



Spatial-temporal Changes in Land Use Land Cover and its Impacts on Wildlife Conservation in Meru Conservation Area, Kenya

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This work was carried out in collaboration among all authors. Author KE designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MA and NC managed the analyses of the study. Author KE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Habitat conversion can be a major threat to biodiversity. Recent and current levels of human activities on landscapes appear to be overriding the natural changes to ecosystems brought about by climate variations in the past millennia. The impact of anthropogenic activities on wildlife habitat and species vary depending on the spatial and temporal scales considered and the persistence of the activities in the landscape. This study was carried out in Meru Conservation Area (MCA) to examine land use and land cover changes (LULC) that have taken place within and around the Protected Area (PA) from 1985 with an emphasis of anthropogenic activities which have altered wildlife habitat and species. The distribution of land use types within and around MCA has produced land use patterns which this study seeks to establish the extent and effects in relation to wildlife conservation. To establish the LULC, Landsat satellite images of medium resolution were acquired and interpretation done using ArchGIS. Four satellite images with a span of three decades from 1985 to 2015 were acquired for analysis. The results revealed significant changes in MCA

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ecosystem over the study period, accounting for 9.9% and 6.1% increase in grassland and bareland respectively. This means that agricultural activities are encroaching towards the protected areas in the land that was formerly used as wildlife corridors and dispersal areas. It is also an indication that there is a significant change in the forestland and shrubland which has reduced by 2.3% and 15.7% respectively resulting to bareland and grassland. The results of the study provide an insight on the threat to the future survival of wildlife in their ecosystems due to declining ecosystems productivity as well as socioeconomic livelihood of communities living around the MCA. The results of this study therefore call for an integrated planning approach towards management of protected areas in order to meet wildlife and human needs in view of the changing climate regimes.

Keywords: Land use; land cover; wildlife ecosystems; planning; climate change.

1. INTRODUCTION

Habitat conversion is a major threat to biodiversity [1,2,3]. Recent and current levels of human activities on savanna landscapes appear to be overriding the natural changes to ecosystems brought about by climate variations in the past several thousand years [4,5]. Land cover changes may occur as a result of natural factors such as fire, drought and climate variations. However, in the case of natural factors, the changes may be temporary and irregular and the ecosystem tends to recover from them. The most destructive land cover changes occur as a result of human alterations which have high a degree of resistance and consistency that minimize chances of ecosystems to recover.

Landscapes such as vegetation cover are modified by land use activities [6]. Such modifications can lead to an increase or decrease in habitat quality and quantity for various species of wildlife native to an area [7] For instance, expansion and intensification of agriculture is now recognized as one of the most significant human interactions of the global environment [8,9]. The use of land to produce goods and services has been undertaken by humans around the world for the entire 10,000 years of settled agriculture [10,11].

In this regard, the impact of anthropogenic activities on wildlife habitat and species vary depending on the spatial and temporal context considered and the persistence of the activities in the landscape. Land use has been defined as a dynamic process that changes in space and time depending on prevailing socio-economic and biophysical conditions [12,13]. Further, Musa and Odera [14] explains land use change as identification of environmental problems such as habitat and species loss.

The study carried out in Meru Conservation Area examined land use and land cover changes that have taken place within and around the protected areas between 1985 and 2015 with an emphasis to identifying anthropogenic activities that have altered wildlife habitat and species depending on spatial and temporal scales [12,15]. The distribution of land use types within and around MCA has produced land use patterns which the study seeks to establish their extent in relation to wildlife conservation. The choice of Meru conservation Area as the basic unit of analysis was considered appropriate due to several reasons [16]. First is that MCA is one of the important wilderness areas in Kenya with diverse wildlife species. Second, it portrays a classical example of a protected area network systems where there are several PAs merged together to form the MCA ecosystem. Third, the area is surrounded by human communities of diverse cultural backgrounds and with differing land use practices such as agriculture, agro-pastoralist and pastoralist. Hence a potential to experience serious land use conflicts [12]. Fourth, like many other savannas in Kenya, areas around MCA have been undergoing major land tenure reforms since 1989 following government directive to shift the tenure systems from communal ownership to privately owned individual subdivisions. According to Otuoma [12], MCA has over the past few decades witnessed a steady immigration of people from the nearby high potential agro-ecological zones into the buffer zones of Murera, Kathithi, Ntoroni and Ngaiya. Improvement of security due to reduced bandit attacks on the livestock farmers have also promoted increase in human and livestock populations in the grazing zones of Kina, Rapsu and Kaningo. This situation has subjected natural habitats that formerly served as communal grazing lands and wildlife dispersal areas to sustained fragmentation and alteration, since these immigrant households take up land for settlement, crop cultivation and for grazing. The

