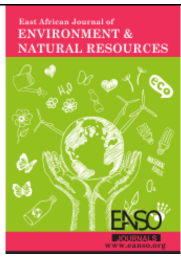

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Original Article

Mapping Land Use Land Cover Changes (LULC) in Eastern Slopes of Mount Kenya; Case of Tharaka Nithi County

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ABSTRACT

Mapping and quantifying the status of Land Use Land Cover (LULC) changes and their drivers are essential for identifying strategic areas for designing and implementing interventions to promote sustainable landscape management. Through a combination of Remote Sensing and Geographical Information Systems (GIS) and interviews with Key Informants, the study analyzed the status of LULC changes and drivers in Tharaka Nithi County, Eastern Slopes of Mount Kenya for the last 22 years. Using Landsat images of 2001,2014, and 2023, four major LULC categories: forest/tree cover, agricultural lands, built-up areas, and water bodies were identified. Results indicate forest/tree cover experienced the most dynamic changes, with tree and forest cover increasing by +38% between 2001 and 2014 and declining by -25.74% between 2014 and 2023. Built-up areas increased by +139.18% over the same period, while agricultural and water bodies remained stable. The main drivers of LULC change include: expansion of built-up areas/settlement areas, expansion of agricultural land, and harvesting of trees for timber, fuelwood, etc, which are driven by population growth. Therefore, to address the causes of LULC change, there is a need to design and implement policies to promote sustainable management and utilization of resources within the study area.

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INTRODUCTION

Land Use and Land Cover (LULC) change assessment has become a top research priority area globally (Chowdhury *et al*., 2020; Hailu *et al*., 2020). To examine LULC change, Remote Sensing (RS) techniques and Geographical Information System (GIS) technologies have been useful in providing information to aid in the decision-making process, and in the formulation of land use policies to support sustainable land management practices (Del Castillo *et al*., 2015; Zafar *et al*., 2021; Teka *et al*., 2018). Investigation of LULC drivers and dynamics is an indispensable effort that is geared towards addressing environmental and socioeconomic challenges, biodiversity conservation, climate change, and reduction and management of impacts and consequences associated with LULC changes at all levels (Foley *et al*., 2005; Winkler *et al*., 2021). LULC dynamics and drivers on the local scale are vital in pursuing effective and sustainable land management strategies to balance development and environmental sustainability within a specified landscape (Hailu *et al.*, 2020). Forest and tree cover are one of the LULC categories that have continued to decline globally due to agricultural expansion and urbanization, illegal logging, mining, climate change, deforestation, and infrastructure development like road and dam construction (Curtis *et al*., 2018; Ferreira *et al*., 2018; Lindley *et al*., 2018; Berenguer *et al*., 2021; Kumar *et al*., 2022). Knowing the complexity and localized drivers of change is critical in making future projections on human-induced strategies and the development of interventions to mitigate the consequences of human-environment interactions (Assede *et al*., 2023). As noted by Xiao *et al.* (2022), deep analysis of drivers of forest cover dynamics is critical for global forest protection and the achievement of Sustainable Development Goals (SDGs).

The global forest cover is approximated to be 4.06 billion hectares, accounting for 31% of the total land mass (Vogt, 2019, FAO & UNEP, 2020, Castrol *et al*., 2023). However, about 420 million hectares of forest were lost due to deforestation between 1990 and 2020 (FAO, 2020). The net loss of forests has reduced due to the decline in forest reduction processes in most countries, while some have significantly increased their forest cover (Ngila *et al.*, 2024). Both anthropogenic and natural factors have continued to influence global land cover changes at multiple spatiotemporal scales (Burka, 2008; Lamichhane, 2008; Rufino *et al*., 2019). Forest cover dynamics and changes are influenced by the interaction of social, political, ecological, demographic, economic, institutional, and environmental factors that occur at different temporal and geographical scales (Geist, 2002; Li *et al*., 2009; Sandel, & Svenning, 2013; Sannigrahi *et al*., 2018).

