranges and space use, making it critical for managing elephant conservation and mitigating human-elephant conflicts.

Description of the Study Area

Maasai Mara Landscape lies in southwestern Kenya. Within it lies the famous Maasai Mara National Reserve (1° 29’24”, 35° 8’38”E), an unfenced and contiguous area with unprotected land to the north, east and west. The Serengeti National Park is to its South. Located between latitudes covering an area of 12, 961km^2. MML could specifically be divided into several regions. These are the Maasai Mara Triangle, Trans Mara areas, Mara conservancies and part of the former Kajiado ranches (Awuaso Kedong, Suswa, Oldinyoke, Olkiramatian, Shompole) and a section of Magadi Concessional area. A large proportion of the study area is within Narok County while a small section is in Kajiado County and borders Tanzania on southwest (Fig. 1-0). Both counties are famous for wildlife conservation and pastoralism.

Animal migrations occur in Maasai Mara, a sight of thousands of these animals migrating together in certain season of the year through the reserve grasslands has been described by many popular accounts as one of the greatest wildlife spectacles on Earth and this has been termed as ‘The seventh Wonder of the World’ (Hoare, 2009; Maasai Mara, 2019).

Maasai Mara Landscape Ecological Zones

The Maasai Mara Landscape has different land use zones. The National Reserve, owned and controlled by two local governments is used exclusively for wildlife tourism and conservation. The adjacent group ranches on the other hand are owned privately or communally and have multiple land uses, ranging from pastoralism, small-scale farming, mechanized faming and wildlife tourism. This ecosystem also lies on the border to Tanzania, where socio-economic, political and land tenure systems are different. Wildlife movement across the borders from Tanzania is another important phenomenon. Animals migrating into Maasai Mara from Tanzania occupy the National Reserve and the adjoining group ranches, while resident wildlife species also migrate between the reserve and the adjoining dispersal areas within the ecosystem. These increased populations of migrating animals make the protected areas within the ecosystem to be inadequate in catering for the welfare of these migratory wildlife species. The overflows of these animals to the adjoining group ranches has a direct influence on wildlife in the protected areas.

Land Use and Land Cover (LULC) Classes and Definitions

Identification of different spectral signatures was important in maintaining high accuracy in the image classification. Thus, Table 1 shows the definitions of different LULC classes that were observed in this study.

MATERIALS AND METHODS

Introduction

The study of the human impact on the environment and its functioning is a great challenge. The development of

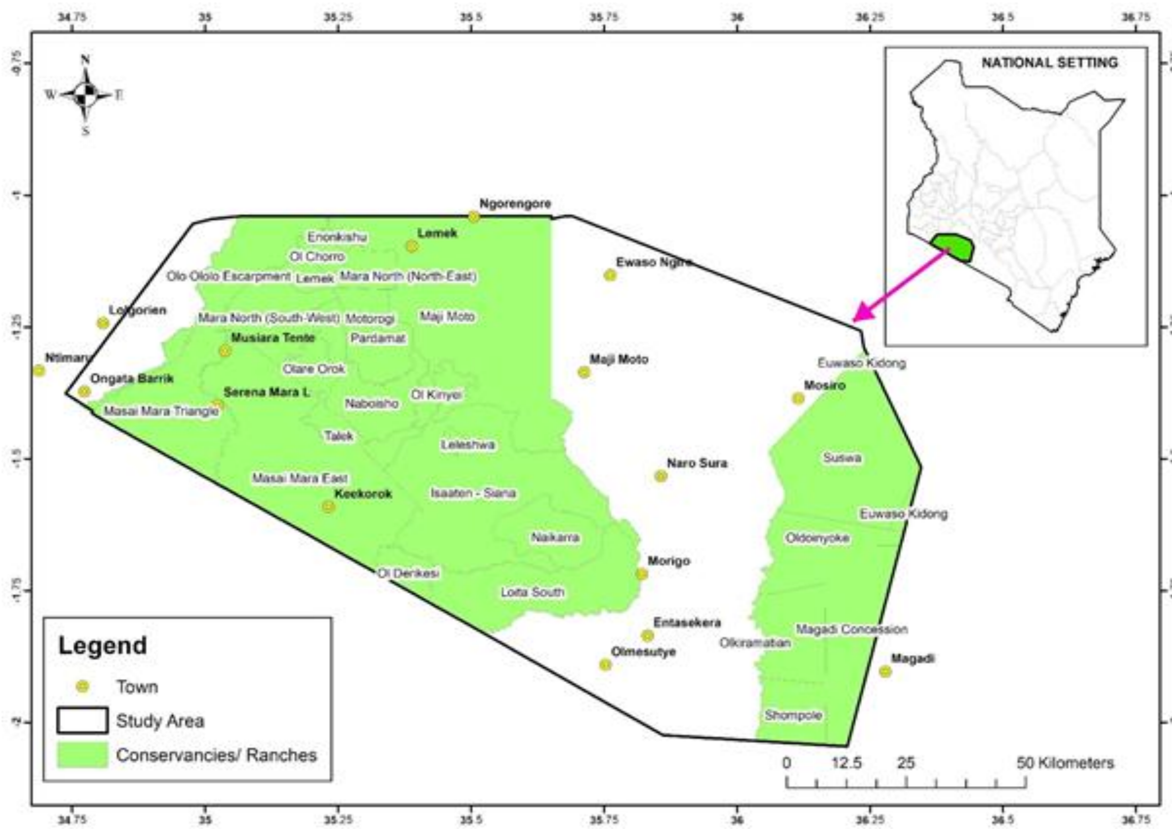


Figure 1-0. A map of the study area – MML.

Table 2.1. Land class and definitions for supervised classification.

