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Land Use and Cover Change Patterns in Lower Moiben Sub-County Catchment Area, Kenya

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Abstract

The changes in land use patterns in Lower Moiben Sub-County catchment area are examined in this study, with a focus on the change between 1995 and 2024. Major land use changes have occurred in the Sub-County catchment area because of socio-economic developments, farming activities, and increased population. Changes in land use that result from the conversion of forests to agricultural land, especially for livestock grazing and increased crop lands, growth of built areas, among others, have affected water supplies and hydrological balance for communities within the catchment. The study used GIS and remote sensing data to assess land use patterns over time and space and also household interviews to understand the observed land use changes. The results shows that there is expansion of croplands (from 51.48% to 77.67%) and built areas (from 0.80% to 4.21 %). Some had slight increase in general, such as, forests (30.53% to 31.22%) and rangeland (12.69% to13.65%) though it is reduction from previous years. The results shows how human activity affects land use/land cover change (LULCC), indicating that whereas certain changes such as increase in built areas mean better development, others changes such as reduced forests may lead to water scarcity. These findings shows that efficient land use management are required in the catchment. These results are useful to policymakers, local communities, and environmental organizations who are strategizing on balancing between development and sustainable land use practices.

Keywords: *Geographic Information Systems (GIS), Hydrology, Land use patterns, Remote sensing*

INTRODUCTION

Land use and land cover change (LULCC) patterns are evidences on environment shift resulting from both natural and anthropogenic causes such as landslide, forest-fires, erosion on the one hand and infrastructural development, urbanization, deforestation, and agricultural expansion, respectively (Chepkurui et al., 2022). Natural resources such as water, vegetation and soil are affected by these factors. It is estimated that, roughly 0.5% of the Earth's freshwater is contained in rivers, lakes, and shallow groundwater (Oyekale & Ogunsanya, 2012). Water supports domestic use by increasing human populations, diverse agricultural activities, industrial developments and ecosystems sustainability. However, as the world faces rapid globalization and the current effects of global warming, water scarcity has become a significant global challenge, affecting billions of people (Uhlenbrook & Connor, 2019). In areas undergoing fast socio-economic changes, it is of value to comprehend the dynamics of LULCC for sustainable environmental planning and management.

Land use refers to human activities and management strategies imposed on land such as settlement while land cover is the physical and biological characteristics of the Earth's surface such as built areas (Tena et al., 2019). These two concepts are linked in the sense that land use decisions are influenced by land cover changes which subsequently are influenced by land use practices. These interactions affects flow of water, soils and ecological health of a catchment.

A variety of techniques and methods such as Geographic Information Systems (GIS), Remote Sensing (RS) and field-based surveys are needed to monitor and evaluate LULCC. Researchers may map, measure, and simulate changes in land use over time with the use of GIS, which offers a platform for spatial data integration, analysis, and visualization (Twisa & Buchroithner, 2019). With sensors like Landsat 8 OLI and Sentinel-2 MSI, identifying changes in land cover through multispectral image processing is made possible, remote sensing provides timely and temporal observations over wide regions (Li et al., 2022). Accurate LULC classification need to be supplemented with field surveys using ground trothing to validate satellite data (Ali et al., 2022)

Researches done both locally and globally, have shown the extent and impacts of LULCC. For example, LULC changes from grassland and cropland have changed river flow and increased erosion in Ethiopia's Gumara Sub-catchment (Birhanu et al., 2019). Similar studies have been seen in Kenya's sub-catchments, where watersheds like Lake Ol' Bolossat (Karuku & Mugo, 2019), the Njoro and Kamweti sub-catchments (Koskey et al., 2021) have been degraded due to deforestation and agricultural expansions.

Assessing LULCC is important in understanding impacts on the flow and quality of water, particularly in river catchments, given their ecological and hydrological importance. This research intends to analyze temporal changes in LULC using remote sensing, GIS and household with an emphasis on understanding how such changes affect the catchment's water systems and ecosystem health.