Forest loss and degradation have contributed to the loss of biodiversity, an increase in soil erosion, an increase in greenhouse gases (GHG), and climate change (Wright, 2005; Hansen *et al*., 2013; Forkuo *et al*., 2021; Ghosh *et al*., 2022). The increase in GHG has triggered climate change, which has threatened human livelihoods, support systems, and the survival of biodiverse species on the planet (Shivanna, 2022). Overall, Land Use Land Cover (LULC) changes have a severe socioeconomic and environmental influence on rural livelihood strategies (Maitima *et al.*, 2010). Research studies have shown that multiple factors that cause forest loss and degradation (Hosonuma *et al*., 2012; Xiao *et al*., 2022), vary regionally and change over time

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(Rudel *et al*., 2009). This is due to the bare fact that countries are at different stages of social and economic development and have employed different protection strategies which may have significant differences in the levels of deforestation, forest protection and conservation (Hosonuma *et al.*, 2012).

According to Igini (2022), twenty-six percent (26%) of land in Africa is classified as forests, accounting for 13.85% of the global forested area. Forest cover distribution in the continent is influenced by rainfall, sunshine, soil properties, natural conditions, and geographical locations (Xiao *et al*., 2022). It is worth noting that the African continent is also experiencing a decline in tree cover, just like other continents in the world. It is experiencing a rapid land cover change due to demographic forces from rural poor populations that are highly dependent on natural resources for their daily survival (Kleemann *et al*., 2017; Assédé *et al*., 2020; Herrmann *et al*., 2020). For instance, the population growth in Ethiopia has caused an increase in demand for agricultural land, leading to significant deforestation and degradation of natural vegetation (Betru *et al*., 2019). The African population is growing at an annual rate of 2.3 percent within the Sub-Saharan region and the population within this region is projected to reach 2 billion by 2050 (Tabutin et al., 2020). More rapid population growth means more people to feed, hence the need to cultivate more land to increase food supplies (Creutzig *et al*., 2019). The global forest keeps on shrinking due to population growth and the associated demand for firewood, charcoal, and construction materials, and the expansion of human settlements (Kindu, 2015; Miheretu, & Yimer, 2018).

Land use land cover change in Africa is mainly driven by the expansion of agricultural land due to unprecedented population growth and climate variabilities (Assédé *et al*., 2023). According to Mwanjela (2018), the continent is estimated to lose 3 million hectares of forest annually through deforestation activities. The primary drivers of forest cover loss and degradation in the continent relate to: biophysical factors, a shift in agricultural practices, rapid population growth, and climate variability (Dibaba *et al*., 2020; Assédé *et al*., 2023). These factors have led to the loss of vegetation, biodiversity, soil erosion, and a decline in agricultural productivity (Assédé *et al*., 2023). Therefore, there is an urgent need for policies and strategies to enhance community forest and tree cover benefits and stimulate the adoption of sustainable land management practices.

Kenya's economy is highly dependent on natural resources and the forestry sector is a strong driver of the key economic sectors like tourism, agriculture, horticulture, and energy which contribute up to 3.6 percent annually to Kenya's Gross Domestic Product (GDP) (Kagombe *et al.*, 2020; KFS, 2022; Chisika *et al*., 2022). On the other hand, it is estimated to have been losing about 50,000 hectares of forest annually (Njora, & Yilmaz, 2022; Rotich, & Ojwang, 2021). Research studies have indicated that this loss has contributed to an economic loss of over 19 million US Dollars (USD) and has reduced the water availability by 62 million cubic meters between the years 2000 and 2010 (Rotich, & Ojwang, 2021; KFS, 2022). Kenya's forest cover stands at 8.83 percent, which is below the international standards and constitutional threshold of 10 percent (KFS, 2022; GOK, 2010). However, in the last few decades, Kenya's LULC has experienced rapid and extensive change due to significant transformations caused by an interaction between the human population and the environment.

