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Impacts of Socio-Economic Activities on Land Use and Land Cover Changes in Narok North Sub-County, Kenya

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Abstract
Narok County is located in the south western part of Kenya. Ii is home to major rivers including the Mara and Ewaso Ng'iro River Basins. Large tracks of land initially under group ranch tenure system have been converted into freehold tenure. Agriculture and livestock production are the main land use practices followed by Wildlife Conservation areas (Narok CIDP 2018-2022). The highland areas of Mau Escarpments provide fertile ground for production of wheat barley, maize, beans, potatoes and peas as well as wool and dairy farming. (Narok CIDP 2013-2017). Uncontrolled urban development coupled with increase in population have been the main reasons for Land Use Land Cover Changes in Narok County.
The purpose of this study therefore, was to assess the impacts of socio-economic activities on Land Use and Land Cover Changes in Narok North Sub-County. It set out to analyse the Land Use and Land Cover Changes between the year 1986, 2000 and 2019 as well as assessing the impacts of socio-economic activities on Land Use and Land Cover Changes in Narok North Sub-County. Both primary and secondary data were used in the study. A structured questionnaire was used to collect primary data on the impacts of socio-economic activities on Land Use and Land Cover Change while secondary data was collected from documents obtained from various agencies and organizations dealing with Environmental Protection. Data was analyzed using descriptive statistics of mean, percentages and frequency while inferential statistics was done to test the association between the variables using the chi square test of association. Landsat satellite images covering Narok North Sub-County were acquired for three epochs; 1986, 2000 and 2019. The study revealed that there is a significant change in the Maasai Mau forest area based on the three images analyzed. The images showed that there was noticeable decrease in the forest cover from 44.8% in 1986 to 22.6% in 2019. The settlement area increased from 25.2% to over 40.6%. The forest land decreased by 8.7% between 2000 and 2019 and a large area of the land was used for farm land and settlement. The study also established that there was a statistically significant influence between the socio-economic drivers and the land use and cover in Maasai Mau forest ($p < 0.05$). The study therefore concluded that there has been a remarkable decrease in forest cover with more of the forest land being converted to farm land and settlements which has affected land cover in the area. The study recommends that all stakeholders in the conservation process must focus their attention on sustainable land use practices in order to protect Maasai Mau Forest.

Key words*: Land Use and Land Cover Changes, Maasai Mau Forest, Socio-Economic Impacts*

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I. Background of the Problem

Land Use and Land Cover Changes (LULCC) is the change in the terrestrial surface of the earth. It is the most ancient human phenomenon induced in the biosphere (Brown, 2017). Land use refers to man's activities and the varied uses which are carried out over land. It includes agricultural land, built up land, recreation area, wildlife management area (Gajbhiye & Sharma, 2012). On the other hand, land cover refers to natural vegetation, water bodies, rock or soil, grassland, forest, artificial cover and others noticed on the land.(Turner, 2011). Changes in land use can be categorized by the complex interaction of structural and behavioral factors associated with technological capacity, demand, and social relations that affect economic capacity along with the nature of the environment of interest(Gessesse *et al*., 2015). Land use is never static but constantly changes in response to the dynamic interaction between underlying drivers and proximate causes (Alvarez Martinez et al., 2011). The conceptual understanding of proximate causes and underlying forces has a crucial importance to identifying the causes of land use and land cover in relation to population growth dynamics and associated human activities (Greene *et al*., 2015).

As global population increases rapidly, pressure exerted on the land results in a tenuous connection between environmental variables (Akinyemi, 2017). The rapid changes of land use/cover particularly in developing nations, are often characterized by rampant urban sprawling (Bajocco et al., 2012), land degradation by agricultural development and tourism industry (Melesse & Abtew, 2015), or the transformation of agricultural land to shrimp farming (Intergovernmental Panel on Climate Change , 2015) leading to enormous cost to the environment (Souza *et al*., 2015). This kind of changes profoundly affects local and regional environments, which would eventually affect the global environment. Human induced changes in land cover for instance, influence the global carbon cycle, and contribute to the increase in greenhouse gas emissions (Bailis, 2010).

In the African Continent many studies have discussed LULCC in arid, semi-arid and agricultural productive land (Dale et al., 2011). Alvarez Martinez et al (2011) studied land cover changes in lake regions of central/south Ethiopia using aerial photographs dated 1972 and 1994 Landsat TM image. In Kenya, LULCC is primarily a consequence of pressure from the increasing population coupled with disorganized and uncoordinated land redistribution and limited education on land-use systems essential for appropriate resource management(Hagos & Holden, 2006). Empirical and proxy evidence has already demonstrated that the degradation is affecting the development of the concerned regions through dwindling river discharges during periods of low flows, pollution mainly from non-point sources and, in other areas, conflicts and insecurity due to competitive demands for the limited land and water resources (Brar, 2013). In the headwater catchments of the central Kenya a prevalent cause of LULCC is unplanned deforestation to allow for human settlements and subsistence agriculture (Olang & Furst, 2010).

Narok North Sub-County has experienced increased frequency of flooding in the past decade with flash floods being experienced every rainy season which have led to loss of lives and destruction of property. Other hazards include windstorms and fire outbreaks particularly in the southern part of the sub-county which have led to serious ecological damage. Forest fires have been reported to cause serious deforestation in parts of Maasai Mau forest. It is evident, therefore, from the above background that there is need for more studies to be conducted on LULCC in Narok North Sub-County.

1.2 Statement of the Research Problem

Kenya has undergone rapid urbanization and tremendous economic growth during the last two decades. Economic development activities have grown significantly in Narok Town. High population growth has forced farming families to expand their fields onto the Riparian land and other ecologically sensitive spaces. From the population census data, the population of Narok North Sub-County which one of the county's six sub county is 251,862 individuals and its growing at 4% (KNBS, 2019). Due to population pressure, built-up areas are rapidly increasing and this is leading to several environmental consequences. Similarly, there is growing socio-economic disparity.

Continued destruction of the Maasai Mau Forests is leading to a water crisis in that, perennial rivers are becoming seasonal, and in some places, the aquifer has dropped significantly while wells and springs are drying up. Large areas, which were once under forest cover, are now exposed to heavy soil erosion resulting into a massive environmental degradation and posing a serious threat to sustainable agriculture and human health. The loss of vegetative cover has resulted in flash floods in Narok Town that has caused massive destruction of property and even loss of lives. This has resulted in formation of big gullies right inside the town.

Our current understanding of historic LULCC in Narok North Sub-County is not adequate. Future understanding of LULCC will need to be greatly improved with systematic methods and designs addressing LULCC research. In order to understand the forces of change, it will be necessary to conduct studies that explicitly reveal the variations in change characteristics. Therefore, this research will address relevant issues on LULCC in relation to the socio-economic set up of the study area and try to provide recommendations which may contribute to the sustainable land management and hence improve the wellbeing of farming communities in the study area and beyond.