Land Cover		Description
1.	**Forestcover**	This describes the areas with evergreen trees mainly growing naturally in the reserved land, along the rivers and on the hills.
2.	**Open shrub**	Describes areas with sparse trees and shrubs.
3.	**Densecover**	This describes the land having the component parts closely compacted together with both vegetation cover and grass.
4.	**Waterresources**	This class of land cover describes the areas covered with water either along the river bed or man-made earth dams, filled sand dams and ponds.
5.	**Bareland**	This describes the land left without vegetation cover. This results from abandoned crop land eroded due to degradation and weathered road surface.
6.	**Grassland**	This class of land cover defines grass as the main vegetation cover.

suitable and reliable indicators which can provide all essential information about the viability of a system and its rate of change and about how that contributes to sustainable development of the overall system presents a key issue (Bossel, 1999). Nowadays, this kind of assessment is greatly facilitated by the data provided by the modern earth observing systems. Remote sensing techniques together with Geographical Information Systems (GIS) increase the capability to analyze the dynamic environment and human impact on the environment by using quantitative and qualitative data in spatial format.

Research Design

The study considered both qualitative and quantitative approaches in describing trends in land use/cover change using remote sensing techniques. The resulting trends in changes were correlated with changes in vegetative condition by classification based on a minimum mapping unit (MMU) of 0.025Ha (50x50m) (Wiens, et al, 2019). We linked multispectral satellite remote sensing and monitored collared elephant's movements and their extent distribution in Global Positioning System (GPS) coordinates with habitat change and elephant movement and distribution data. In order to derive land use/cover (LULC), three epochs of medium resolution Landsat imagery (NASA, 2019) spaced in every ten year time steps were acquired for the years 1997, 2007 and 2017. Image interpretation was subjected to the 3 epochs separately by applying both unsupervised and supervised classification methods using ERDAS 11 software (GIM International, 2019). The land use/cover classes followed the standard Intergovernmental Panel for Climate Change (IPCC) classification scheme of 2003 namely: Forest land, open shrub, Grassland, Water resources, dense shrub and bar ground (IPCC, 2003). Change detection was fulfilled using the to/from overlay technique using ESRI's ArcGIS 10.5 software (ESRI, 2016) to develop change matrix between image pairs.

Data Collection Methods

Analysis involved 10-year changes in land use and land cover using three epochs from 1997, 2007 and 2017 to generate six land use classes. Landsat images were downloaded from United States Government Geological Survey (USGS) (USGS, 2019) defined by the study area which lie in the path/row of 169/061. Landsat 8 image (2017) and Landsat 5 images (2007 and 1997) were acquired for wet season and image preprocessing carried out. Topographical and atmospheric corrections were done to remove errors which might affect classification results. Layer stacking, process of combining different image bands to form image composite, was carried out where bands 1-7 were stacked except for thermal band 6 (Landsat 8) and bands 1-6 for Landsat 5 images (2007 and 1997). Study area extents for the three imageries were created by sub-setting from larger imageries and subjected to supervised classification. Image visual interpretation was carried out based on expert knowledge using elements such as feature shapes, texture, color/hue, pattern, size and association. Several spectral signatures were created using distinct training sites on the image. Training sites were representative to avoid bias in classification. Six spectral signatures were identified each representing a land use/ land cover class. All spectral signatures were subjected to spectral signature curves where similar curves indicated feature mix-up and separate and distinct curves showing higher resolution of individual features. This process was repeated until best results were achieved. Classification was finally carried out using Maximum Likelihood Classifier (Enderle et al., 2005) for each epoch in conforming to Land Cover Classification System (LCCS).

Classification Analysis

Classification results were subjected to ground truth to improve accuracy. Representative sampling for each of the land use/land cover class was done. Ground data were collected using releve record sheets which entailed collecting information on mapping unit information, vegetation structure, plot size, species composition, Global Positioning System (GPS) coordinates, altitude, and general land forms and date of collection among other aspects. Images reclassification was carried out and accuracy assessment performed using reference data. Change detection was done through the area analysis where the land use/ land cover was statistically analyzed to highlight the trends and rates of changes between 1997, 2007 and 2017. Image classification was performed using ERDAS 11 while further analysis was done. Cartographic map production was done using the Arc GIS 10.5 software (ESRI, 2016). Results were presented in maps and tables.

Instruments

The instruments used were remote sensing apps and GIS coordinates. Landsat images were downloaded from United States Government Geological Survey (USGS). Global Positioning System (GPS) coordinates for 15 collared elephants were used to examine distribution and movements. On the chosen sample population, 6 male, 9 female elephants were considered. 5 old elephants (2 male, 3 females-55 years and above) nearing the end of their life spans were considered in Category 1 (C_1). 2 bull elephants and 5 cows in their prime ready to mate were considered in Category 2 (C_2). In category 3 (C_3), the rest of the sample population consisting of 2 young male elephants and 1 female. C3 would help determine how the vulnerable members of the elephant population related and depended on the rest for survival. The collaring was done at the beginning of long rains in April and the end of October, the dry season. These are the two main wet and dry seasons, and would provide a fairly good result on movement patterns and feeding behaviour of the elephants. Cartographic map production was done in Arc GIS 10.5 to produce land use cover maps.

RESULTS

Land Use and Land Cover Changes within the Maasai Mara Landscape

The findings for the six classes of the land use/land cover; forest, dense shrubs, open shrubs, grassland, water and bare ground showed that: Forest class comprised of trees ranging from 5m and above, canopy cover of above 60%. Forest class also included river line vegetation above 5m in height. Dense shrubs comprised of woody and non woody vegetation with canopy coverage of over 70% and trees height below 5m. Open shrubs classification was as that of dense shrubs but with a lower canopy cover of 40% and below. Vegetation was more scattered than dense shrub class. Grassland comprised of grasses and sedges of up to 1.5m and coverage of more than 50%. Water class comprised of all above ground water accumulation stagnant of flowing. Bare ground class was an aggregation of dry/ wet soil, sand, cultivated areas, settlements and degraded grounds. The entire classification was based on a minimum mapping unit (MMU) of 0.025Ha (50x50m).