In Kenya, numerous factors have been known to cause LULC change. Examples of such factors include the conversion of forest lands for residential and settlement in rural and urban areas, expansion of infrastructural projects like roads, expansion of agricultural land, logging, and extraction of timber and other resources (Mutuku *et al.*, 2018; Oloo *et al*., 2020; Jebiwott *et al.*, 2021). In addition, trees

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have been lost both in gazetted forests and private agricultural lands (Ngila *et al.,* 2024). The drivers of deforestation in any location should be investigated to assist in recommending and implementing effective and sustainable land management practices, and RS and GIS are powerful tools in providing that information. However, most studies on LULC changes have focused on a macro scale (KFS, 2022), and a few studies have covered regional and small geographical areas in Kenya. Even though few studies on LULC changes have been carried out, investigation on the drivers contributing to these changes at national, regional, and local levels has remained scanty. Hence, there has been growing interest in studying LULC over space and time but these kinds of studies are still limited in Africa (Biaou, 2021), Kenya included.

Like most parts of the country, Tharaka Nithi County faces multiple environmental challenges related to increased deforestation, loss of biodiversity, soil erosion, and land degradation (Tharaka Nithi County CIDP, 2013; Gitonga *et al*., 2024). Thus, these LULC changes call for continued research to understand the extent, dynamics, and causes of change to guide the formulation of relevant policies and the implementation of sustainable land management practices. The county has been experiencing a decline in precipitation and an increase in temperature due to climate change (Gioto, 2016). Climate variability in the county has led to low agricultural productivity and a decline in natural resources like forests and water (Muthaura *et al*., 2015).

Therefore, the objective of this study was to establish the LULC change and the drivers of LULC between 2001 and 2023 with a sharp focus on the forest/tree cover within the agricultural landscapes. The findings from this study will provide information that will be useful in the formulation of sustainable landscape management policies, guidelines and strategies to promote the protection, conservation, and utilization of natural resources in the study area and other areas with comparable ecological and economic characteristics.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Tharaka Nithi County, which is located on the Eastern Slopes of Mount Kenya. The county lies between Latitude 00º 07' and 00º 26' South and between Longitudes 37º 19' and 37º 46' East with a total area of 2,662.1 Km^2, including 360Km^2 of Mt Kenya forest (Tharaka Nithi County Integrated Development Plan, 2018) (Figure 1). The county borders the following counties: Meru to the North and North East, Embu to the South and South West and Kitui to the East and South East (Tharaka Nithi County Integrated Development Plan, 2018). Based on the 2019 national census, the county's population is estimated to be 393,177 persons with a population density of 153.3 individuals per km^2, and the total number of households was 109860 based on (Kenya National Bureau of Statistics, 2019). The County is divided into five administrative sub-counties, namely Maara, Chuka, Tharaka North, Tharaka South, and Igamba Ngo'mbe. The sub-counties vary with their geographical area coverage; Maara and Chuka counties border the Mt. Kenya Forest in the upper part, while other sub-counties are found in the lower part of the county. The county comprises three constituencies, namely Maara, Tharaka, and Chuka Igamba Ngo'mbe. The study focused on the entire county, excluding the Mount Kenya forest area, which is a gazetted zone.

The highest altitude of the county is 5,200 meters above sea level (m.a.sl.) in Chuka and Maara (The highest peak of Mt. Kenya), while the lowest is 600 m.a.s.l Eastwards in the Tharaka sub-county. The topography of Chuka Igamba Ng'ombe and Maara constituencies is greatly influenced by Mt. Kenya volcanic activity, creating 'V' shaped valleys within which the main tributaries of River Tana flow, originating from Mt. Kenya Forest.