MATERIALS AND METHODS

Study area

Location

The catchment area is situated roughly between longitudes 35.1°E and 35.5°E and latitudes 0.6°N and 0.9°N (Figure 3.1). The catchment area covers most of Moiben Sub-county in Uasin Gishu County. It is also covers some parts of Trans Nzoia and Elgeyo Marakwet Counties. The catchment's terrain is made up of rich plains and hills with slopes making it ideal for agricultural practices (Kiprop, 2018).

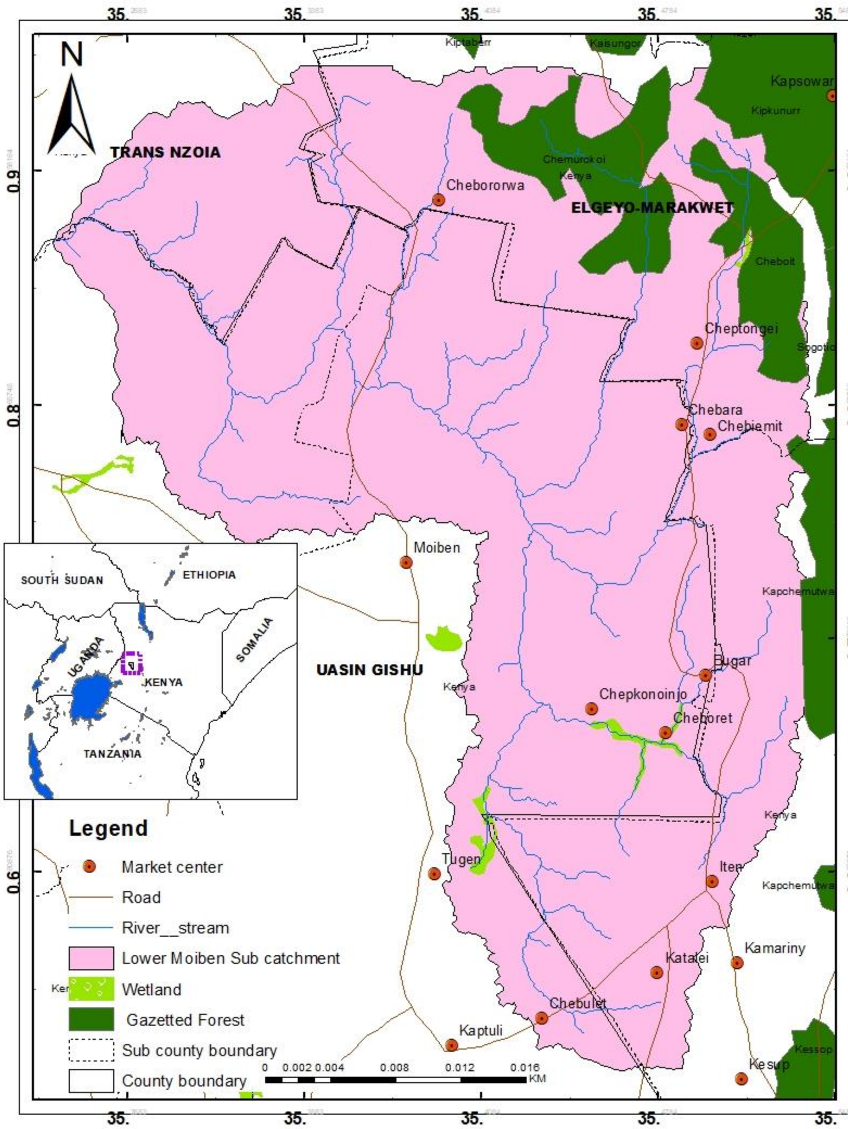

Figure 1: Map showing Lower Moiben Sub-County catchment area

General climatic and physical conditions
The catchment area has an average annual temperatures of 18°C and terrain that rises gently from 1500m to 2700 m above sea level (Kiptoo, 2023). Rainfall in the northern and southern parts range between 1000-1800mm annually and the western part receiving above 1500mm. It is also reliable and evenly distributed throughout the year with driest months like November and February receiving some rainfall.