most affected are the wetter margins of the western and southern buffer zones of MCA which are critical for livestock and wildlife especially during the dry season. This situation has therefore resulted in a reduction in the livestock grazing range, decline in the livestock and wildlife resource base and increased competition among wildlife, livestock and people. Due to the above challenges, studies by [17-19] have reported the reduction of animal home ranges as a result changing land use/land cover within and around the protected areas culminating to loss of species and increased human wildlife conflicts.

2. METHODS

The objective of the study was to establish changes in land use and land cover that have occurred in Meru National Park and Mwingi National Reserve in Meru Conservation Area over a period of 30 years and its impacts on wildlife conservation and management. Medium resolution Landsat TM images (1985, 1995, 2005

and 2015) were acquired from the Regional Centre for mapping and Resources development (RCMRD) in Nairobi, Kenya to identify and delineate different land use land cover types in MNP, MNR and their adjacent areas. The images (Landsat TM 30m resolution) were all taken for the dry month of August. The difference in ground resolution was assumed negligible for this study because the total area converted at a landscape scale (1/50,000) is what the study measured.

Land cover changes were assessed by use of these Landsat TM images, topographic maps of the MCA that comprises MNP and MNR as well as ground validation using GPS for geo-referencing. Field observation and existing data by KWS was useful in assessing the impacts of the land cover changes on wildlife through observing the species occurrence, distribution and population, reported incidences of human wildlife conflicts and encroachments.