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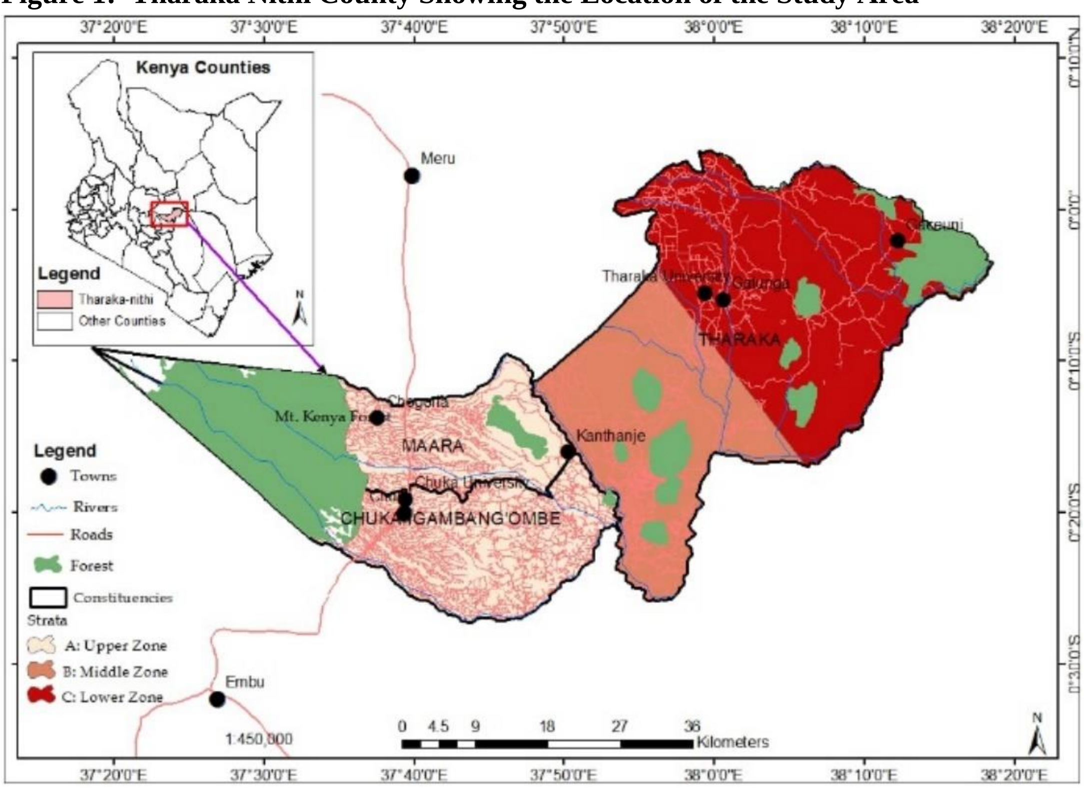
The county has a bimodal rainfall pattern with the long rains being experienced from March/April to June and the short rains from October to December. Rainfall distribution in the county ranges from 2,200 millimetres in Chogoria forest areas to 500 millimetres in the lower zone, where it is unreliable and poorly distributed. In terms of rainfall distribution, the county can be divided into two regions; high-potential areas covering parts of Maara and Meru South, and low-potential areas covering the arid zone of Tharaka (Jaetzold *et al*., 2006). Mean annual temperatures range between 14^0 C to 30^0 C in the upper zone and 22^0 C to 36^0 C in the lowland areas of Tharaka.

The forest cover in the county constitutes 44,617 ha of gazetted forests and 3,344 ha of non-gazetted forests. The main Indigenous natural forest is found in the upper zone of the Chuka and Chogoria forests covering 179 Km^2 and 184 Km^2 respectively. However, the forest has been facing a high rate of degradation due to over-exploitation by the local population that depends on it for timber, firewood, poles, charcoal, herbs, fodder, beeswax, honey, and wild fruits. Some of the major activities that have aggravated environmental challenges in the county, include poor farming methods on sloppy lands, overgrazing on both gazetted and community forests, charcoal burning, quarrying and sand harvesting along the riparian areas (Tharaka Nithi County Integrated Development Plan, 2018). The study area is enriched with both indigenous and exotic tree species that are widely distributed across the landscape.

Agriculture is the main land activity in Tharaka Nithi County and the majority of the households are small-scale farmers who cultivate multiple crops (Wawire *et al*., 2021). Most farmers practice mixed farming of cash crops, food crops, and livestock keeping. The major cash crops in the county are tea and coffee, mainly grown in upper zones (Mairura *et al*., 2022).