Hydrology and drainage

Lower River Moiben serves the people that live in the catchment area (Kiprop, 2018). The river also has tributaries which include river Tangasir which is a seasonal river, river Chebororwa and river Arbabuch.

Vegetation

The catchment area has vast grasslands dominated by plants such as Kikuyu grass (Pennisetum clandestinum) and Red oat grass/ Kangaroo grass (Themeda triandra). A sizable section of the land is used for agriculture alongside plantations growing tea (Camellia sinensis) and coffee (Coffea Arabica) (Ngunjiri et al., 2019). Along with plantation forests of Pinus (Pinus spp) and Eucalyptus (Eucalyptus spp), the catchment also has areas of natural forests with native trees including Yellowwood (Podocarpus spp) and African pencil cedar (Juniperus procera). While shrublands and bush lands in the area dominated by tough species like Acacia(Vachellia tortilis) and Euphorbia(Euphorbia tirucalli), are common in places with poorer soils or less rainfall, riparian vegetation flourishes along rivers and streams, preserving biodiversity.

Soils and Geology

Soils in the catchment area are red loam soils, red clay soils, brown clay soils, and brown loam soils (Ngunjiri et al., 2019). Gneisses, schists, and quartzites rocks are mainly found in the western sections of the catchment while volcanic rocks cover most of the catchment area.

Socio-economic activities

The catchment's economy is based mostly on agriculture (Ngunjiri et al., 2019). Beyond agriculture, Eldoret City, the administrative and economic Center of Uasin Gishu, is home to a growing industrial sector that includes food processing, textile, building material industries among others.

Population size and distribution

The population of Uasin Gishu County, according to the 2019 population and housing census, was 1,163,183 with a density being at 343 per km² and growing at a rate of 3.8% (Kenya National Bureau of Statistics, 2019). About 24,679 people reside in the catchment area where the study was conducted.

Target population

To efficiently assess the challenges affecting the catchment area in providing water to Lower Moiben residents, a target population of 24,679 that live in the catchment was examined. This population consisted of residents from the following sub-locations: Kaplolo (2,865), Kapsubere (3,040), Meibeki (9,617), Chebororwa (2,150), Tuikoen (2,947) and Moiben (4,060).

Sample size determination

The sample size that was used was obtained from Yamane's formula (1967), the formula was given as: $n = N / (1 + N (e^2))$ which produced a sample size of 388.According to Kenya National Bureau of Statistics, (2019), the households in the catchment area was 6170. This guided in determining the number of households in each sub-location using proportional allocation. The formula used was; Sample size of sub-locations= (households in each sub-location/ total households) ×Total sample size. The sample size distribution as per sub-locations in the catchment area was as follows; Kaplolo(45),Kapsubere(48),Meibeki(151),Chebororwa(34),Tuikoen(46) and Moiben(64).

Data Sources

The LULC of the catchment were obtained from LANDSAT 7, LANDSAT 8, LANDSAT9 and Sentinel-2 satellite images. Remote sensing satellite images were acquired from United States Geological Survey (USGS) https://earthexplorer.usgs.gov, which had 30 meters resolution and Sentinel images from Copernicus Open Access, which had a resolution of 10meters. Ground based surveys were also carried out to complement satellite images. Household interviews with the members of the catchment area were also used to gather observed changes of land use land use and drivers.

Data processing.

Geometric correction was applied to all the satellite images to ensure that all spatial features were accurately aligned with real-world coordinates. This process was important as it removed spatial distortions caused by factors such as movement of the sensor, Earth's curvature, and changes in terrain. Ground Control Points (GCPs) were identified using United States Geological survey (USGS) images to guide the correction process. The images were then rectified and projected to the Universal Transverse Mercator (UTM) coordinate system, ensuring consistency in all the satellite images enabling accurate overlay with other geo-referenced images.