1.3 General Objective

The main objective of this study was to assess the impacts of socio-economic activities on Land Use and Land Cover Changes in Narok North Sub-County, Kenya.

1.3.1 Specific Objectives

The study was guided by the following objectives;

i. To analyse the Land Use and Land Cover Changes between the year 1986, 2000 and 2019 in Narok North Sub-County
ii. To examine the impacts of socio-economic activities on Land Use and Land Cover Changes in Narok North Sub-County.

1.4 Research Questions

The study sought to answer the following research questions;

i. What is the Land Use and Land Cover Changes between the year 1986, 2000 and 2019 in Narok North Sub-County?
ii. What are the impacts of socio-economic activities on Land Use and Land Cover Changes in Narok North Sub-County?

1.4.1 Research hypothesis

The study sought to test the hypothesis that; *Ho; there is no association between socio-economic activities on land use and land cover changes in Narok North Sub-County*.

The chi square test of association was used to test this assumption where the test was done at 5 % level of significance.

1.5 Research Premise

The existing interventions for sound land use practices is not effective and efficient. Activities carried out on land contribute to socio-economic development in Narok North Sub-County and yet have adverse impacts on the environment.

II. Literature Review

2.1 Land Use and Land Cover Change

Land use impacts have the potential to significantly affect the sustainability of the agricultural and forest systems (Lambin & Meyfroidt, 2011). Land use and land cover are continuously changing, both under the influence of human activities and nature resulting in various kinds of impacts on the ecosystem. In Malaysia, land use has undergone many changes particularly after the country achieved its independence. In Penang Island in Malaysia, a study was carried out on land use land cover, what emerged was that highly built area increased dramatically whilst grassland areas increased moderately. Therefore, through the ages there has been land use land cover changes in Malaysia attributed to different causes and underlying forces. In Ethiopia, major land uses that were taken into consideration were agriculture, forest, shrubland/grassland and settlements (Tahir & Hussain, 2013). The study conducted in 2016 showed that the land use land cover was taking a different trajectory with the forest cover was reducing as a result of the expansion of agricultural land.

In Kenya the scenario is not different. With LULCC being equally widespread (Boitt, 2016). This has happened against backdrop of an increasing population and an expanding development. With a greater than average national mean land holding size, Narok County's 16.2 Hectares provides for alternative land uses which such as agricultural, livestock production, real estate development and wildlife conservation. The most prevalent land-use in the county is mixed farming units, with portions of the farm allocated to tree crops, cash crops and vegetables, while fallow land is used to graze livestock. There is also great potential for Eco-tourism, forest expansion and pasture development in the county.

It is worth noting that due to competing land uses, Narok North Sub-County is highly prone to inter-ethnic and human-wildlife conflicts, which are mainly due to unplanned land uses. Land is either individually owned in high potential areas or communally owned in low potential areas. Over the past five years, the issuance of title deeds has been successful and land surveying has been undertaken and 46 per cent of the farmers hold title deeds. In the lower lying areas, where agricultural activities are minimal, community land and group ranches have currently been (or are currently undergoing adjudication. The county has some landless people especially Mau Forest evictees found in Olmekenyu in Oloolulunga division. Others are found in trading and urban centers; these are mainly job seekers from the neighboring counties who end up unemployed.

Land use is never static but constantly changes in response to the dynamic interaction between underlying drivers and proximate causes (Lambin & Meyfroidt, 2011).Proximate causes operate at the local level (individual farms, households, or communities) while underlying causes are at regional and national levels such as districts, provinces or countries. Underlying causes are often external and beyond the control of local communities (Environmental, 2010). This study established that both proximate and underlying causes contributed to the changes in the Maasai Mau forest but the underlying forces are mainly political influence.

2.2Socio-Economic Activity Impact on Land Use and Land Cover

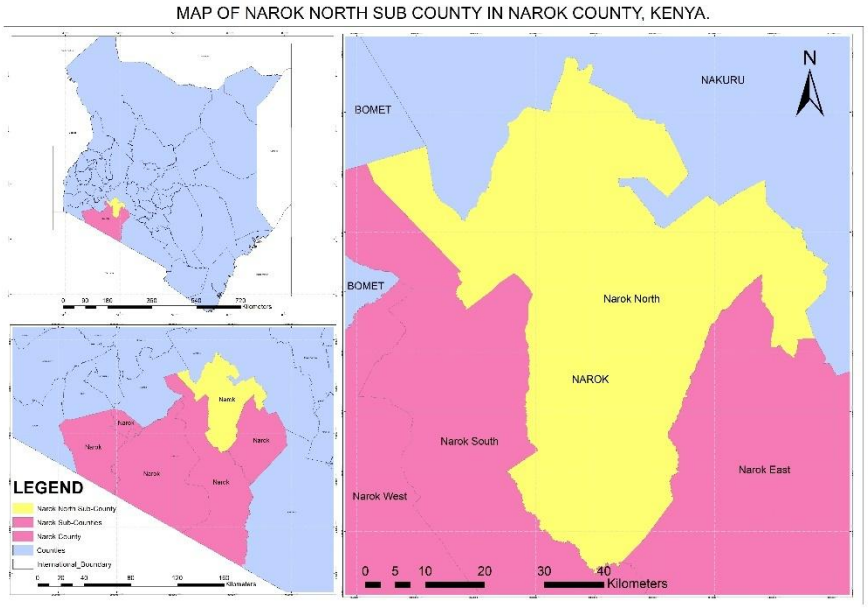
Socio-Economic activities impact greatly on changes in land use and land cover. Changes from forest cover to other land uses has been one of the important issues on land use change research. In earlier times when there was little human population and low level of economic activity, deforestation was not a problem because the natural regeneration of forest was adequate to cover for any loss of forest by human beings. Sustainable Land Management (SLM) is the use of land resources, including soils, water, animals and plants, for the

production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and maintenance of their environmental functions. Kenya's Vision 2030 proposes the sustainable management of natural resources. SLM is a holistic approach and is considered crucial for sustainable development, building on the complements of twin objectives of enhancing agricultural productivity and building long-term ecosystem resilience and environmental health. Basic SLM interventions may range from intensive agriculture and management of natural ecosystems, to policy and institutional reforms. The salient features of SLM include (but not limited to) preserving and enhancing the productive capabilities of croplands, forests and grazing lands; catchment protection/maintaining the integrity of watersheds; sustainable exploitation of groundwater aquifers, and finally, reducing and/or reverse soil erosion.

III. Methodology

3.1 Study Area

Narok North Sub-County is located in Narok County, Kenya and covers an area of 2,603 km^2. The sub-county is ecologically robust and thus farmers can reliably depend on rain for agriculture and water (County & Development, 2018). The main economic activities within the study area include business activities and agricultural practices. The main agricultural crops grown include wheat, barley, maize, beans, potatoes and peas.