Figure 1: Tharaka Nithi County Showing the Location of the Study Area



Source: Author (2024)

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Data Collection Procedures

The study relied on both primary and secondary data sources. Primary data was collected on a first-hand basis (Jonathan *et al*., 2014) and in the study; key informants were interviewed to provide insights on historical LULC changes in the area. The field data was collected between December 2023 and March 2024. Secondary data was obtained through internet search engines like Google Scholar and websites of relevant government ministries and agencies. Other sources of secondary data included reports from both national and county governments, libraries, and other public offices.

For classification of the Land Use Land Cover (LULC) categories, the study relied on open-source images that were acquired from the United States Geological Survey (USGS); https://earthexplorer.usgs.gov/) website as summarized in the table below (Table 1) The data sets that were used for this study include Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) satellite images of 4th and 11th March 2001 (30m and 15m) resolution, Landsat 8 OLI (Operational Land Imager) satellite images of 24th and 15th March 2014 (30m by 30m) resolution and Landsat 9 OLI images of 15th and 21st March 2023 (30m and 30m) and panchromatic band 8 at 15m by 15m. Landsat Images were acquired for selected months that had less cloud cover (< 10%) within the study area.

Table 1: Detailed Information on Landsat Images Used in the Study

S.no	Satellite	Sensor	Path/Row	Spatial Resolution	Spectral Bands	Date of acquisition	Source
1	Landsat 7	ETM+	167/060	30m and 15m	1,2,3,4,5,7& 8	4th/3/2001	USGS
			168/060	30m and 15m	1,2,3,4,5,7& 8	11th/3/2001	USGS
2	Landsat 8	OLI	167/060	30m and 15m	2,3,4,5,6,7& 8	24th/3/2014	USGS
			168/060	30m and 15m	2,3,4,5,6,7& 8	11th/3/2014	USGS
3	Landsat 9	OLI	167/060	30m and 15m	2,3,4,5,6,7& 8	21st /3/2023	USGS
			168/060	30m and 15m	2,3,4,5,6,7& 8	4th/3/2023	USGS

Image Pre-Processing and Land Cover Classification

Six monochrome bands for Landsat 7 ETM+ i.e. 1(visible blue), 2(visible green), 3(visible red), 4(NIR), 5(SWIR1), and 7(SWIR2), six monochrome bands for Landsat 8 and 9 OLI i.e., 2 (visible blue), 3 (visible green), 4 (visible red), 5 (Near Infra-red) & 6 (Short wave infra-red1), 7 (Short wave infra-red2) were combined to produce composite images. Panchromatic band 8 at 15m by 15m was used to pan-sharpen the composite images from 30m by 30m to 15m by 15m. The study area straddled two Landsat 7 ETM+, 8 OLI, and 9 OLI images, hence were mosaicked together and clipped using the shapefile of the study area (Tharaka Nithi County and constituencies) obtained from Kenya National Bureau of Statistics (KNBS). Four land cover classes (i.e. forest, agriculture, water bodies, and built-up area) were modified from (Anderson, 1976) classification scheme to fit into the study area (Table 2).

Table 2: Land Use Land Cover Classes Used in the Study

S.No.	Land cover classes	Description
1.	Forest	Planted and natural
2.	Agriculture	Cultivated and non-cultivated
3.	Water bodies	Rivers, ponds, wetlands
4.	Built-up areas	Settlements, roads, and any concrete feature

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LULC changes were estimated from satellite images selected to reflect a time series pattern spanning from 2001 to 2023, a period of 22 years. The images were analyzed and interpreted using GIS technology, and Ground Control Points (GCPs) were established in the study area to support different steps of image processing and classification for change detection. GCPs were also used in field observation to confirm information on the type and nature of the various land use and land cover classes prevalent in the study area.

Supervised Classification and Accuracy Assessment

A supervised Maximum Likelihood Classification (MLC) algorithm was applied to each image where the basic equation assumes that these probabilities are equal for all classes; and that the input bands have a normal distribution (Bailly *et al*., 2007). The accuracy assessment procedure was followed (Congalton, 1991). The process produced four metrics, namely, the user's accuracy, the producer's accuracy, the overall accuracy, and the Kappa statistic (Congalton, 1991). The producer's accuracy indicates the percentage of correctly classified ground truth sites for each class. The user's accuracy indicates the proportion of correctly classified sites in the classified image for each class, while the overall accuracy is a combination of the two accuracy measures. The Kappa statistic shows the probability that the values presented in the error matrix are significantly different from those from a random sample of equal size (Benjamin *et al*., 2007). A nonparametric Kappa test was also used to measure the classification accuracy, as it accounts for all of the elements in the confusion matrix rather than the diagonal elements (Rosenfield, & Fitzpatirck-Lins, 1986).