Data analysis

Satellite images categories from 1995, 2004, 2014, and 2024 were independently classified using supervised classification. Training samples were chosen for each image to serve as a guide for the classification process to capture the unique land cover condition of each year. These samples were used to train the classification algorithm by providing it with known examples of land cover types such as forest, built areas and bare land. Maximum Likelihood Classification (MLC) algorithm was used to classify the satellite images. This algorithm was selected because it is the widely used supervised classification method and it is effective in classifying multi-spectral data. It allocates each pixel to the class it most likely to belong according to the determined probabilities, while assuming that the statistical distribution of each class in the training samples follows a normal distribution. The study reduced classification errors that might persist over time periods by classifying each image independently. Land use and land cover changes throughout the time within the catchment area were analyzed and compared using the precise categorized maps created by this method for each year. This was achieved with the use of ArcGIS, Version 10.8 Tool.

The respondents from household interviews was analyzed using descriptive analysis.

Accuracy assessment was also conducted using a confusion matrix and the Kappa coefficient derived from ground truth data.

RESULTS

Land use/land cover change along Lower Moiben catchment area from 1995-2024

Table 1 shows the land use land cover areas in hectares and their respective percentages in parenthesis from 1995 to 2024.

Table 1: Land use land cover areas in hectares and percentage (%) from 1995 to 2024

Area	**Year**			
	1995	**2004**	**2014**	**2024**
Surface water	82.59 (0.10)	76.50 (0.09)	99.41 (0.11)	98.62 (0.11)
Bare land	0.014 (0.00002)	0.245 (0.00028)	1.609 (0.00185)	0.3787 (0.00044)
Cropland	44672.40 (51.48)	58874.23 (67.86)	66538.01 (76.68)	67399.49 (77.67)
Grassland	3.7421 (0.004)	3.3129 (0.004)	3.9158 (0.004)	3.6314 (0.004)
Rangeland	11009.67 (12.69)	9478.25 (10.93)	12.023.74 (13.86)	11843.28 (13.65)
Forest	26487.42 (30.53)	20972.38 (24.17)	27612.93 (31.83)	27087.56 (31.22)

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Built area	693.20 (0.80)	1452.36 (1.67)	1531.08 (1.77)	3650.05 (4.21)
Total land area	86741.16 (100.00)	86741.16 (100.00)	86741.16 (100.00)	86741.16 (100.00)

Figure 2 represent various land use Land cover changes from 1995 to 2024.