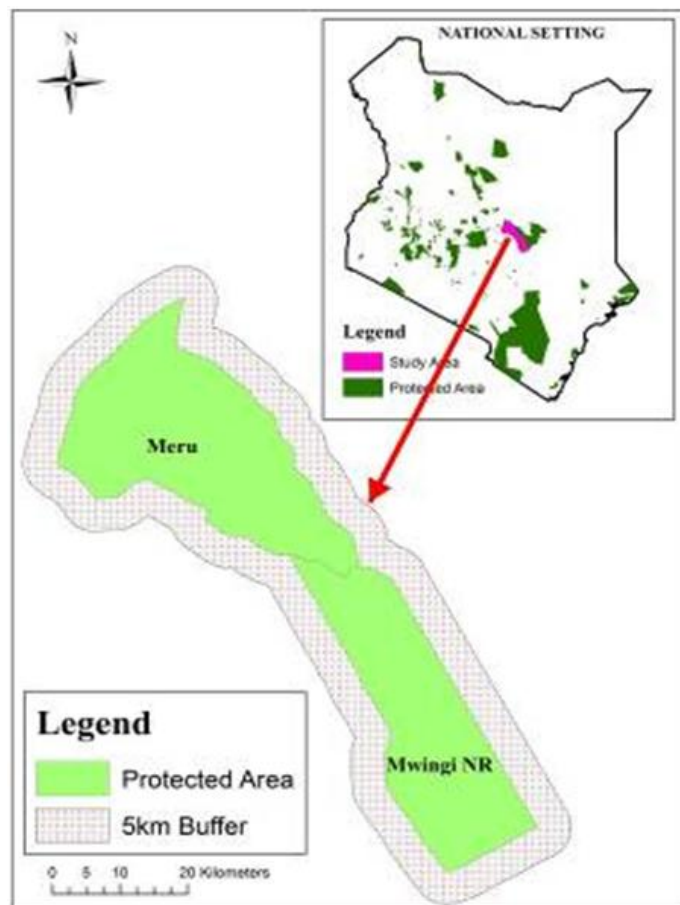


Fig. 1. Map of the study area

Land use land cover (LULC) analysis was achieved through acquisition, interpretation and analysis of the Landsat TM images using the ArcGIS and IDRISI. The Landsat TM image of 1985 was geo-referenced against a topographic map at a scale of 1/50,000 using a number of control points that were determined during the field visit. This was followed by image to image registration by geo-referencing the satellite images of 1995, 2005 and 2015 against the geo-referenced image of 1985. This ensured that the pixel grid of 1995, 2005 and 2015 conformed to the geo-referenced image of 1985 to enable pixel by pixel comparison of the image. The images were then analyzed for various land use types while changes in land classes were mapped and quantified. Land use land cover changes were analyzed using descriptive statistics to show the variations from 1985 to 2015. This involved calculation of the size of areas under each land use for the years (1985, 1995, 2005 and 2015) using the database query module in Arc Map. The areas were then transferred to excel for computation of land use changes over time. Pearson correlation coefficient (r) statistic analysis was performed to determine linear association between different land use changes in MNP and MNR.

3. RESULTS AND DISCUSSION

3.1 Population Growth and Land Use Activities

From the study's findings, 34(28.3%) of the respondents were agriculturalist occupying mainly the Baibariu block on the western part of MCA, 43(35.8%) were mixed farmers practicing livestock keeping and subsistence farming at Ntoroni and Kaningo blocks while 41(34.2%) were pastoralist occupying the Rapsu block on the northern border of MCA. The other category that represented 2(1.7%) respondents engaged in business in the locally upcoming centers or those who were not specific on their reporting.

The findings established that there has been a dynamic growth in human population around MCA since late 1980s. This was after security operations were improved by KWS to drive away the bandits and pastoralist who had earlier on invaded the protected areas for wildlife hunting and livestock grazing [1,20]. This improved the security situations thereby attracting many immigrants into the area. For instance, the population of people in southern of Ntoroni MNP in Tharaka rose from 391 households in 1980 to 717 in 2000. While the current population in

study block according to 2009 census stand at 917 households which is an increase of 57.4%. Upon investigation on the duration of stay and method of land acquisition, it was established that majority (79%) of the households that occupy the buffer zones were migrant who came to the area in search for more land for agriculture and livestock keeping. The majority of these had moved from agricultural rich areas of Meru, Nyeri, Murang'a and Kiambu. The main affected areas of MCA were the northern and southern buffer zones which led to permanent settlement due to higher rainfall gradient where 45% had either purchased or leased the land.

Investigation on the form of land ownership established that 48(40%) of the respondents reported that the land they live in is under private tenure, 52(43.3%) reported that the land is under communal ownership while 20(16.7%) of the respondents reported that they knew the land to be under public ownership since individuals do not have title deeds as proof of absolute ownership. This investigation further observed that due to lack of title deeds as a security of land tenure, majority of the respondents had built temporary structures for fear of eviction or re-allocation of the land to another individual when land adjudication was done. The information from the location leaders tallied with that of the respondents that the land is under adjudication and the title deeds are yet to be issued.

Results of this study supports the previous findings by (KWS and AWF 2008) that communities have not only utilized the buffer areas adjacent to the parks, but have further occupied the land that was initially set aside as movement corridor for wildlife from MNP to Ngaya forest. In MNR, local communities have extended their shifting cultivation, charcoal burning and livestock grazing inside the reserve. It regularly takes the intervention of KWS to evict and arrest those found carrying out such illegal activities, an issue that has continued to harbor resentment by the residents and fueling human-wildlife conflicts.

3.2 Land Use Land Cover Classification

Classification of different satellite images was guided by specific land use land cover (LULC) categories as shown in Table 3.