The Mau Forest Complex is the largest remaining indigenous forest in East Africa. It is classified as a montane forest with mountain ecosystems that form life zones characterized by dense forests at moderate elevations which transit to grasslands or tundra as the altitude increases. The Maasai Mau forest which is a block of the Mau Forest Complex is majorly located in Narok North Sub-County.

3.2 Data and their Sources

For this study, Landsat satellite images covering Narok North Sub-County were acquired for two epochs; 1986 and 2000. The satellite images were acquired from Landsat 5 and 7 satellites which carries the Thematic Mapper and the Enhanced Thematic Mapper Plus (ETM+) sensor for1986 and 2000 epoch and Sentinel 2B which carries Multi Spectral Instrument 2019 epoch. LANDSAT 5 has 7 bands that is; band 1-5and 7 with 30M spatial resolution and band 8 (panchromatic band) with a spatial resolution of 15M. Sentinel B has 13 bands with a spatial resolution of 10M except for band 8 which has 5M spatial resolution which is used to enhance the image because of its better resolution.

3.3 Digital Image Processing

Landsat 4-5 and 7 images were resampled and accessed at a resolution of 30M while Sentinel Images were acquired at 10M resolution which is a higher resolution than the Landsat Images. Sentinel Image was therefore reduced from 10Mresolution to 30M resolution. The output result was smaller in size and was easily processed. Bands 4, 3, 2 were used for layer stacking of Landsat 4-5 and Landsat 7 images of 1986 and 2000 respectively for the false color combination.

The area of study lies between two rows 060 and 061 for Landsat imageries and lies between 4 Sentinel imagery blocks namelyT36MZE, T36MZD, T36MYD and TDMYE. Both the Landsat and Sentinel imagery cut through a section of the Narok North sub-county. Narok North Sub-County is captured mostly on the 169-path row 061 while a small section overlaps with row 060. In the Sentinel Imagery, sections of the Narok North Sub-County are captured in the T36MYE, T36MZE, T36MZD and T36MYD. The Mosaicking process was conducted using the Seamless Mosaicking functionality located in the toolbox in ENVI 5.3. The Land sat Images overlap vertically while the Sentinel imagery overlap both horizontally and vertically. For the Sentinel Imageries, the four-layer stacked image files of four blocks capturing the Narok North Sub-County were loaded. Seam lines were generated to avoid data masking of some regions in the overlap area. After generation of seam lines seamless feathering was applied then Exported to the project folder in DAT file extension.

A shape file of Narok North Sub-County was used to subset images of the three epochs. The image was subset based on the Narok North Sub-County boundary. The Narok North Sub-County region was clipped from the full mosaic images of both the Landsat images and the 2019 Sentinel Mosaic image. The shape file was acquired from Kenya Roads Board shape file datasets repository in the sub-county shape file, where the area of interest is exported for purposes of clipping.

Supervised classification was done using 90 training datasets for each cover class that was developed in this study (Planted farmlands and other vegetation, Forest land cover area and Settlement and Bare Land). Maasai Mau Forest Area consisting of dense forested regions of Narok North Sub-County based on the Google Earth Pro ground truthing vectors. The Planted farmlands and other vegetation area class consisted mainly of planted croplands and shrub lands where a small amount of spectral signature of chlorophyll was used to come up with the class values. The Settlement and Bare Land areas included cleared farms prepared for planting; human settlements and existing bare-land were used to come up with training data for this class. Supervised and unsupervised classification was used in this project. Where a particular type of land cover is present in the sub-county between different epochs was determined then the algorithm computes the spectral reflectance. The algorithm used Maximum likelihood algorithm for classification purposes. The areas with known land cover were digitized, then the image processing software i.e. ENVI 5.3 computed the spectral reflectance of the land cover types. Training sites were developed for the three-land use/ land cover classes based on Google earth and familiarity with the study area. The classes include Planted farmlands and other vegetation, Maasai Mau Forest Area and Settlement and Bare Land.

The generation of the NDVI was generated by running the NDVI generation functionality in the Toolbox in ENVI. It prompts one to select the Near Infra-red band together with the red band as variable inputs to compute the NDVI by outputting the values between -1 and 1. The Near Infra-red band in Landsat 4-5 TM and Landsat 7 ETM+ is band 4 and band 8 for the Sentinel 2B image package (Liu & Mason, 2013). The Red band is band 3 in Landsat 5 and 7 and band 4 for the Sentinel image package. The NDVI was generated for each year and the +1 and -1 values were represented in grayscale.

Ground truthing points were collected in the area of study using Google Earth Pro timeline platform. The points were evenly distributed in the area of study (Westrope *et al*., 2014). These points were used to validate the accuracy of classified image for the year 2019. The land cover found at the date of the image acquisition was compared to the mapped supervised classified image for the same location. In ENVI the accuracy assessment was conducted using the Confusion Matrix using Ground truth ROI and selected vector shape files of the ground truthing points were used against the Supervised Classification images of all the three different epochs. This was evaluated by computing the level of accuracy and precision on the maps measured by the kappa coefficient.

3.4 Sociological Survey

A population is the group of interest to the researcher, the group to which the researcher would like to generalize the results of the study(Ayala & Elder, 2011). In this study the population involved all the residents of Narok North Sub-County. The target population in this case was 251,862 as per the census in the year 2019 Kenya Population and Housing Census, the formula will be applied as follows; (KPHC, 2019).

3.5 Sample design

Sampling is the process by which a researcher selects a sample of participants for a study from the population of interest (Etikan, 2016). (Ayala & Elder, 2011) defines sampling as process of choosing a small group of people or things from the population. For objective one and two the research design involved selecting the sample size and sampling procedures.

3.6 Sample Size determination

Sample size was determined using the formula recommended by (Gatotoh *et al*., 2011)

$$n = \frac{NCv^2}{Cv^2 + (N-1)e^2}$$

Where n= sample size
N=population
Cv= Coefficient of variation (taken as 0.5)
e=Tolerance of desired level of confidence taken as 0.05 % at 95 % confidence level Since Narok North Sub-County has 59,996 Households as per 2019 Kenya Population and Housing Census (KPHC, 2019) the formula will be applied as follows;

$$n = \frac{59{,}996 * 0.5^2}{0.5^2 + (59{,}996 - 1) * 0.05^2}$$

This gives a total of 100 households as the sample size.

The stratified random sampling and systematic random sampling. Was used to select the sample to ensure that all the areas under study were covered. Primary data was collected using a structured questionnaire.

Validity of the instrument was ascertained, using The Kaiser-Meyer-Olkin Measure of Sampling Adequacy computed from the factor analysis test as suggested by Field (2009). A KMO absolute value of 0.4 and above was considered appropriate for an instrument to be valid according to Richardson et al. (2015). For this study a KMO measure of sampling adequacy was 0.548 indicating that the instrument was valid and hence appropriate for use in the study.