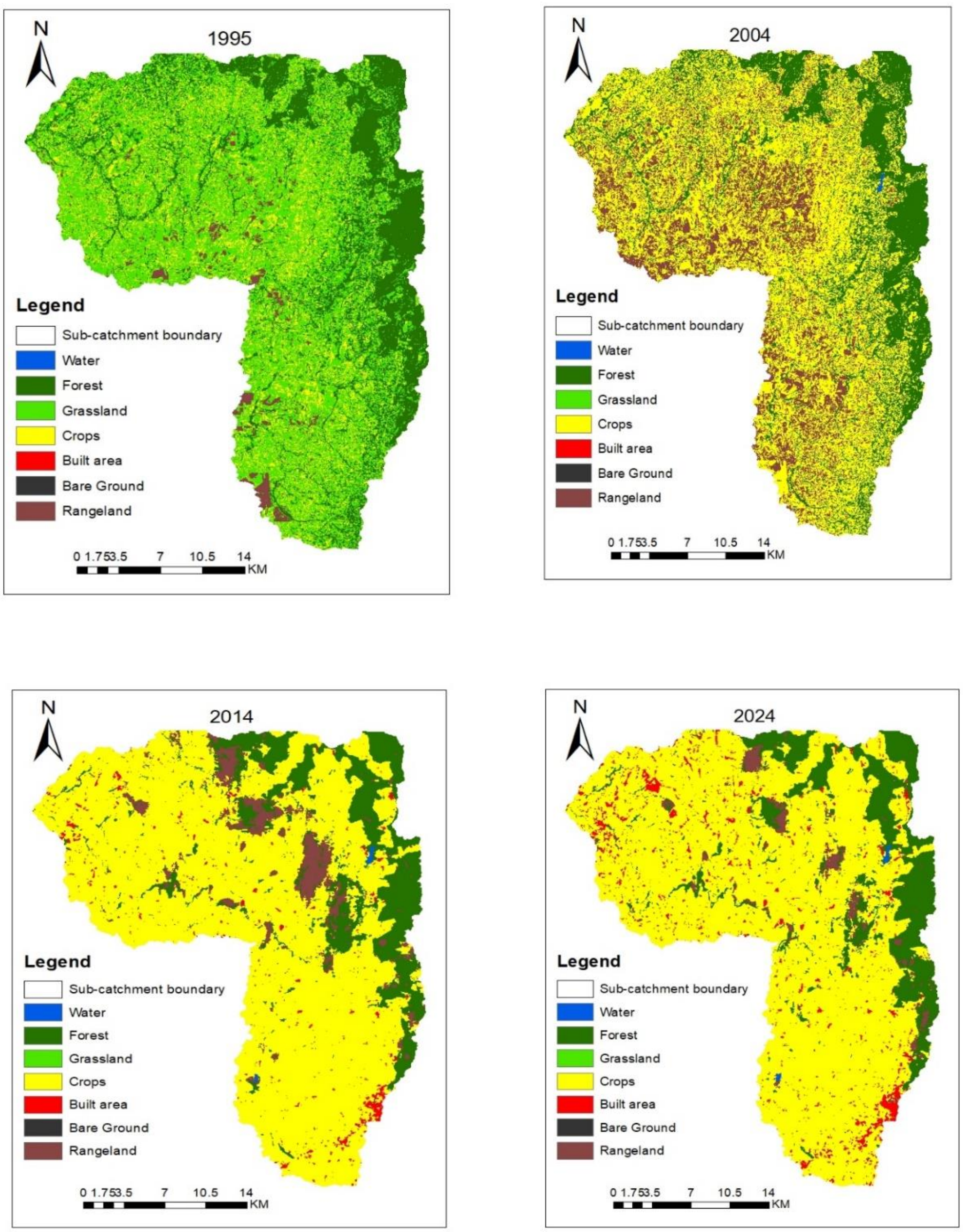

Figure 2: Land use land cover in the Lower Moiben catchment area from 1995-2024

Change in land cover land use from 1995-2024

The percentage changes in LULC from 1995 to 2024 reveal significant transformations in the catchment area as illustrated in Table 2

Table 2: Percentage land use land cover change from 1995 to 2024

Land Use Class	1995–2024 (%)	1995–2004 (%)	2004–2014 (%)	2014–2024 (%)
Surface Water	**0.02**	**-0.01**	**0.03**	**-0.01**
Forest	6.59	-6.36	7.65	-0.60
Grassland	-0.01	-0.01	0.01	-0.01
Cropland	26.79	16.37	8.83	1.00
Built Area	4.26	0.87	0.09	3.30
Bareland	0.42	0.27	0.16	-0.01
Rangeland	0.96	-1.77	2.93	-0.19

Accuracy assessment

Kappa Coefficient (κ) was used to assess the accuracy between the classified data and reference data. A value of 0.924 was obtained.

Observed changes in land use and cover over the past 20 years in the area

The observed Land use Land cover changes over the past 20 years are illustrated in Figure 3