Area Calculation and Change Detection Analysis

After the accuracy assessment, the areas for each land cover class were calculated using the field calculator geometry. The field of 'counts' was multiplied by cell size for each image, that is, 15*15 for Landsat 7, 8, and 9, respectively. Change detection was done by calculating the changes in land cover between three consecutive images, i.e., 2001-2014, 2014-2023, and 2001-2023, to know the magnitude of change between land cover classes. Each of the three classified images (2001, 2014, and 2023) was converted to a polygon from raster, and in the attribute table, the classes were labelled and their areas auto-generated using the calculate geometry tool. Using the geo-processing intersect tool, two successive images, i.e., 2001-2014 and 2014-2023, were intersected to get which land cover changed to what and at what area.

RESULTS

Land Use Land Cover Accuracy Assessment

The accuracy assessment based on error (confusion matrices) showed an overall accuracy of 90.00 - 96.5% and a Kappa coefficient of 0.866 - 0.953 (Tables 3, 4 and 5). The datasets used in this study showed a high level of accuracy since there was an insignificant difference in the user and producer's accuracy for individual classes. The accuracy results provided a basis for analyzing LULC change and trends from 2001 to 2023 in the study area.

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Table 3: Accuracy Assessment Results for 2001 LULC Change Map

	Reference Data					
LULC Type	**Forest**	**Agricultural**	**Water bodies**	**Built-up areas**	**Total User**	**User's Accuracy (%)**
Forest	50	0	0	0	50	100
Agricultural	4	39	0	7	50	78
Water bodies	0	0	50	0	50	100
Built-up areas	0	9	0	41	50	82
Total Producer	54	48	50	48	200	
Producer's Accuracy %)	92.6	81.25	100	85.41		

Overall accuracy=90%, Kappa coefficient=0.866

Table 4: Accuracy Assessment Results for 2014 LULC Change Map

	Reference Data					
LULC Type	**Forest**	**Agricultural**	**Water bodies**	**Built-up areas**	**Total User**	**User's Accuracy (%)**
Forest	50	0	0	0	50	100
Agricultural	0	46	0	4	50	88.46
Water bodies	0	0	50	0	50	100
Built-up areas	0	6	0	44	50	88
Total Producer	50	52	50	48	200	
Producer's Accuracy %)	100	88.46	100	91.66		

Overall accuracy=95%, Kappa coefficient=0.933

Table 5: Accuracy Assessment Results for 2023 LULC Change Map

	Reference data					
LULC Type	**Forest**	**Agricultural**	**Water bodies**	**Built up areas**	**Total User**	**User's Accuracy (%)**
Forest	50	0	0	0	50	100
Agricultural	0	47	0	3	50	94
Water bodies	0	0	50	0	50	100
Built-up areas	0	4	0	46	50	92
Total Producer	50	51	50	49	200	
Producer's Accuracy %)	100	92.1	100	93.9		

Overall accuracy = 96.5%; Kappa coefficient = 95.3

Land Use Land Cover Dynamics between 2001-2023

Figure 2 shows the spatial distribution and representation of LULC classes in the study area from 2001 to 2023. The area coverage for each of the four LULC types that were extracted in the study area from 2001 to 2023 of LULC change and trend analysis is summarized in Table 4. Results indicate that at the beginning of the study period in 2001, agricultural areas were the predominant LULC category at 73.45%, with forest/tree cover at 25.91%, built-up areas at 0.4%, and water bodies at 0.24%, respectively.