Land Use and Land Cover for 1997

The LULC classification for 1997 from Landsat 5 satellite image is shown in Figure 4.1.
Figure 4.1 shows that forest cover was found around Entasekera, Morigo, Olmesutye, Lolgoren and Oloololo escarpment. Other smaller pockets occurred in the east of Lemek, north of Ewasongiro and Mosiro running south to Entasekera (Figure 4-1). Dense shrubs were found around Musiara, Enonkishu conservancy and Entasekera. Open shrubs covered the Maasai Mara East and the Mara Triangle, Oloololo escarpment and conservancies in the north of the study area. Grasslands occurred at the edges of open shrubs and forests whereas bare ground occupied the central section of the study area (Maji moto) extending towards the eastern edges. The areas for land use and land cover classes for the year 1997 were calculated and the results are shown in Table 4-1.
Table 4.1 shows the study area land cover for 1997. Vegetation covered 74.6% of the total area, while bare are covered 25.2 %. Open shrub land (34.3 %) covered most of the study area followed by grassland (28.8 %).

Land Use and Land Cover for 2007

The LULC classification for 2007 from Landsat 5 satellite image is shown in Figure 4-2
Figure 4-2 shows intact forest coverage occurred around Entasekera and Oloololo escarpment. Substantive pockets existed around Ol-Derikesi, Loita South and Isaaten-Siana conservancies and within Lemek centre. Dense shrubs were evident inside the forest stand of Entasekera. Open shrubs dominated Masai Mara East, Masai Mara Triangle, Oloololo escarpment, Loita South and edges of Morigo-Entasekera-Olmesutye forest. All the conservancies were dominated by grassland. It also extended to the belt from Ewaso Ngiro, Mosorio, NaroSura centres towards the south of the study area. Open expansive cover were seen as bare ground within the conservancies while the central, north eastern and south eastern section of the study area were predominantly bare. The areas for land use and land cover classes for the year 2007 were calculated and the results are shown in Table 4-2.
Table 4-2 shows the study area land cover for 2007. Vegetation covered 61.4 % of the total area, while bare are covered 38.4%. Grassland (32.1 %) covered most of the study area followed by open shrubland (20.1 %).

Land Use and Land Cover for 2017

Classification were grouped into six land use/ land cover classes; forest, dense shrubs, open shrubs, grassland, water and bare ground. The LULC classification for 2017 from Landsat 5 satellite image is shown in Figure 4-3.
Figure 4-3 shows forest coverage in 2017 reduced drastically and only occurs in the Morigo- Entasekera-Olmesutye section. Evident expanse pockets of dense shrubs occur inside the above mentioned forest while open shrubs dominate Oloololo escarpment which was formerly forested. Grasslands occur within the conservancies and along the eastern belt of Mosiro and NaroSura. The land cover classes for the different cover types are shown in Table 4-3.
Table 4-3 shows the study area land cover for 2017. Vegetation covered 48.8% of the total area, while bare are covered 51.1 %. Grassland (29.1%) covered most of the study area followed by open shrubland (14.9 %). The land cover for the different cover classes for 2017 show that bare ground (51.1%) was the highest, while the vegetation covered 48.8%.

Trends in Land Use and Land Cover

The trends in land use and land cover in the study area from 1997 to 2017 are shown in Table 4-4.
The vegetation cover decreased from 74.6% to 61.4%, while the bare areas increased from 25.2 % to 51.1 %. Forest cover decreased from 10.6 % to 4.1 %. These changes can be related to the changes that have occurred within the study area. The increase in bare ground can be related to the increase in clearing of the area of vegetation to grow crops, while the reduction in forest cover and open shrubs can be related to elephant browsing of the woody plants. These overall changes in the pattern for the identified LULC classes with relative area change during the following study periods: 1997-2007, 2007-2017 and 1997-2017 are graphically displayed in Figure 4-6.

Changes in the Spatial Extent of Vegetation Cover

The land use/cover changes that have occurred in the study area were assessed over a period of 20 years

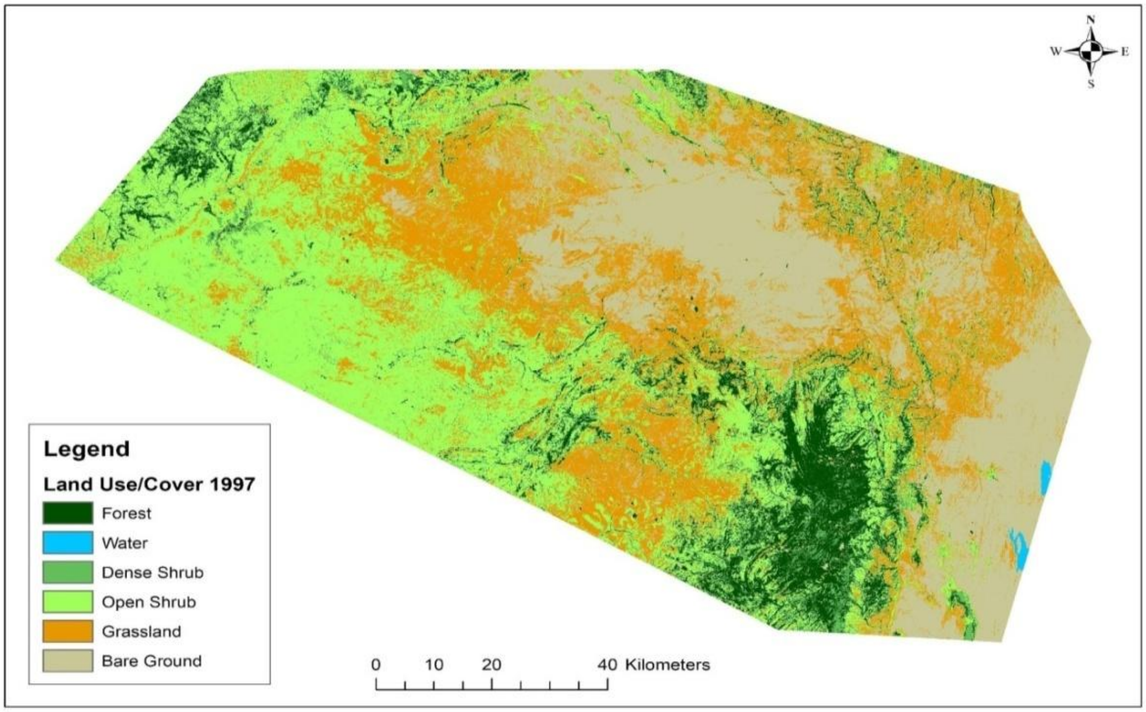


Figure 4-1. LULC classification map of the study area for the year 1997.