The analysis of the classified images produced the area in kilometer squared (Km²) for each

LULC class over the study period and the percentage (%) of each land use category as indicated in Table 2.

The analysis of LULC changes revealed substantial transformation in MCA ecosystem over the 30-year study period. For instance, the grassland and bareland are the land cover categories that were found to have significantly expanded in area respectively from 48659 Ha and 28065 Ha in 1985 to 76923Ha and 46048 Ha in 2015, accounting for approximately 9.9% and 6.1% increase in these land cover change. This could be an indication of agricultural activities that are encroaching towards the protected areas which were formerly available as wildlife corridors and dispersal areas. It is also an indication that there is a significant change in the forestland and shrubland which have reduced respectively from 46667Ha and 152353Ha in 1985 to 40255Ha and 107587Ha in 2015 accounting to 2.3 and 15.7% decline resulting to bareland and grassland.

The result of image classification as per the period is as shown in the Figs. 2 and 3.

The Fig. 2(a) represents the results of the 1985 image classification into six different land cover

land use classes. As per this period, the study shows that the total land cover for forest was 46677 km², shrubland was 152,353 km², grassland covered 48,659km², riverline vegetation was 8247 km², water was 727 km², and bareland was 28,065 km². While Fig. 2(b) shows the image where all other LULC classes have been isolated to remain with the bareland which according to this study represents the human activities such as farmlands, settlements and grazing areas.

Fig. 3 represents the results of the 2015 image classification which revealed significant change in the six land use land cover categories. For the entire study period, the forest cover was reduced from 16.4% cover to 14.1%, while bareland had increased from 10.1% cover to 16.2%. Other land uses showing a significant change were grassland with +9.9%.

The classified images in Fig. 4 show the changes in different LULC for the 30-year period from year 1985 to year 2015. The LULC class represented as bareland increased from 28065km² in 1985 to 46048km² in 2015 which account for the 6.1% change from 10.1% in 1985 to 16.2% in 2015.

Table 1. Description of image classification classes of land cover in MCA







Land cover class	Description
 Bareland	Refers to areas with no vegetation cover, cultivated agricultural land, built up areas and livestock degraded areas
 Forest	Denotes areas with high density of trees. It is both homogenous and heterogeneous.
 Grassland	Represents areas of land with more grass cover and a few scattered trees such as acacia Combretum and Doum palm.
 Riverline vegetation	Refers to the dense vegetation that was observed growing along the rivers that flow across the protected area.
 Shrubland	Areas comprising of arid land with short vegetation scattered and surrounded by short grass
 Water	Areas of open water sources within the protected area such as springs, swamps and rivers.

Table 2. Showing LULC characteristics in the study area over time

LULC Class	y1985 (Km ²)	% cover	y1995 (Km ²)	% cover	y2005 (Km ²)	% cover	y2015 (Km ²)	% cover	% change
Forest	46677	16.4	45792	16.1	75888	26.7	40255	14.1	-2.3
Shrubland	152353	53.5	207470	72.3	138449	48.6	107581	37.8	-15.7
Grassland	48659	17.1	6665	2.3	29773	10.5	76923	27	9.9
Riverline	8247	2.9	750	0.3	14278	5.1	12677	4.5	1.6
Water	727	0.3	538	0.2	7034	2.3	1244	0.4	0.1
Bareland	28065	10.1	23513	8.3	19306	6.8	46048	16.2	6.1
Total	284728	100	284728	100	284728	100	284728	100	0