Reliability of the questionnaire was determined using the internal consistency value determined using SPSS version 23. The acceptable range for alpha internal consistency value (r) is 0.70 and above (Ayala & Elder, 2011). The overall reliability for all the 32 structured items was 0.740 standardized to 0.723, the reliability related to the objectives, Socio-economic impacts of land use land cover change and Land Use and Land Cover changes were 0.787, 0.726 and 0.788 respectively. This implies that the questionnaire was suitable for use in the analysis as it met the required reliability threshold of 0.7 and above according to Ayala & Elder, (2011).Besides the kappa coefficient was used to assess the accuracy of precision in the various images and it was established that all the values indicated substantial strength of precision which fell within the category of 0.6 -0.8 according to Landis and Koch (1977)

A total of 102 questionnaires were administered. Since the study took stratified random sampling based on the six-county representative wards each ward involved sampling of 17 households. The households also in those strata were sampled using systematic random sampling in order to find respondents.

3.7 Data analysis and presentation procedure

The statistical analysis was carried out on the impacts of land use/ land cover change. Several land types and land use of the study area were computed for analysis. The data was analyzed using descriptive statistics of means, frequency and percentages and inferential statistics of correlation ANOVA. Background data was analyzed and presented descriptively while the objectives were analyzed using both descriptive and inferential statistics. Microsoft Excel was used together with the statistical package for social sciences version 23 as key tools for analysis. Association between test variables was done using chi square test at a significant level of 5%.

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IV. Results and Discussions

4.1 Background Information of the respondents

The study sought to analyze the background information about the respondents to assess whether they were a representative sample or not. Data was collected and analyzed based on the gender, the age bracket, marital status, years having stayed in the study area, education and occupation, level of income and sources of income. From most house holds the majority of the respondents (85%) were male with only 15% being female. This was expected because in most households, men were the key decision makers in most issues about land use. Most women go by the decision of the males because of the cultural background. The results show that most of the respondents (40%) were in the age bracket 31-40 years, followed by 27% in the age bracket of 20-30

years, 18% in the age bracket of 41-50 years and 15% in the age bracket of above 50 years. This indicates well-represented sample with 55% of the respondents being above 30 years. This implies they have a good understanding of the previous and current situation in terms of land use and environmental changes. The study showed that majority of the respondents (66%) were married while the rest 34% were still single.

The results also showed that most of the respondents (24%) have lived in the area for the last 30 years, 19% had lived in the area for the last 40 years, 18% have lived since birth while 15% have less than 10 years and only 11% have lived in the area for less than 20 years. This implies that majority of the respondents have been in the area for 30 years and above hence, they have appropriate knowledge and understanding of the environmental changes that have taken place since the 1988.The results shows that most of the respondents (33%) had attained secondary education, 29% had attained university education and 28% had attained tertiary education, while 10% had attained primary education. This implies that the respondents were distributed across all the education levels and hence the results were representative of the population. Education is important in decision making involving land use.

The results show that most of the respondents (69%) were business people, 16% were social workers,7% were farmers 5% were administrators and 3% were health workers. This implies that majority of the respondents engaged in small and medium enterprises including kiosks and grocery shops which have had a major contribution on the use of land and the changes that have taken place in the study area. As people seek to expand their businesses, they buy and clear available land near the town alongthe mainroads.

The results showed that majority of the respondents earned an income of less than Kshs 10,000.00 per month from their occupation, 26% earned an income of between kshs 10,000.00 to 20,000.00 and only 7% earned an income of between Kshs 21,000.00 and 30,000.00. This indicates that the people in the study area earn on average less than Kshs 10,000.00. This income exposes them to engage in other activities aimed at generating more income. These activities usually involve the use of land and hence increased level of land degradation. The results further indicated that majority of the respondents (44%) earned their income from off farm activities, another 44% earned their income from on farm activities and the rest indicated that they earned their income from both off farm and on farm activities.

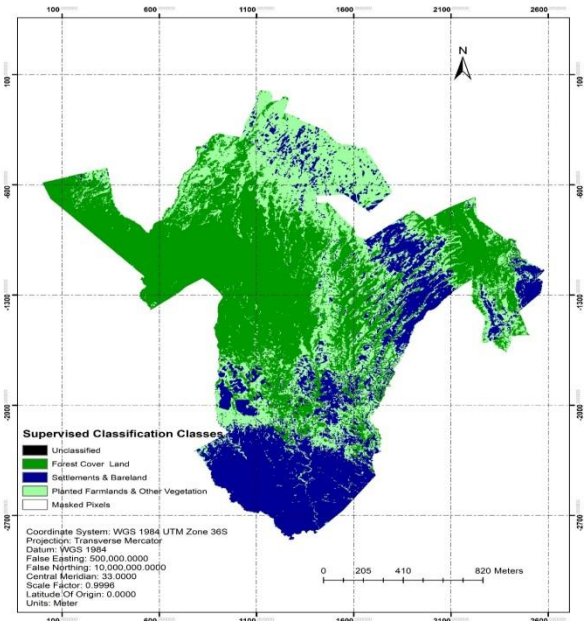
The results show that most of the respondents 55% indicated that income had a moderate effect on land use, 35% indicated that income had a great effect on land use, 6 % indicated that income had a very great effect on land use. Only 1% and 3 % indicated that income had no effect or little effect on land use. The results show that most of the respondents over 86.4% indicated that income of the respondents had an effect on land use and changes in the study area.

The results also showed that most respondents 47% were not sure of the changes in the rainfall pattern in the area since the 1980s. Only 33% said it was not frequent, 14% said it was frequent and 6 % said the rainfall was very frequent. This implies that most respondents were not in a position to recall how the rainfall patterns have changed in the study area.

4.3 Post Classification Visual Comparison

The 1986 thematic map (figure 1) showed that most of the forested area was under closed canopy and a small portion under planted farmlands and other vegetation with even a smaller part under Settlement and Bare Land. Settlements and Bare Land areas included built up areas, bare land and even newly prepared farms.

The Supervised Classification results of the year 2000 (figure 2) showed a decrease in coverage of the areas under forest and planted farmlands and other vegetation classification class while areas under cover class Settlement and Bare land increased .When the three maps are compared it is very clear that there has been a gradual change in the physical feature of the area which is an indication that the land use and cover has been changing over the study period. The period 1986 indicated that the densely populated forest area (shown by the deep green colour),compared to that of year 2000 and 2019 shows a reduction in the forest density and increase on other vegetation's like farming crops (figure 1, 2 and 3). This implies that the period between 2000 and 2019 had increased land use and hence reduction in land cover by the natural vegetation. Much of the reduction in the land cover was also witnessed in the northern western region of the sub-county. These findings agree with the other previous studies such as Olang & Kundu (2011); Ongong, (2012) and Proposal (2010) who also established that there was a reduction in the land cover by forests in the Mau forest and other forest areas in Kenya due to increased human activities in the forests.