Table 4-1. LULC Classes and their Corresponding Areas for the Year 1997.

Land Cover Types	**Area in Hectares**	**% Land Cover**
Forest	137,469	10.6
Dense Shrub	11,558	0.9
Water resources	2,243	0.2
Open Shrub	445,342	34.3
Grassland	373,990	28.8
Bare Ground	327,106	25.2
Total	**1,297,708**	**100**

using differences in land cover between 1997 and 2017 remote sensed images using both remote sensing and GIS techniques. The land use changes are summarized in Table 4.4, which shows the acreage of the different land cover classes for the two periods 1997 and 2017. The spatial extent of the different land use types in the study area were found to have changed during the period that was studied. As presented in Figure 4-4, different LULC classes changed differently over the years from 1997-2017. Some of the categories increased in area coverage while others decreased. Table 4-4 shows that there was forest loss of 26.35% and 47.67% between years 1997- 2007 and 2007- 2017 respectively. Dense shrub coverage increased between years 1997- 2007 by 39.15% but decreased drastically by 49.03% in the years 2007-2017. Above ground water (streams, earth dams, swamps, rivers, ponds) decreased by 6.69% (years 1997- 2007) and decreased by a further 36.6% between 2007- 2017. Open shrubs reduced by 41.48% in the first 10 years and further reduced by additional 25.86% in the years between 2007 and 2017. Similar to forest, dense shrubs and open shrubs reduced. In contrast, grassland

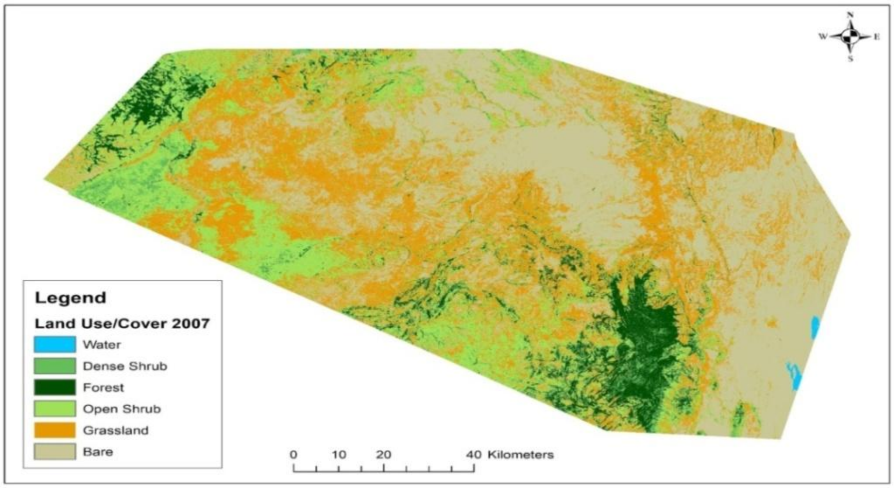


Figure 4-2. LULC classification Map of the Study Area for the Year 2007.

Table 4-2. LULC Classes and their Corresponding Areas for the Year 2007.

Land Cover Types	**Area in Hectares**	**% Land Cover**
Forest	101,245	7.8
Dense Shrub	18,993	1.4
Water resources	2,243	0.2
Open Shrub	260,608	20.1
Grassland	416,106	32.1
Bare Ground	498,663	38.4
Total	**1, 297,708**	**100**

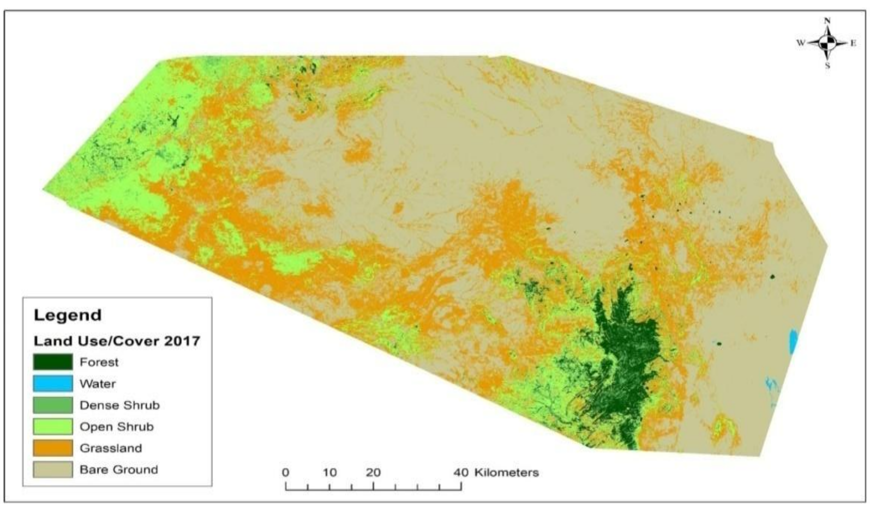


Figure 4-3. LULC classification map of the study area for the year 2017.

through succession dominated the study area increasing by 10.125 (1997-2007) but reduced by 9.36% (2007-2017). Finally, bare ground coverage increased all through the study period (34% between 1997- 2007 and 24.83% between 2007- 2017).