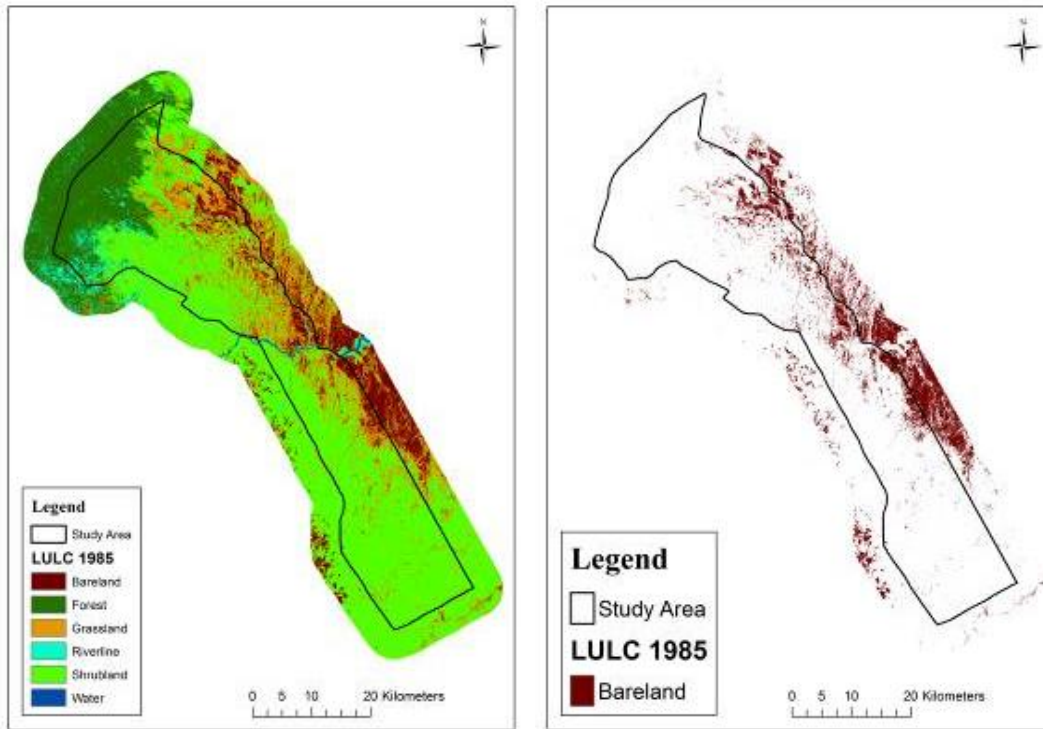


Fig. 2. Image for 1985 showing (a) all the LULC classes (b) Degraded areas (Developed from Landsat Image data acquired from RCMRD, Nairobi (2014) with permission)