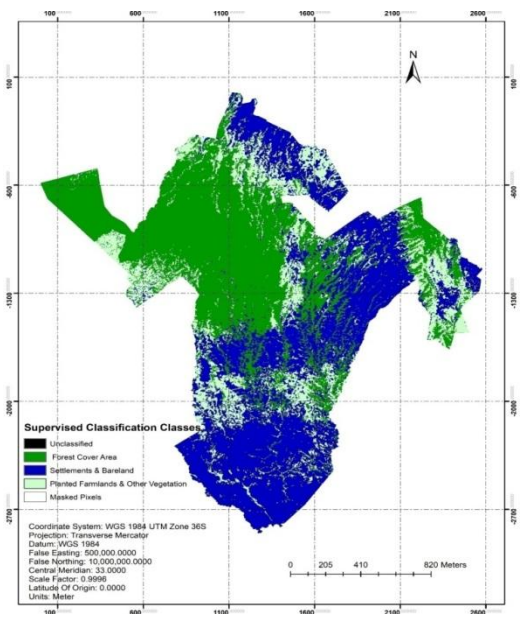
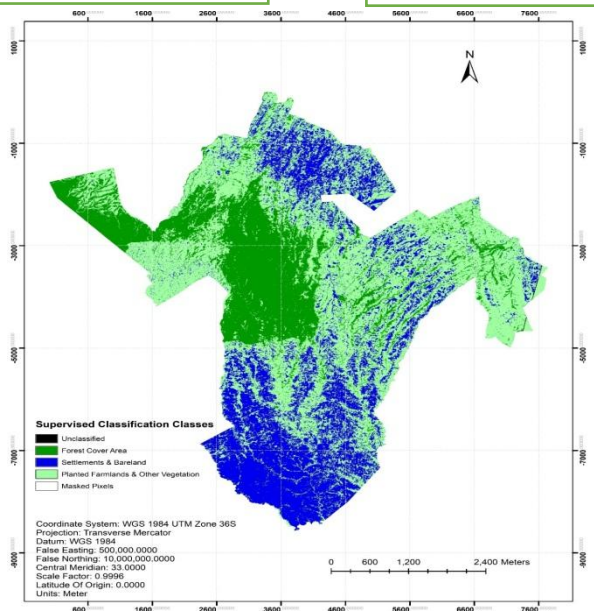


Figure 1: Narok North Sub-County Image of 1986



4.4Post Classification Area Comparison

When considering the post classification area, the study used a time series land cover class quantification for the period 1986, 2000 and 2019 imageries. The results are presented in table 3.

Table 3: Thematic Cover Class Areas for 1986, 2000 and 2019 classified imageries

Class Category	1986		2000		2019	
Cover Type (Class)	Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)
Maasai Mau Forest Cover area	119,765 ha	44.877%	107,066 ha	40.119%	60,321 ha	22.603%
Settlements & Bare land	67,232 ha	25.192%	108,509 ha	40.660%	71,129 ha	26.653%
Other Vegetation& Planted farmlands	79,873 ha	29.929%	51,294 ha	19.220%	135,333 ha	50.711%

The results show that in 1986, closed canopy forest occupied the highest class with 44.877% of the total classes. The other vegetation occupied about 14.543% of the classes while non-vegetated land was 3%. Clearance of forest land for forest products and other human needs for the forest land were established when land cover and land use for 1986 and 2000 were compared. Forest land was 82.912% showing an increase in forest land cover in 1984 while area under other vegetation was 14.440%, a reduction of 1.13% and 0011% from the class coverage in 1986. During the same period, non-vegetated land reduced from 3.517% to 2.648%, a reduction of about 1%.

The period between 2000 and 2019 the area under close canopy reduced by about 5.317% during these 19 years, the area under other vegetation increased by about 5.039%. This was mainly due to increased agriculture practice and area under Settlement and Bare land cover slightly increased by about 0.278%. This means that, more clearance was done in the area under the Maasai Mau forest land and this resulted in the increase in the area under Settlement and Bare land. The results agree with the findings of Tahir & Hussain,(2013) who sought to understand land use and land cover in Ethiopian forest areas and Boitt(2016) who sought to assess the same in Kenyan forests .

4.5Trend, Magnitude and Rate of Land Cover Change

In order to assess the trend, magnitude and rate of land cover change, the visual images were analyzed to determine the area covered by the Maasai Mau Forest Cover area, Settlements & Bare land and Other Vegetation& Planted farmlands.

Table 4: Annual Rates of Change in Land Cover Category

Class Category	1986 – 2000		2000 – 2019	
Cover Type (Class)	Area (Hectares)	Percentage (%)	Area (Hectares)	Percentage (%)
Maasai Mau Forest Cover area	-907.035	-0.33988	-2460.24	-0.92189
Settlements & Bare land	2948.428	1.104821	-1967.41	-0.73722
Other Vegetation& Planted farmlands	-2041.39	-0.76494	4423.142	1.657419

Source: survey data 2019

The study also sought to assess the annual rates of change in land cover. The results show that between 1986 and 2000, there was an annual rate of change in forest land of -3571.69 hectares; area under planted farmlands & other vegetation had an annual rate of change of -1202.92 hectares while the area under non-vegetation changed at an annual rate of 1795.15 hectares. The area under forest experienced an annual rate of change of -3604.4 hectares during the period 2000 to 2019. During the same period, the area under planted farmlands & other vegetation changed at the rate of 7796.3 hectares per annum while the area under non-vegetation experienced a rate of change of -5168.99 hectares per annum. This again supports the findings of Turner and Meyer (1994), Lambin & Meyfroidt (2011) and Bajocco *et al*., (2012) who indicated that in most partsof Africa the land use and land cover are asa results of conversion or modification of the land for other human activities. This is exactly what has impacted on the forest cover in the Maasai Mau Area. This implies that the notable changes in the land use and cover are justified by the fact that as human activities increased, more land was converted from other vegetation to agriculture, settlement and even clearance to get timber for

construction, among others. These processes continued adding to the increase in areas under non-vegetated cover.

It was also important to assess the level of coverage class changes over the study period 1986 to 2019. Figure 13 indicates changes in cover classes in hectares against time. The values above the X- axis represented cover types that had increased while the values below the X- axis represented the cover types that decreased over the same period. The need to conserve the Maasai Mau forest cover in the Narok North Sub-County to recover and rehabilitate from the heavy encroachment experienced during the period of 2000 to 2019.