Impacts of Land Use/ Land Cover Changes on Elephant Distribution

Study findings indicate movement / distribution of elephants being related to land use/cover within the Mara

Table 4-3. Land Cover Classes and their Corresponding Areas for the Year 2017.

Land Cover Types	Area in Hectares	% Land Cover
Forest	52,981	4.1
Dense Shrub	9,681	0.7
Water resources	1,327	0.1
Open Shrub	193,211	14.9
Grassland	377,169	29.1
Bare Ground	663,339	51.1
Total	**1,297,708**	**100**

Table 4-4. Trends in Land Cover Classes between 1997, 2007 and 2017.

	1997		**2007**		**2017**	
LULC Types	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Forest	137,469	10.6	101,245	7.8	5,298	4.1
Dense Shrub	11,558	0.9	18,993	1.5	9,681	0.8
Water Resources	2,243	0.2	2,093	0.2	1,327	0.1
Open Shrub	445,342	34.3	260,608	20.1	193,211	14.9
Grassland	373,990	28.8	416,106	32.1	377,169	29.1
Bare ground	327,106	25.2	498,663	38.4	663,339	51.1
Total	**1297,708**	**100**	**1,297,708**	**100**	**1,297,708**	**100**

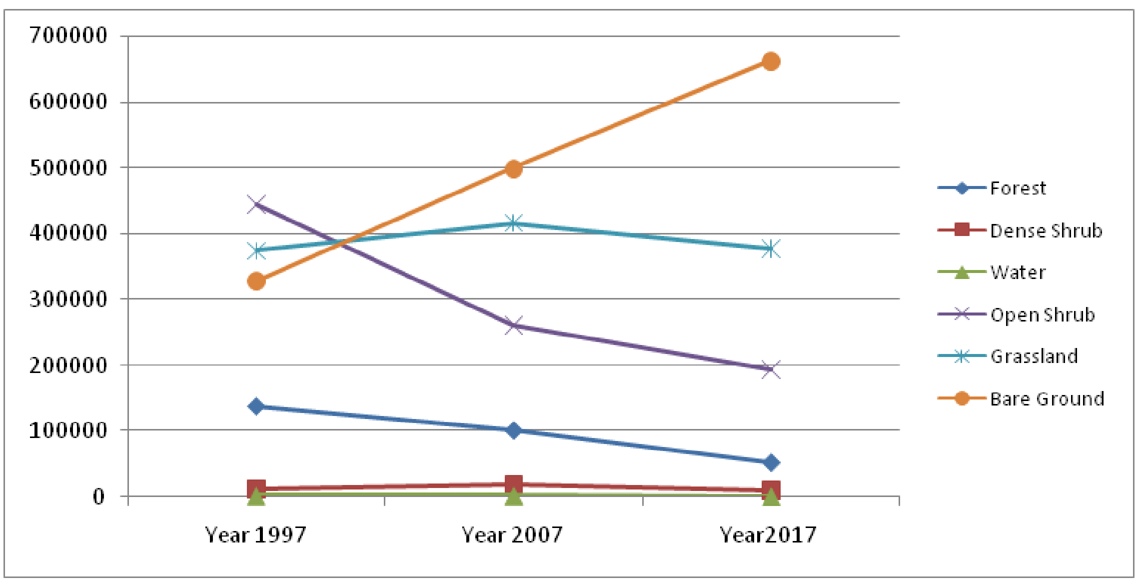


Figure 4-4. Gradual changes in LULC categories from 1997 – 2017 in MML.

ecosystem. Elephants were highly concentrated on Maasai Mara Triangle, Mara North, Lemek, Olkinyei, Majimoto, Leleshwa and Isaaten- Siana conservancies within Narok County. In Kajiado County, highest densities were recorded in Suswa, EwuasoKedong, Olkiramatian and Shompole ranches as shown in Figure 4-5.

The 2007 map shows elephant distribution in more degraded habitats as compared to 1997. Suswa and Shompole ranches (where on the map) are almost bare. These areas are normally candidate habitats for elephants but also have high densities of livestock from pastoralists. A similar but more alarming trend is on the

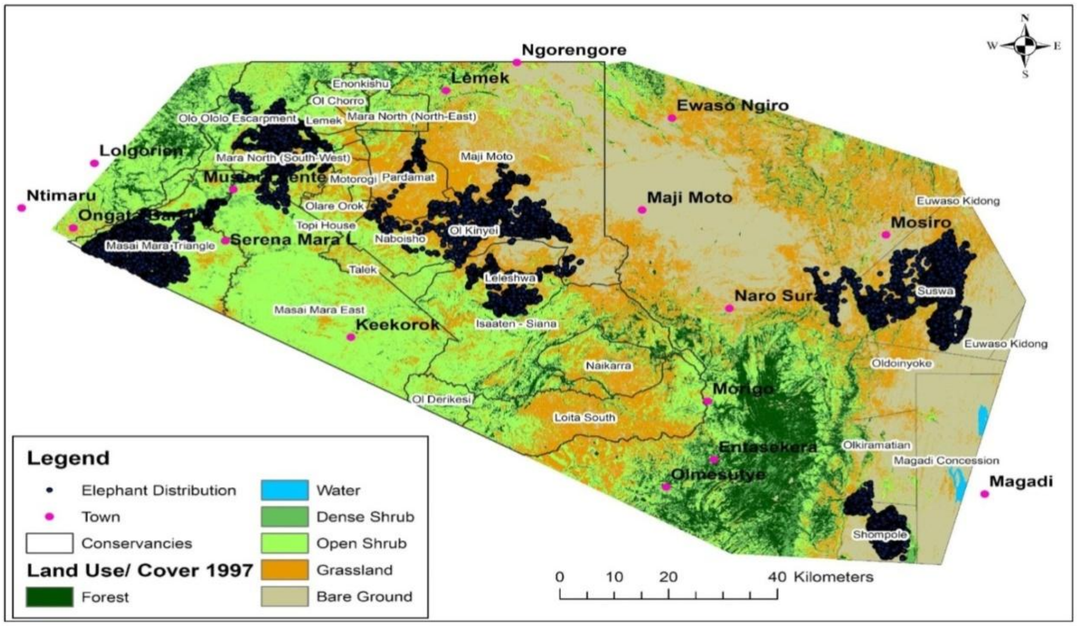


Figure 4-5. A map of 1997classification showing elephant distribution in MML.