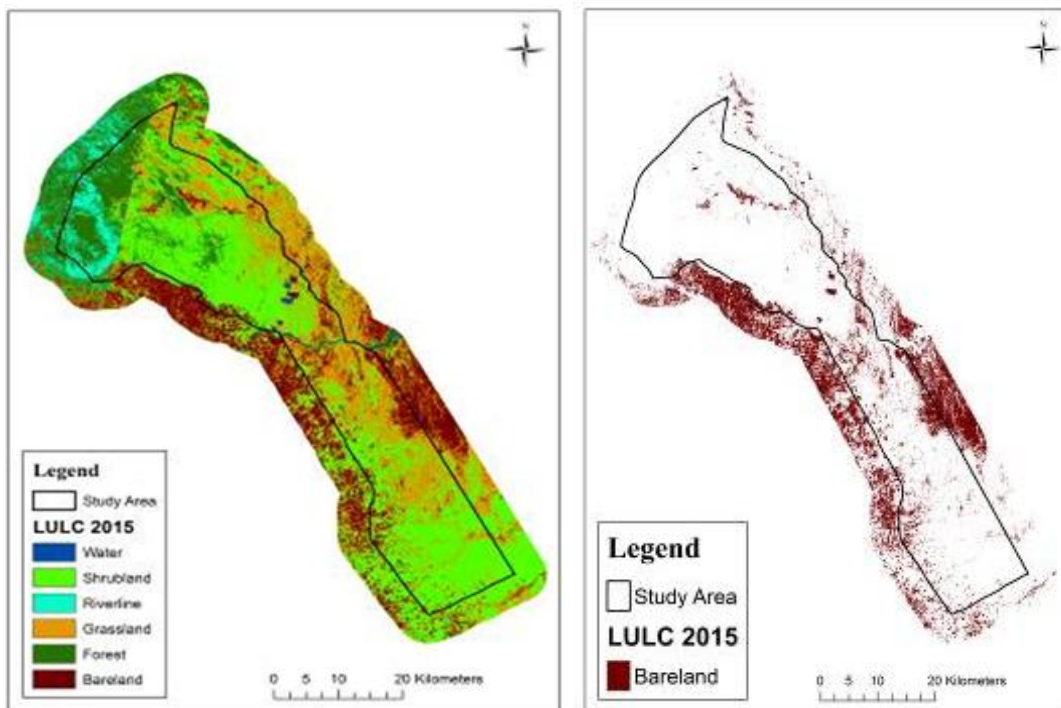


Fig. 3. Image for 2015 showing all the LULC classes and isolated bareland (developed from landsat image data acquired from RCMRD, Nairobi (2014) with permission)

Table 3. Correlations between various LULC classes in MNP and MNR

		Forest	Shrubland	Grassland	Riverline	Water	Bareland
Forest	Pearson Correlation	1					
	Sig. (2-tailed)						
Shrubland	Pearson Correlation	-.073	1				
	Sig. (2-tailed)	.927					
Grassland	Pearson Correlation	-.361	-.898	1			
	Sig. (2-tailed)	.639	.102				
Riverline	Pearson Correlation	.473	-.913	.648	1		
	Sig. (2-tailed)	.527	.087	.352			
Water	Pearson Correlation	.964	-.296	-.153	.651	1	
	Sig. (2-tailed)	.036	.704	.847	.349		
Bareland	Pearson Correlation	-.692	-.631	.860	.269	-.481	1
	Sig. (2-tailed)	.308	.369	.140	.731	.519	

*. Correlation is significant at the 0.05 level (2-tailed)