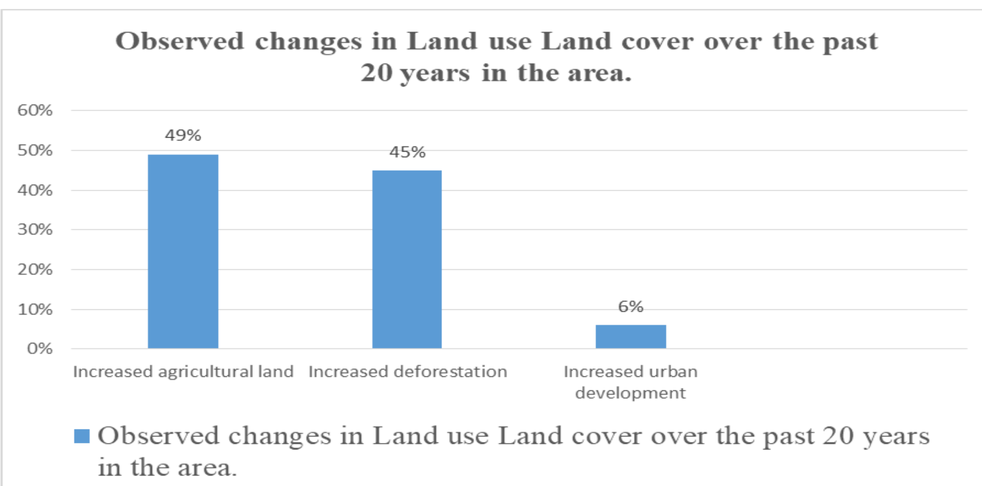

Figure 3: Specific land use and land cover changes

The main drivers of Land use Land cover changes are shown in figure 4.

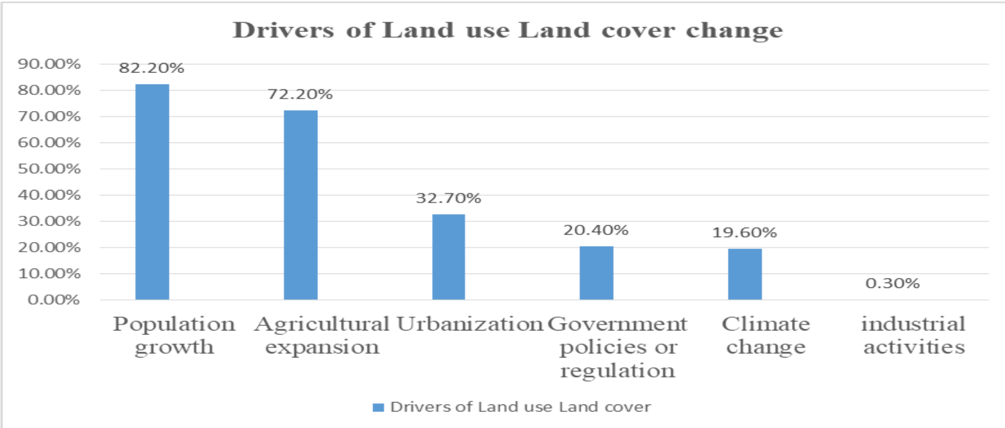

Figure 4: Observed main drivers of land use/land cover changes by the respondents

DISCUSSION

Discussion on Land use and cover change along Lower Moiben catchment area

The catchment's land uses has changed significantly nearly the past thirty years due to both natural and human-induced causes. Grassland, forest, rangeland, cropland and bare-land have decreased, while built areas have increased (Table 1). Surface water has increased over time probably due to human activities such as construction of dams. Built-up areas have increased indicating increase in settlements. These changes could be as a result of socio-economic advancement, conservation initiatives, and agricultural activities.

The growing agricultural sizes of land is similar with broader trend in Kenya, where needs for food security and population growth have led to increased croplands. Agricultural expansions is the main cause of change in many catchments as noted by studies done by Oduor et al. (2023) and Opiyo et al. (2022). The reduction of grassland and rangeland fit the research done by Langat et al. (2019), who noted that croplands and tree plantations usually get replaced by croplands which ultimately affects the soil stability and biodiversity.

The changes in forest size lies between relationship between restoration efforts and deforestation because forest has not reduced much in recent years compared to early years. According to Onyango et al. (2020), previous deforestation was probably caused by the need for farming land, settlement land, and firewood for fuel, which is similar to other East African forests. Forest cover hasn't reduced much in recent years, which could me that conservation efforts, afforestation initiatives and land management regulations are beginning to pay off. Mansourian & Berrahmouni (2021), believe that efforts from the community and the government in reforestation initiatives assisted in reversing previous deforestation.

Improved land use, whether by re-forestation, soil conservation, or efficient agricultural practices, is shown by the decrease in bare land (Table 1). According to Ndungu et al. (2023), improved land management practices such as afforestation and smart agriculture are frequently associated with a decrease in Kenya's bare land. Opiyo et al. (2022) warns that even in regions that are under cultivation, inadequate land management techniques can cause soil deterioration, despite the apparent benefits of less bareland.