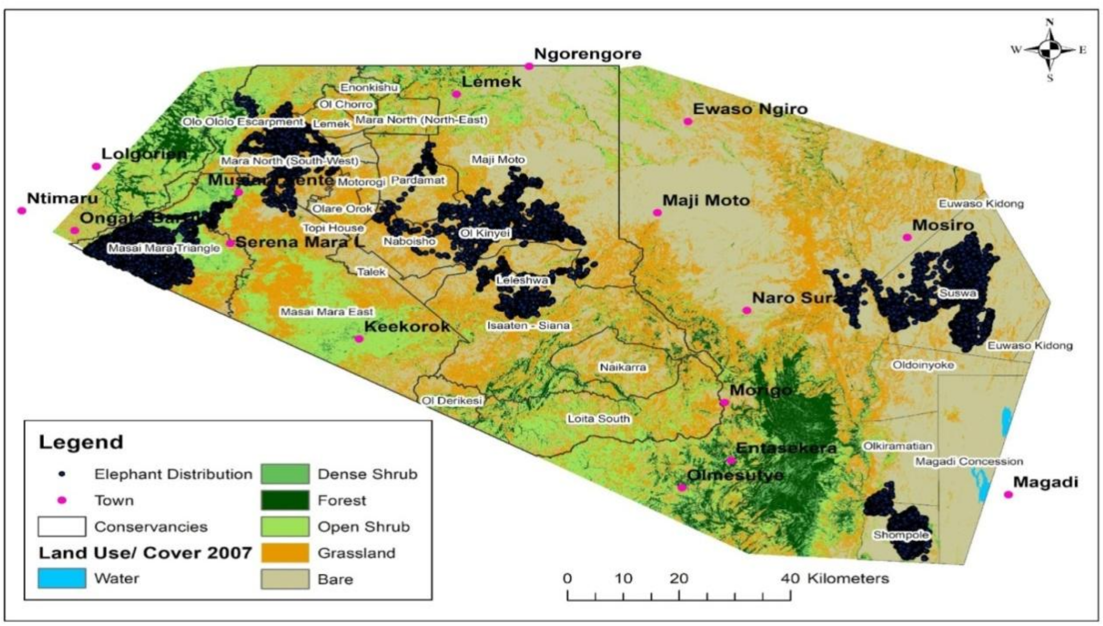


Figure 4-6. A map of 2007 classification showing elephant distribution in the MML.

map which is more worrying for survival of elephants.

Generally, the study area has undergone continuous but fast degradation due to land use changes. Increase in livestock densities have led to high competition of pasture with wildlife. Land subdivision, land conversion to agriculture and other uses, fencing, prolonged droughts and human settlements are the major drivers for land use/ cover changes in the area. Distribution of elephants has been restricted to small home ranges (as shown on the 1997 – 2017 maps) hence accelerating the rate of habitat destruction and degradation. High human attack/ death incidences, crops invasion and even destruction of property have risen.

Impacts of Land Use and Land Cover Changes on Elephant Home Ranges

Elephant home ranges were greatly affected by the changes that have occurred within the ecosystem as indicated in Figure 4-8.
Elephants have now been moving from Mara Triangle and the neighbouring conservancies to Shompole and Suswa ranches. Due to significant land use and cover changes within the Mara landscape, the study has found that elephants prefer to remain in hills or thick riverine forest during the daytime and may sometimes venture into open areas to drink or during the rains when there is much grass available, but they usually don't leave the dense bush until the evening or in the early morning which is likely due to past pressures from human activities. Vegetation reduction increased elephant home ranges. However, land fragmentation, for instance, fencing and land conversion to agriculture, blocked migratory and movement corridors for wildlife hence reducing their home ranges.

DISCUSSION

Land Use and Land Cover Changes within the Maasai Mara Landscape

Changes in Forest Cover

During the 20 year study period, forest coverage continued to decrease. More than 36,000 ha of forest cover were lost in the first decade and approximately 49,000 ha between 2007 and 2017 as indicated in Figure 4-4 and Table 4-4. This drastic change can be attributed to the immense impact of human activities in the ecosystem. Mara ecosystem has been under threats from logging, illegal charcoal burning and over extraction of timber products (Mara Conservancies, 2017). Other drivers include increased human population, increased poverty levels, laxity in enforcement of environment and conservation laws, inadequate conservation education and awareness (Teketay, 2001; Taddese, 2001; Getachew et al., 2011; Bewket and Sterk, 2005; Amsalu et al. 2007; Moges and Holden, 2009). Impacts of climate change should not be underestimated. The ecosystem has suffered from the effects of prolonged droughts. Increased elephant density has led to forests destruction and habitat degradation (Holtmeier, 2014:44)

Changes in Dense Cover

This class comprised of woody and non- woody vegetation ranging between 2-5m. These habitats are largely used by elephants for foraging. There was a slight increase in dense cover in the first decade which can be attributed to the opening up of forest cover due to various drivers acting singly or in combination. The second decade recorded a 50% reduction, a sign of habitat degradation and similar conclusions were reported by Tsegaye et al., (2010) and Tekle and Hedlund, (2000). An increase in elephant population and anthropogenic activities can largely be considered the cause for this sharp decrease in dense vegetation.