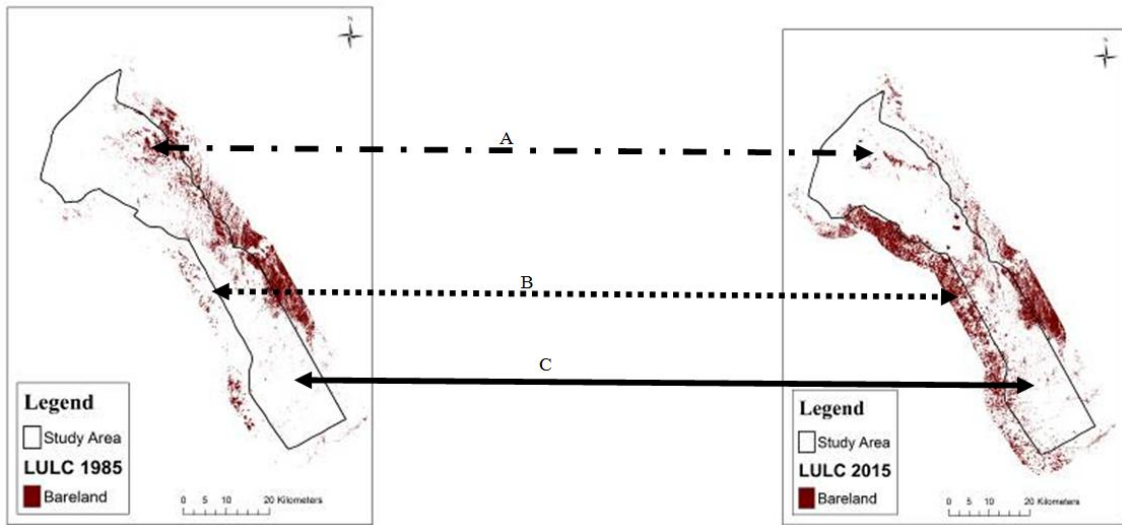


Fig. 4. Comparison of LULC changes from 1985 and 2015 images

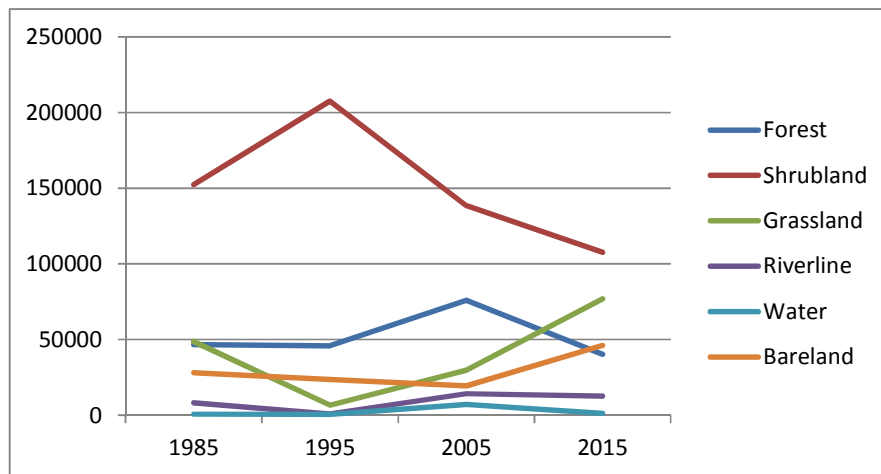


Fig. 5. LULC from 1985 to 2015

The study associated the changes that occurred in both MNP and MNR and their surrounding land to the ongoing anthropogenic activities such as farming, livestock grazing, charcoal burning and human settlements. The colored section A – Fig. 4 pointed by the arrow above, shows some disturbances of the habitat inside MNP in 1985 which was attributed to the past disturbances that were experienced in the park during the 1970s to late 1980s where many species of wildlife mainly elephants and rhino were killed by bandits. During this time, there was high insecurity in the park and it is reported that the pastoral community from the northern boundaries had invaded the protected areas. However, this has significantly improved over time as shown by the 2015 image. Due to improved security in the protected areas, community consultation, fencing and improved management strategies, cases of livestock encroachment in MNP has been prohibited.

The arrow B – Fig. 4 shows the land cover and land use changes that have occurred in the buffer zones and dispersal areas of both MNP and MNR. The human activities have increased from low population in 1985 to high human settlements and farming as shown in the darker pattern in the 2015 image. Further, the arrow C – Fig. 4 represents the changes in land use and land cover in MNR from 1985 to 2015. As indicated in the image, the vegetation disturbances have been increasing significantly in the reserve over the years. This is associated with observed and reported cases livestock encroachment in dry spells, charcoal burning and farming in the reserve.

As the human population increased, it posed a profound effect on land use, land cover and wildlife around the MCA. Different community groups had varying forms of interaction with the land. For instance, the study established that 28.3% were practicing pure agriculture, 34.2% agro-pastoralist and 35.8% were pure pastoralist. Increase in farming activities contributed to change in vegetation cover as well as degradation due to overstocking and overgrazing. Further implication of these changes included loss of wetlands which have been reclaimed for farmland, loss of rainy season dispersal areas and a corridor to Ngaya forest due to expanding farms towards the park boundaries and encroachment of pastoral communities in the Protected Area for forage and water during the dry season particularly in the Northern buffer of Meru National park and

Bisanandi National Reserve. In addition to human population increase, variation in seasonal temperature and rainfall over time have resulted to changes in land cover hence contributing to decline in wildlife ecosystem potential in MCA. The changes in land cover such as forests to grassland or bareland have thus reduced the ability of the ecosystem to support viable wildlife populations leading to death or migration of species.

Further the study argues that land cover changes may occur as a result of natural factors such as fire, drought and climate variations. However, the changes may be temporary and irregular and the ecosystem tends to recover from them. But the most destructing land cover changes are as a result of human alterations which have high degree of resistance and consistency that minimize chances of ecosystems to recover. For instance, farming and grazing activities around MCA have significantly contributed towards changes in the land cover where once forested areas have been converted to open grassland or worse of bare grounds that are rarely covered due to excess degradation.

The data on LULC was subjected to person correlation coefficient to establish the linear relationship between different classes as shown in the Table 3.