4.6 Thematic Land cover change between 1986 and 2000 and 2019

During the period 1986 to 2019 a slight decrease on the forest cover was experienced while a slight change from Forest land converting to both non vegetated area and other vegetation class. The results show that there was more land converted from forest land to settlement and planted farmland between the period 1986 and 2000.6.28% of forest land was converted to settlement (3.44%) and planted farm land and other vegetation (2.84%) compared to only 4.48% of land that was converted from settlement and bare land (0.84%) and planted farm land and other vegetation (3.53%) converted to forest land. This implies that there is more forest land being converted to settlement & bare land than or to farm land & other vegetation than that being converted to forest land. A similar trend was observed by Bajocco et al., (2012) and Souza et al., (2015) who in their study also observed that the rate at which forest land was being converted to settlement and dry land and farm land was higher than the rate at which forests were being created. This can be seen on the map below that shows the conversion of the land to various used. The area under forest covers between the year 1986 and 2000. The pink colour shows the area under forest cover between the year 1986 and 2000. The brown color shows the area under settlement while the green patches shows the area that is covered by farm land and other vegetation. The brown color shows the area under settlement while the green patches shows the area that is covered by farm land and other vegetation (figure 4)

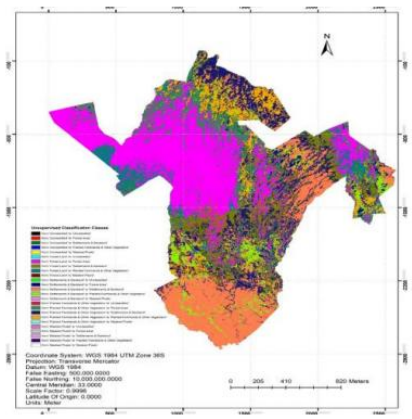


Figure 4: Overlay of 2000 and 2019 Images

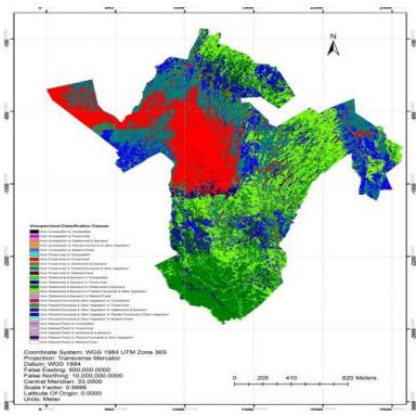


Figure 5: Changes in Land Use and Land Cover between 2000 and 2019

Figure 5 shows that there is a reduction in the forest cover area as shown by the red color compared to the earlier map which showed the forest cover with the pink colour. The area under settlement is shown by the dark green colour while the light green colour shows the area under farmland and other vegetation. This implies that there is great evidence of conversion of forest land to more settlement land and farm land in the Maasai Mau forest.

The results further shows that there are massive land cover changes were noted during this period between the years 2000 – 2019. A percentage of 14% drop in forest land and an increase in other vegetation an indication of tree cutting to pave way for farming activities in areas that were previously occupied by forest cover. A slight increase in non-vegetation land indicated cleared land for farming practices by the illegal invaders into the forest area. Most of the cleared forest land was converted to other vegetation land cover class indicating increase in planted crop lands and shrub occupied area. Since the eviction of illegal settlers in the forest cover area of the Maasai Mau forest earlier this year this period indicated the highest rate of deforestation of all periods (1986 – 2000 and 2000 – 2019) compared. This implies that there was greater conversion of forest land to settlement land and farm land in the Maasai Mau forest between the study periods.

4.7Accuracy Assessment

The accuracy assessment was conducted for each year epoch, 1986, 2000 and 2019. According toSrivastava et al., (2012) there are two common errors that are observed in the interpretation of the spatial imaging pictures used in the assessment of the land use and land cover; the errors of omission and error of commission. Error of omission occurs when a feature is left out of the category being evaluated**,** Error of commission occurs when a feature is incorrectly included in the category being evaluated. An error of omission in one category is counted as an error in commission in another category. This is evaluated by computing the level of accuracy and precision on the maps measured by the kappa coefficient where values lying between 0.6 - 0.8 indicate substantial strength of precision.

The results of the accuracy for this period were assessment. It is noted that the level of precision was very high with only 0.21% error of commission against a 17.45 percent error of omission in the interpretation of the area covered by the forest. The error of commission was more than 50% in estimating both the area under other vegetation and settlements compared to 64.14 % and 23.04% error of omission. The level of accuracy was also confirmed by the overall accuracy score of 92.049% and the Kappa coefficient of 0.88647. This implies that the level of precision in the presentation of the maps was very high hence appropriate for making deduction about the level of land use and land cover in Maasai Mau area between the years 1986 to 2019.

The study also established that the error of commission and omission committed in the interpretation of the area under forest land were 0.06 % and 34.3% respectively, while the errors of commission and omission committed in the interpretation of the area under other vegetation was 77.03% and 67.14% respectively. Regarding the area under settlement the study established that the errors of commission and omission committed were 46.64% and 15.04% respectively. This implies that the presentation of the maps was appropriate for use in the analysis as the overall accuracy level was 86.4729% confirmed by the level of kappa coefficient of 0.7669. The reduction in the level of accuracy can be explained by the density of other vegetation's and farm land crops which made it difficult to accurately map out the area under each category.

The results also indicated that the level of precision improved in the estimation of the land under other vegetation's and settlement. It is noted that the error of commission for forest land was 0.12% compared to the error of omission of 29.93%. For the area under other vegetation the percentage of commission and omission is 64.11 % and 71.08% respectively while for area under settlement the level of accuracy was 33.64% and 23.43% defining the errors of commission and omission respectively. This implies that the results are accurate in assessing the level of land use and land cover in the Maasai Mau Forest area. Given that the kappa coefficient values in all the three test periods were all within 0.6 -0.8 range which indicates substantial precision and accuracy.

4.8 Impact of the socio-economic practices on land use and cover.

The study sought to establish that beliefs and practices have increased land commercialization where the results show that most respondents 46% agreed while 32% strongly agreed that beliefs and practices have increased land commercialization. This implies that beliefs and practices have increased land commercialization in the study area.

The study also established that most of the respondents 46% agreed and 22% strongly agreed that socio-economic activities have increased animal keeping leading to degradation of land. It was also noted that most respondents 51% agreed and 30% strongly agreed with the statement that there is increased animal movement that has impacted negatively on the land use and land cover in the forest area. This implies that socio-economic activities like population growth have impacts negatively on the use of forest land hence affecting the land cover in the Maasai Mau Forest area.

On whether Poverty pushes people to sell land hence degrading the environment, the study established that most respondents 41% agreed and 24% strongly agreed with the statement. This implies that poverty has an impact on the land use and cover and this affects the environment. Poverty has also drove people to charcoal business as a way of raising income, the results show that 53% and 26% agreed and strongly agreed that poverty has led to charcoal business hence degrading the environment.

It was noted that increased population has pushed for more demand for land for settlement leading to high level of degradation, majority of the respondents 47% agreed with the statement while 17% were not sure while 14% disagreed with the statement. This implies that the need for settlement land due to social factors leads to high level of degradation. In regard to whether politics has had a role to play in reduction of the land cover most of the respondents 58% agreed with the statement while 23% strongly agreed with the statement. It was also noted that most respondents 55% strongly agreed while 45% agreed that the socio-economic activities have reduced the land cover which has negatively affected the rainfall pattern in the area. It was also noted that most respondents 53% agreed with the statement while 46% strongly agreed with the statement, that social activities have increased the intensity of land use and hence leading to reduction in the land cover. This implies that farm related activities have a great impact on the land use and land cover in Narok County and hence this accounts

for the changes in whether patterns observed between 1986 to now. This supports the findings of Souza et al., (2015) who noted that land use impacts have the potential to significantly affect the sustainability of the agricultural and forest systems, because as the rain pattern change the sustainability of agriculture becomes even more difficult.