Changes in Open Shrub

There was a decline in coverage of open shrubland over the study period. A large proportion of the cover was lost between 1997 and 2007 (Fig. 4-4). This is commensurate with forest cover loss in the same period. This can be attributed to high elephant densities within the shrub lands, overgrazing, conversion of land to agriculture and other human activities necessitating clearance of vegetation for various uses. This resulted in the need for more food and settlement area as found out by other similar studies (Zubair, 2006; Rindfuss and Adamo, 2004; Vitousek, 1997).

Changes in Grassland

An increase in grassland cover was recorded between 1997 and 2007 but a slight decrease occurred from 2007 to 2017 (Figure 4-4). Degraded forests, dense and open shrub vegetation turned to closed or open grasslands. As similarly found out by Alemu et al., (2015), the abandonment of agricultural lands due to unfavorable climatic conditions may lead to the conversion of these lands to grasslands. Also, the conversion of barelands to grasslands through natural growth may be a reason for the increase in coverage of grasslands during this period as similarly documented by Dwivedi et al., (2005) and Garedew et al., (2009). In the case of slight decrease in 2007 – 2017, Maasai Mara ecosystem has largely been reduced to savannah grassland. This has favored pastoralism which has a direct impact on grass cover due to overgrazing. Classification maps showed continuous loss of grass cover to bare ground. This has an impact on elephant pasture availability and leads to human wildlife conflicts. The growth of small urban areas due to population growth and the resulting need for social amenities on lands that were initially grasslands contributed to the observed reduction as also concluded by Mundia et al., (2006).

Changes in Bare Ground

Study indicates a steady continuously increasing cover of bare ground and this implies that habitat deterioration and degradation is taking place (Figure 4-4). As a result, it has a multiplier effect on the functioning of the ecosystem including wildlife, livestock and human beings. Conversion and decrease in other classes such as forests, open shrub land, grassland and dense cover

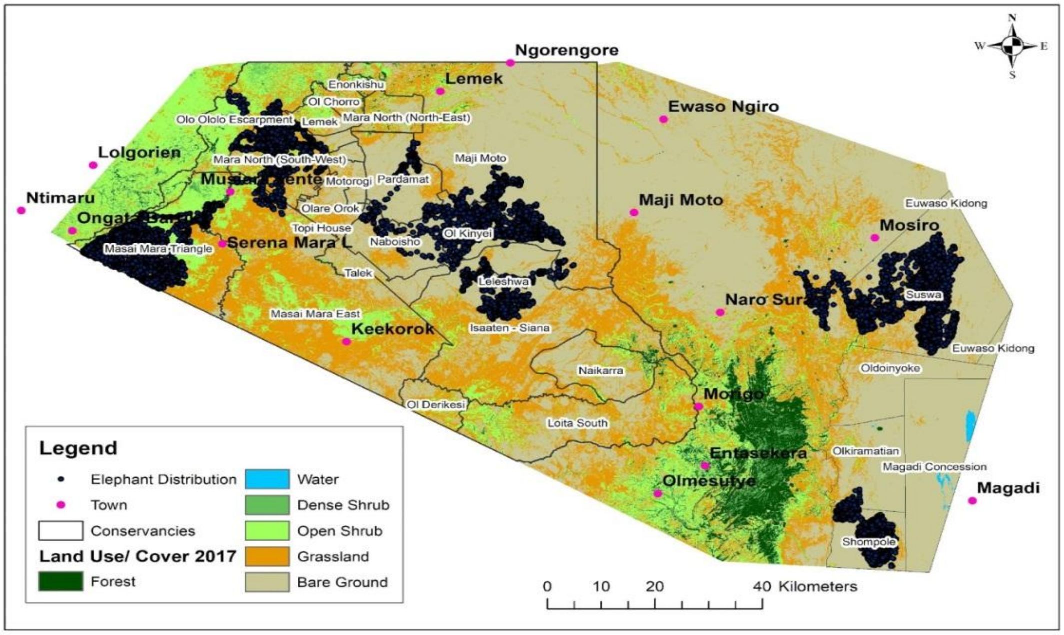
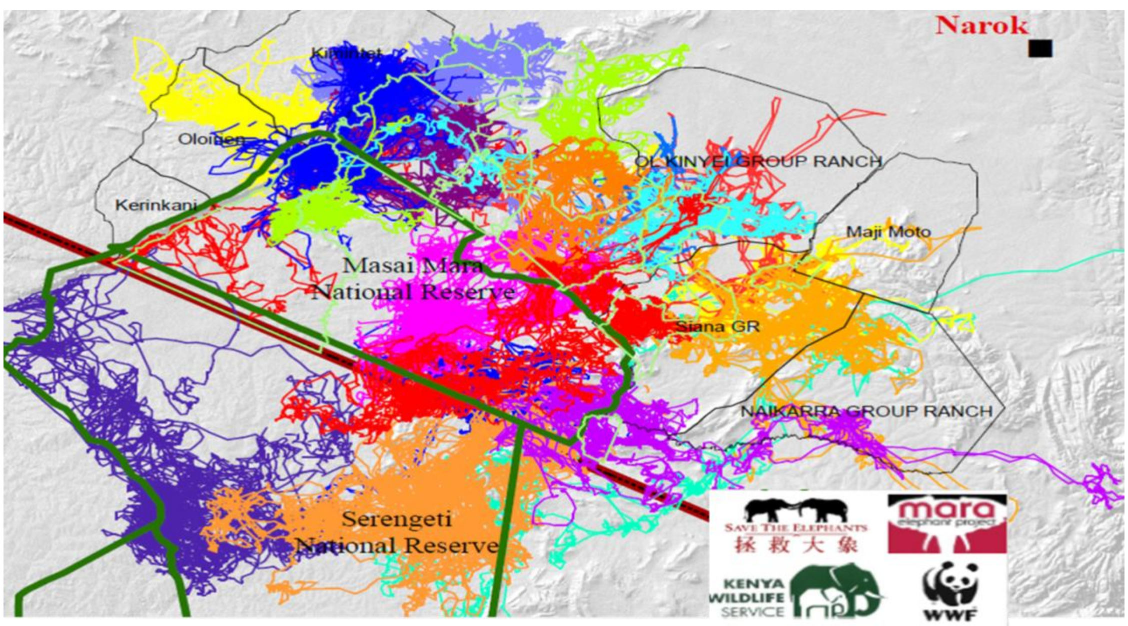


Figure 4-7. A map of 2017 classification showing elephant distribution in the MML.