There was positive correlation between forests and water ($r = .964$, $Df = 2$, $P = 0.036$), riverline and water ($r = .651$, $Df = 2$, $P = 0.349$), bareland and grassland ($r = .860$, $Df = 2$, $P = 0.140$). on the other hand, a significant negative correlation occurred between forests and bareland ($r = -.692$, $Df = 2$, $P = 0.308$), shrubland and bareland ($r = -.631$, $Df = 2$, $P = 0.369$), grassland and shrubland ($r = -.898$, $Df = 2$, $P = 0.102$) and between bareland and water ($r = -.481$, $Df = 2$, $P = 0.519$).

The graph (Fig. 5) represent the trend in changes of different LULC categories from 1985 to 2015.

The findings of this study agree with those of [21,22] who observed that a continuous increase in human population contributes significantly to land cover changes particularly in areas that have for a long time been protected due to their rich natural resource potential such as parks and reserves. The study established that these particular areas do not easily recover since the demand for grazing and cultivating land is increasing with the expanding human settlements around the PA hence putting wildlife

and their ecosystems at jeopardy with no hope of recovering. This is a similar scenario that was experienced in MNR where the communities living around the reserve have intensified grazing charcoal burning and subsistence farming. The outcome of this as observed in the study area is that potential and preferred habitat for wildlife has been destroyed over time leading to migration of many wildlife species to neighboring MNP and KNP where there is less encroachment. Further in his study, Esikuri [6] agrees to these findings that landscapes such as vegetation cover are modified by land use activities. Such modifications can lead to an increase or decrease in habitat quality and quantity for various species of wildlife native to an area [7,23] For instance, expansion and intensification of agriculture in the western boundary of MNP at Baibariu block is now recognized as one of the most significant human threat to wildlife dispersal and movement to other ecosystems such as Ngaya forest, Mt. Kenya, Samburu and Laikipia. The farming has extended up to the boundaries of the park leaving no space for wildlife movement.

The foraging behavior by wildlife may have contributed to the decline in the forested areas and shrubland to expanded grassland and bareland within the protected areas. This is after it was observed in the study that there was significant destruction of trees and shrubs by the elephants resulting to an ecological succession. Another cause that accounts for the observed change in the land cover is the frequent ecological disturbances such as fires that are either introduced by the management to control pest and diseases or that which was found to be caused local communities accidentally when they invade the protected area to harvest honey.

4. CONCLUSIONS

From the study findings, it is evident to make a conclusion that the human population around MNP and MNR has increased over time due to improved security in the area by the presence of KWS rangers who have managed to drive away the bandits who had invaded the protected areas illegally killing wildlife. The communities have not only utilized the buffer areas adjacent to the PAs, but have further occupied the land that was initially set aside as movement corridor for wildlife. The continuous changes in different land use land cover classes have been accelerated by human activities such as farming, livestock grazing and settlements.

The land use and land cover in MNP and MNR has changed over time showing a positive and significant correlation between different land use classes. These changes have affected distribution and abundance of wildlife species due to transformation of their habitat. Continuous changes in land use and land cover has altered wildlife ecosystem to an extent that they are not able to easily recover due to increasing demand for grazing, farming and settlement land by humans.

Implementation of the study recommendations to achieve an integrated and sustainable wildlife conservation and land use practices within and around protected areas have received a positive backing through the strengthening of institutional and legislative frameworks in Kenya. For instance, the current Wildlife Conservation and Management Policy, 2012, the Wildlife (Conservation and Management) act of 2013, the Wildlife Conservation and Management (Conservancy and sanctuary) regulations of 2015, and the just concluded Consumptive Wildlife Utilization taskforce report, 2019 provides a framework through which the local communities should interact with wildlife. Further, from the study findings, the constant challenges of human wildlife conflicts, encroachments and land use changes can be significantly reduced through sustainable utilization as outlined in these legal documents through a participatory support from the state conservation agency, conservation organizations, land owners and the local communities.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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