On whether legislation and the laws have had any impact on the land use and lad cover, the study established that due to the poor status of land regulation there is increased destruction of forest land which is being converted to other uses that are leading to land cover reduction. This is supported by 45% of the respondents who agreed with the statement while 24% strongly agreed with the statement. This agreed with the findings of Bajocco *et al*., (2012) who also established that the absence of applicable forest policy is cited as a contributing factor for deforestation in different parts of the World. In Brazil, for example, national policies aimed at the transformation of agricultural base and developing the Amazon commercially have caused the deforestation of 1.1-2.1 million hectares annually.

It was further noted that majority or the respondents 77% strongly agreed while 23% agreed that urbanization has led to decline in biodiversity in the sense that as the forest and continue being cleared hence reducing the land cover the animal species and also plants decline. The study revealed that most respondents 55% agreed and 33% strongly agreed that there Urbanization and land use has led to decline in biodiversity. This implies that activities of urbanization on land use and cover have had a very large impact on the environment. The increased human wildlife conflict in the Mau area is a clear indication that people have invaded the forest driving the wild animals away and in the process there is a lot of conflict which has led to destruction of property, crops and death. This agrees with the findings of Lynch and Carpenter, (2003) who noted that as urbanization intensifies, agricultural and nonagricultural land use conflicts become more severe leading to increased environmental degradation.

4.9.1 Analysis of variance

The results further sought to assess whether the socio-economic practices impact on and use and land cover was statistically significant or not at a significant level of 5%. From the results it is noted that the impact of socio-economic practices on land use and cover was statistically significant at an F statistic of 14.062 compared to the critical f statistic of 2.02 at (df: 13,77). This indicates that the model is a suitable predictor of the impact of socio-economic factors on the environmental degradation following the changes in the land use and land cover.

4.9.2Estimated percentage of current estimated land cover

The respondents were required to give their opinion on the level of land cover between 1988 and 2018. On a five scale Likert where; 1-Less than 10%, 2- between 10 -20%, 3- between 21- 50%, 4 – between 51-70% and 5 more than 70% the results from the respondents were presented. The results on figure 16 shows that most of the respondents 45% indicated that currently the vegetation cover on land is less than 10%. It can be further noted that 25% of the respondents indicated that the vegetation cover currently is between 10-20% with only a total of only 30% indicating that the vegetation cover is over 50%. This implies that there are only few areas where the vegetation cover has not changed much but in most areas, there is a big change in the vegetation cover resulting into environmental degradation. This supports the findings by Intergovernmental Panel on Climate Change & Intergovernmental Panel on Climate Change, (2015) who established that in Kenya, land cover and land use change has significantly affected plant biodiversity.

In regard to soil erosion level, 52% of the respondents indicated that there is increased soil erosion in most parts of the sub-county with only 12% of respondents indicating a level of less than 10%. 7% indicated a level of 10-20% while 30% of the respondents indicated an increase of more than 50%. This shows that in most parts of the sub-county there is increased level of soil erosion which could be as a result of reduced level of vegetation cover. This agreed with the argument of Bajocco *et al*.,(2012) and Souza *et al*.,(2015) who indicated that land use and land cover changes have affected the rate of infiltration and runoff which causes soil erosion that degrades the land and hence the environment.

With regard to farming activities the results show that 58% of the respondents indicated there is an increase in the level of farming from 22% to 50% in the study area, followed by 20%% who indicated an increase from 51% to 70 % while 7% indicated an increasing farming activities of more than 70%. This implies land use and land cover has changed due to increased farming activities in the area. This agrees with the findings of Souza *et al*., (2015) who noted that land use impacts have the potential to significantly affect the sustainability of the agricultural systems in the future.

Regarding urbanization, the results show that 70% respondents 70% indicated that there is an increase in urbanization of between 22-50%, followed by 16% who indicated that there is an increase of 51-70%. This implies that majority of the respondents indicated that there was an increase of more than 22% in the level of buildings and urbanization in the county. This accounted for the environmental degradation in the area. These

findings are in line with the concerns of Wu and Cho (2007) who established that Urbanization has presented many new opportunities for farmers forcing them to put more natural and to agricultural use to meet the demands of their emerging new customers. There is more legitimate concerns about the use and condition of rural natural resources, because of the pressure from urbanization.

The population of wildlife was an important indicator of the land use and cover in the area. The study therefore sought to assess the level of wild life population in assessing the level of change in the environment. The results how that most respondents 35% felt that the population levels of wild life was between 10-20%, followed by 30% who indicated that it is between 22-50%, while 21% indicated that a population of less than 10%. Only 7% indicated that the population is more than 51%. This implies that the population wild life has reduced which is an indication of environmental degradation. This agrees with the findings in a study by Lambin & Meyfroidt (2011) and Alvarez Martinez et al,(2011) who indicated that the annual loss of plant species in tropical Africa due to land use and land cover changes is very high and takes place at multiple levels that is at landscape and ecosystem level and at species level..

The study also sought to assess the level of rainfall in the area between the study periods. The results revealed that most respondents 43% indicated that the amount of rainfall received in the area is less than 10%, followed by 26% who indicated that the level is between 22-50% while 20% indicated that the eve of rainfall is between 10-20%. Only 9% and 2 % respectively indicated a rainfall level of between 51-70% and above 71%. It is therefore important to note that the results presented are evident that there is environmental degradation in the study area which is caused by the current land use and cover.

4.9.3 Analysis of Variance

Further analysis to assess whether the response given had any statistical significance and hence could be relied upon to make any deduction. The study used the analysis of variance to test the differences in the means of the responses. The results show that there is a statistically significant variance between the means of the respondents which indicates that the results can be relied upon to made deduction that there has been a change in the land use and land cover which has had a negative impact on the environment. The F statistic is 2.99 compared to the tabulated F statistic of.2.444 at a p value of less than 0.05 (0.012). The model is therefore a good predictor of the impact of socio-economic practices on environmental degradation.

4.10Chi square test of Association (χ^2)

It was important to test the association between the socio-economic practices and the impact they have on the land use and cover hence environmental degradation in Narok County. The chi square test statistic between socio-economic practices and land use and cover changes was computed. The results show that there is a very strong association between the socio-economic practices and the level of land use and cover in Narok North Sub-County. From the table the calculated chi square is 3.46.161 with a p value of 0.000 indicating very high level of significant association between the variables. This implies that socio-economic practices affect the land use and cover in Narok North Sub-County. This agrees with the findings of Lubowski *et al*. (2006) who established that socio-economic practices have led to conversion of most land into farming activities and urban settlement. This exposes the available land to soil erosion, salinization, desertification, and other soil degradations.