Surface water fluctuations are probably because of a combination between human activities such dam construction and changing climatic patterns. Similar trends were noted by Onyango et al. (2020) in Kenyan catchments, where the shift in rainfall patterns and rising agricultural practices causes variation in water availability. The recent decreases however may be likely due to over extraction and sedimentation or it may be reflecting better conservation.

The decline of grassland and rangeland indicates a possibility of increase in farming activities or planted forestry (Table 1). According to Langat et al. (2019), comparable shifts have been observed throughout East Africa, where land that was formerly covered in grass and bushes is now being used for crop farming or tree plantations. Future land use planning must take into account the ecological effects of this change, especially with regard to biodiversity and water infiltration.

The steady growth of rural population is reflected in the increased built-up areas. According to Ndungu et al. (2023), as population increase, infrastructural development also grow thus contributing to the gradual spread of built-up areas, even in mostly rural areas. This trend indicates the need to look into the impacts of the growing development that it has on the land resource even if it is still small in comparison to cropland.

Over time, the changes in land use have not been consistent. Before the attempts to restore the forest vegetation in recent years, a large amount of land was cleared between 1995 and 2004, most likely for farming activities or the growth of settlements. This trend is similar with more general results from land use research done in Kenya, which emphasize that degradation and restoration cycles are brought about by changes in the environment, economy, and policies (Oduor et al., 2023; Mansourian & Berrahmouni, 2021).

These finding have illustrated that the catchment's land use changes are similar to those of other catchments in Kenya. Conservation and land management regulations have contributed to the altering of the landscape, even when agricultural expansion continues to be a key cause of change. Although the reduction of bare land (Table 1) may indicate improvements in land management, the reduction of rangeland and grassland raises questions about the stability of the ecosystem. Future sustainable land use will depend on finding a balance between human activities, agricultural practices, and environmental management.

Observed Changes in Land Use and Cover Change Over the Past 20 Years

A huge number (94.8%) of respondents noticed major changes in LULCC. Most noticed increase of agricultural land (49%) and deforestation (45%). This was backed up by key informant who mentioned the proposed Meibeki valley irrigation project which is meant to increase agricultural practices in the catchment. Some also noted more infrastructure development, such as roads and buildings, while urban expansion was less frequently mentioned.

The majority believed that what is causing these changes is population increase (82.2%), urbanization (32.7%) and agricultural expansion (72.2%). The minor drivers included climate change (19.6%) and government policy (20.4%). This shows that as communities grow, they utilizing more land for housing and farming at the price of forests. Betru et al., (2019) observed that the main drivers of land cover change in many developing countries are agriculture and population growth. Deforestation and urbanization are rapidly changing the environment, impacting local temperatures and biodiversity, as noted by Alemu et al. (2021).

CONCLUSION AND RECOMMENDATIONS

Over the past 20 years, Lower Moiben Sub-county catchment area has experienced a lot changes in LULC. Surface water, rangeland, and forests have decreased in the recent years, while croplands and built areas have increased. Despite the recent conservation campaigns, forest cover have not yet fully recovered, hinting that conservation efforts are still low and human impacts are still severe. Variations in surface water shows that both anthropogenic causes such as construction of dams and climatic changes are shaping the size of surface water.

The findings from household interviews confirm that local people are aware of the changing environment and they are able to identify issues that are causing these changes such as population growth and rising demand for agricultural land. Concerns regarding soil degradation and loss of biodiversity were evident from land covers such as grasslands and rangelands. Even though bareland reduced suggesting improved land management practices, the balance between environmental sustainability and human development remains unstable.

It is recommended that the National Environment Management Authority (NEMA) and County governments should stop the unsustainable land uses by strictly enforcing land use policies such as cultivation on riparian zones. Sustainable land management techniques including terracing, regulated grazing, and preserving vegetated buffer zones around the must be promoted to farmers and landowners. These methods support groundwater recharge, lessen surface runoff, and preserve water quality. Legislative bodies and urban planners should incorporate environmental concerns into development framework to ensure that land use are not compromising the sustainability of water sources.

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