(Key- Each colour represents individual collared elephant with names tracked within the landscape for the part of the period under study**).**

Figure 4-8. Individual Elephants Tracked in the MML between 2011 – 2015 (Source: STE, MEP, KWS, WWF).

attribute to bare lands as agreed with the results of Leemans et al. (2001) and Lepers et al. (2004). Livestock overstocking, overgrazing, farming, settlements and increased wildlife numbers may have a cumulative effect on the ecosystem leading to loss of vegetative material. Furthermore, intermittent floods have resulted in massive erosion of soils and vegetation. The prolonged periods of dry spells experienced in the ecosystem have also contributed to vegetation loss. Overstocking of livestock and the lack of knowledge on more sustainable methods and strategies of livestock feeding is considered the reason behind the overgrazing. The results of these underlying factors agree with conclusions of other LULC studies done in other areas (Ermias, 2006; Cihlar, 2000;

Reid et al., 2000).

Changes in Water Resources

The ecosystem showed a reduction in land area covered by water over the study period (Table 4-4). This can be attributed to the continuous degradation of the area and the fact that the area receives low mean annual rainfall. This may be aggravated by the rising need of sustainable ways of storage and utilization of water as a crucial resource by humans. Similar findings have been documented in other studies (Framer-Browers et al., 2006; Getachew et al., 2011 and Kidane et al., 2012).

In total we found significant changes of various classes across the years. Forest, water and open shrubs coverage decreased from 1997 to 2017. Dense shrub decreased from 2007 to 2017. Grassland coverage decreased drastically between 2007 and 2017. Classification noted a serious concern within the study area of continuous increase of bare ground coverage across the study years.

Impacts of Land Use/ Land Cover changes on Elephant Distribution

The study area has recently been under a lot of pressure from a wide range of threats. They include: land conversion to agriculture, land subdivision and fencing, over grazing and emergence of urban centres. As a result, elephant movement and migratory corridors have been blocked, leading to insufficient sustenance for wildlife and human-wildlife conflict. Land conversion to agriculture, for instance, is ranked as one of the most significant human alterations to ecosystems (Matson et al., 1997). Landscape characteristics such as vegetation cover are modified by land use activities which in turn lead to increase or decrease in habitat quality and quantity for various species of wildlife inhabiting an ecosystem (Esikuri, 1998).

The elephants monitored in this study preferred areas with low levels of human activity, especially protected areas such as conservancies and the National Reserve, and many unoccupied areas like river banks. This is broadly consistent with previous studies of large mammal distribution in relation to anthropogenic factors (Parker & Graham, 1989; Eltringham, 1990; Barnes et al., 1991; Hoare & Du Toit, 1999). Due to significant land use and cover changes within the Mara landscape, the study has found that elephants prefer to remain in hills or thick riverine forest during the daytime and may sometimes venture into open areas to drink or during the rains when there is much grass available, but they usually don't leave the dense bush until the evening or in the early morning which is likely due to past pressures from human activities. In the dry season, or during a drought, one of the biggest problems are of course fewer water sources. Furthermore some water sources previously used by wildlife are now being fenced in which aggravates the conflict. Therefore, when it is dry we find that elephants seek out areas which are close to permanent water sources. This behaviour is challenging as most water sources are within or very close to communities. From what we have seen, the distribution of elephants is still widespread within unoccupied or conservation areas perhaps because they require the space. With this respect, droughts may force them into areas they might otherwise avoid and at the same time elephant movements are undoubtedly increasingly curtailed due to human encroachment across the region. This result is in agreement with many studies on the movement of African elephants in a human-dominated land-use mosaic (Dickson and Adams, 2009; Hoare & Du Toit, 1999, Vitousek, 1997).

Impacts of Land Use and Land Cover changes on Elephant Home Ranges

Due to the current changes, foliage for elephants have reduced drastically hence necessitating wildlife to travel longer distances in search for food. As a result this increases their home ranges. Elephants have therefore been forced to deviate from their traditional movement routes and subsequently invade human settlements and farms (Figure 4-8). It is likely that elephants have to find new access routes in order to reach preferred habitat and certain areas have been entirely blocked off from elephants. This result agrees with the finding by Thouless, (1996) on African elephant movement and home ranges. There is evidence that elephants do not occur in landscapes with human populations above a certain level of density (Parker & Graham, 1989; Eltringham, 1990; Barnes et al., 1991; Happold, 1995; Hoare & Du Toit, 1999). However, elephants and people may co-exist across a range of different land uses and human population densities in Africa (Said et al., 1995; Blanc et al., 2007).

CONCLUSIONS

This study reveals that six major LULC classes exist in Maasai Mara landscape. The evidence is that significant LULC changes have occurred in Maasai Mara landscape during the selected study period of 1997 – 2017. It was also noted during this study, that unplanned developments come up in wildlife conservation and riparian areas in disregard to existing laws and policies that are supposed to govern utilization. One of the major drivers of the observed detrimental changes that result in environmental degradation is the unplanned uncontrolled LULCC which is not guided by informed decision making process. Wildlife movement and distribution depends on forage availability is a function of spatial and temporal patterns of rainfall. Ecosystems are considered self-regulating and hence not drastically affected by natural calamities such as droughts. However, land use/cover changes especially human induced ones have detrimental impact on the balance of ecosystems with an uncertain chance for recovery. Increased human populations, overgrazing, land fragmentation, land conversion, deforestation, poaching, fires and encroachments into wildlife habitats are key drivers of land use/cover changes and may have a direct impact on distribution and movement of wildlife including elephants.

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