The study also sought to assess whether there is an association between the impact of the socio-economic practices and land degradation in Narok County. The results show that there is a very strong statistical association between the impacts of the socio-economic practices and use and cover changes in Narok County since chi square value is 371.448 and the p value is 0.000. This implies that the impacts caused by the socio-economic practices have a very significant effect on environmental degradation in the area. The results are in line with the geospatial change detection results presented in the first section of this study which have Cleary shown that there is a big change in the land use and land cover in the study area resulting in environmental degradation.

5.2.0 Summary of the findings

5.2.1 Demographic Analysis

The response rate from the field study was 85% which was acceptable as appropriate. Majority of the respondents who participated were male, aged between 31-40 years. Which indicates that they have a good understanding of the previous and current situation in terms of land use and environmental changes? It was also established that all the respondents were residents in the area and they had lived in the area around Maasai Mau forest for more than 30 years this indicates that they understood the area well and hence could provide appropriate data on land use and land changes. On the level of education, the study establishes that majority of the respondents were literate as they had attained secondary school and above qualifications. In regard to occupation most of the respondents said they were in business occupation. Most of them were low income

earners earning less than KShs. 10,000 per month. This implies that the respondents have to engage in other income generating activities to make ends meet of which it entails clearing of the land for cultivation or construction of business units. The study established that majority of the respondents indicated that the level of income contributed to the land use and land cover in the study area moderately. The study established that majority of the respondents felt that the pattern of rainfall has changed with the area receiving reduced amount of rainfall in current years compared to previous years.

5.2.2 Geospatial findings of Land Use and Land Cover changes between the year 1986, 2000 and 2019

The study analyzed the spatial maps taken from the three periods, 1986, 2000 and 2019, it was established that there was a clear line of distinction between the land use and land cover in the Maasai Mau forest. The map taken in 1986 showed that the forest was dense compared to the images that were taken in 2000 and 2019. In 1986, the land cover showed a dense forest canopy which occupied 45% of the area. The reduction in the forest cover is brought about by increased agricultural activities.

There is also increased acreage under settlements and bare land and other vegetation and planted farmlands leading to reduction in the actual land cover in the study area. Between 1986 and 2019, there was a decline in the forest land changing from of -3571.69 hectares to a change of -3604.4 hectares; this was due to increased far land and other vegetation cover on the forest land. The results showed that most of the had been converted from forest land to settlement and planted farmland between the period 1986 and 2000, which implies that there is more forest land being converted to settlement & bare land or to farm land & other vegetation than that being converted to forest land. There was high level of precision with an accuracy of more than 80% with a Kappa coefficient of between 0.6 -0.8 indicating that all the three maps were considered accurate and precision providing the required information.

5.2.3Socio-Economic activities impact on Land Use and Land Cover Changes in Narok North Sub-County

The impact of the socio-economic practices on land use and land cover was also assessed for the period 1986 to 2019. Rearing of livestock and farming activities all which had a statistically significant impact on the land use and land cover as indicated by the mean differences determined by the F statistics has a $p < 0.05$ and an F statistic more than the critical F value (14.062> 2.02 at (df : 13,77). This indicates that the model is a suitable predictor of the impact of socio-economic factors on the environmental degradation following the changes in the land use and land cover. It is therefore important to note that the results presented are evident that there is environmental degradation in the study area which is caused by the current land use land cover. The results were also noted to be very significant as the F statistic calculated was 2.99 compared to the tabulated F statistic of.2.444 at a p value of less than 0.05 (0.012). The researcher is therefore very confident that the results provide a good predictor of the impact of socio-economic practices on environmental degradation.

There was a very strong association between the socio-economic practices and the level of land use and cover since the calculated chi square was 346.161 with a p value of 0.000 indicating very high level of significant association between the variables. The results further showed that there was a strong association between the test variables; the impact of the socio-economic practices and land degradation where the chi square value was 371.448 and the p value is 0.000, which implies that the impacts caused by the socio-economic practices have a very significant effect on environmental degradation in the area. The results support the geospatial change detection results presented in the first section of this study which have Cleary shown that there is a big change in the land use and land cover in the study area resulting in environmental degradation.

5.3 Conclusion

This study sought to assess the impacts of Socio-Economic activities on Land Use and Land Cover Changes in Narok North Sub-County. It evaluated the extent to which the Mau forest has been degraded by analysis of satellite images of the study area of the three epochs 1986, 2000 and 2019.

Based on the findings of the study it is concluded there is evidence of massive land use and land cover changes in the Maasai Mau Forest area. With a precision of accuracy of more than 0.6 as defined by the kappa coefficient, it is evident that since 1986 there are a lot of land use changes which have impacted negatively on the land cover. The study also concludes that most of the drivers of land use and land cover in the Maasai Mau are socio-economic with population growth, politics and urbanizations having a very high impact on the land use and cover. It is also concluded that there is massive destruction of the forest to pave way for settlement and farm land between 1986 and 2000.

The results have also indicated that drivers of Land Use and Land Cover Changes in Narok North Sub-County such as beliefs and customs, poverty, law income levels, population growth, institutional policies and politics have played a major role in the destruction of the forest. Their impacts are very evident in the sense that majority of the respondents agreed there has been an increase in the level of destruction as witnessed by the increase in the land for settlement, farm land and other vegetation cover replacing the natural cover. Therefore,

the Sustainable Management of Land highly depends on how the various drivers will be managed. Hence there is a very significant impact of Socio-Economic activities on Land Use and Land Cover Changes in Narok North Sub-County

5.4 Recommendation

Theoretical recommendation

The study contributes in a great way to the theoretical knowledge in the sense that many studies that have been done on the Maasai Mau Forest have not looked at the actual drivers of the degradation of the forest. The knowledge and understanding of the socio-economic drivers of the land cover change significantly adds to the already exiting theory on environmental degradation in the Maasai Mau Forest. Environmental agencies such as the Narok County Government Department of Environment and Natural Resources, The Kenya Forest Service, they can use the information generated to put in place measures to protect the forest and bring it back to its state.

Policy recommendation

Based on the findings the study further makes the following policy recommendations; focus should be given to the various law enforcement agencies to ensure that they go deeper to understand the socio-economic drivers of land use and land cover in Kenya in order to put in place policies that will effectively protect the forests instead of the continued focus on the degradation.

The policies on use of forest land for agriculture under the integrated policy on forest land must be reviewed given that this seems to create a loophole for the illegal loggers to encroach into the forest and use it for their own benefits. This has also been an avenue for many to claim ownership of the land and hence replacement of the indigenous forest cover with farm land and artificial trees.

Policy to provide guidance on urbanization needs to be reviewed to discourage the conversion of forest land to settlement and urbanization which have contributed to increased conversion of forest land, clearing of the natural vegetation for paving way for increased settlement areas and also for land that is to be used for agriculture, burning of charcoal which is the common supplement for cooking fuel.

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