Comparing the LULC trends in the study period (phase one, 2001- 2014, and phase two, 2014-2023), forest and tree cover increased by +38% from 2001 to 2014 and decreased by -25.74% from 2014 to 2023. Within the same period, agricultural areas decreased by -13.86 % (2001 -2014) and increased by +14.05% between 2014 and 2023. During the period under consideration, built-up

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areas expanded by +49.1% between 2001 and 2014 and stretched further by +60% between 2014 and 2023, respectively. For the water bodies, the LULC category decreased by -34.54% between 2001-2014 and increased by +6.26% between 2014-2023. Agricultural and forest, and tree cover occupied the largest portion of the landscape during the entire study period from 2001 to 2023.

Figure 2: LULC Classification Map for the Study Area (a) 2001, (b) 2014 and (c) 2023

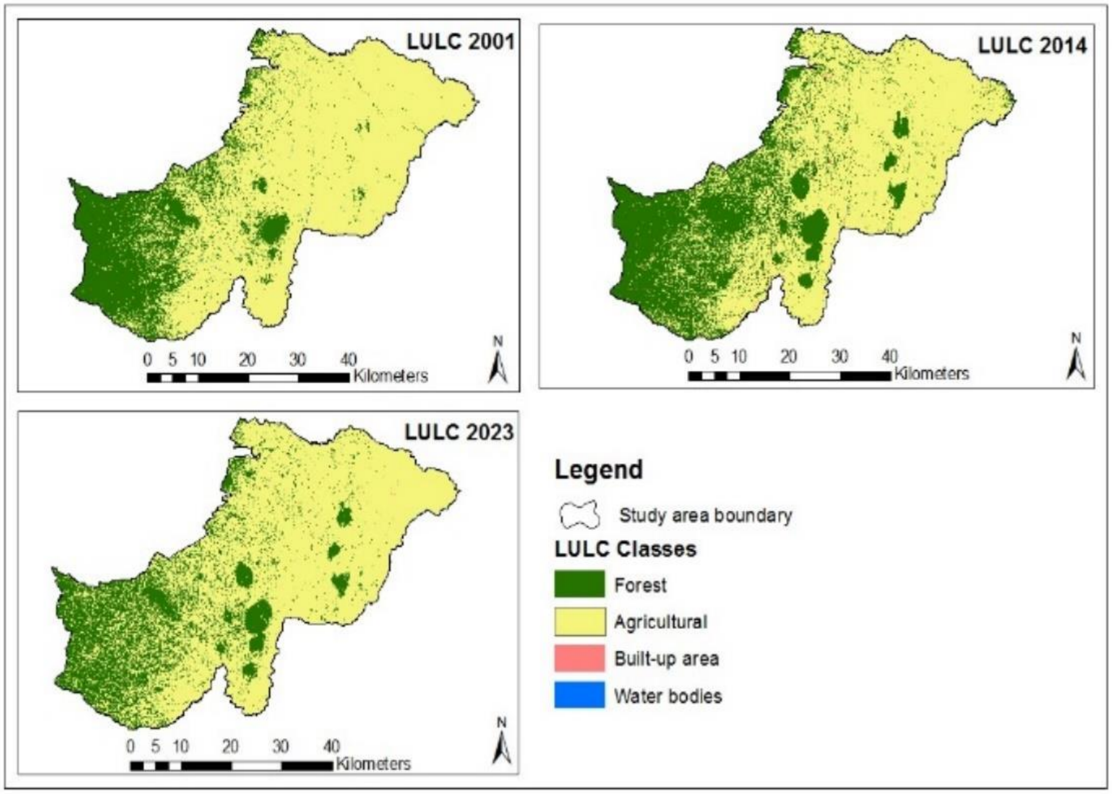

Table 6: LULC Distribution and Changes (Area, Ha and %) in the Study Area

LULC type	Year 2001		Year 2014		Year 2023		LULC change (2001-2014) (%)	LULC change (2014-2023) (%)	LULC change 2001-2023) %
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%			
Agricultural	167341.59	73.45	144136.53	63.27	164395.78	72.16	-13.86	+14.05	-1.76
Forest	59016.15	25.91	81960.12	35.97	60853.77	26.71	+38	-25.74	+3.11
Built-up areas	911.43	0.40	1359.54	0.60	2180	0.96	+49.1	+60	+139.18
Water bodies	541.44	0.24	354.42	0.16	381.06	0.17	-34.54	+6.26	-29.62
Total	227810.61	100	227810.61	100	227810.61	100			

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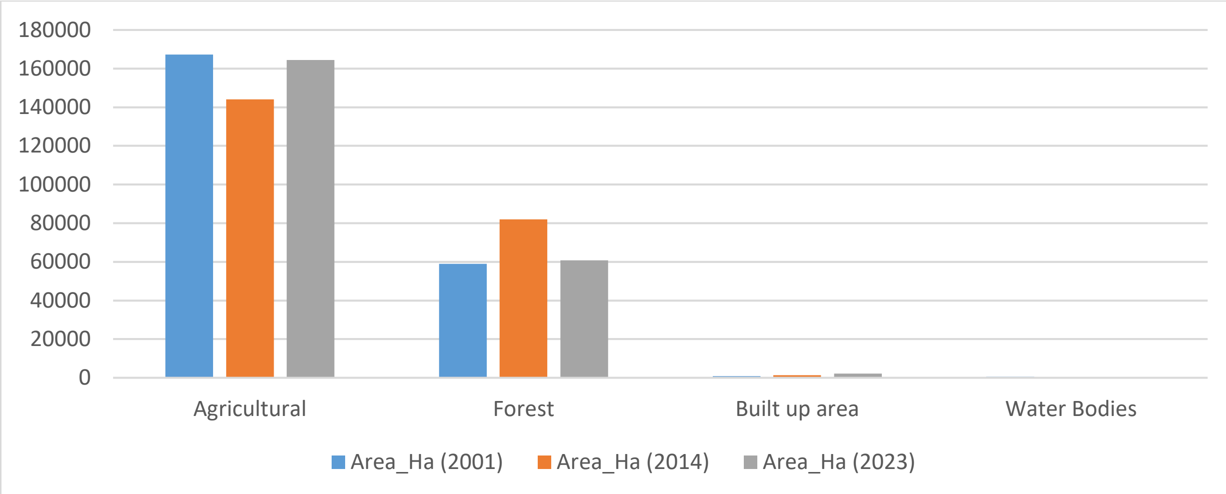
Major Land Use Land Cover Changes in Tharaka Nithi County from 2001 to 2023

Observing the overall LULC categories from 2001 to 2023, the amount of change in terms of area varied from one LULC category to another, with agricultural land decreasing by -1.76 % and forest and tree cover increasing by +3.11%. During the same period, built-up areas increased by +139.18%, and water bodies declined by -29.62% (Figure 3).

Figure 3: Major LULC Changes in TNC from 2001 to 2023



DISCUSSION

Post-classification and comparison of change detection analysis showed an extent of LULC change that occurred in Tharaka Nithi County between 2001 and 2023, and agricultural land and forest/tree cover are the major LULC types that dominate the area. In terms of LULC change, agricultural lands, forest/tree cover, and built-up areas land categories experienced the most dynamics. Forest and tree cover had an increase of +38% from 2001 to 2014 and a rapid decline of -25.74% from 2014 to 2023. Built-up areas' land cover category increased by +139.18% from 2001 to 2023. The expansion of built-up areas/categories was due to the increased construction of buildings to support residential, commercial, learning institutions, social facilities, and new administrative centres in the study area. For instance, the expansion of settlements especially in areas adjacent to major towns within the study area, has contributed to the loss of tree cover and agricultural lands. For example, in major towns like Chuka, the establishment and growth of a public university in the area has attracted massive investment in residential houses, rental apartments, commercial areas, and social facilities. This has significantly contributed to a loss of trees and agricultural land to built-up areas. The increase in building and construction activities has exerted more demand on timber and other construction materials. Trees are ordinarily harvested or bought from individual farmers as processed timber or whole trees, where they are processed by timber dealers and sold out for construction purposes. Timber is also sold out to make products like beds, tables, chairs, etc., to meet the demand from an increasing population within the county. This trend has also been replicated in other areas within the study, like the expansion of learning institutions.

On the other hand, the introduction of devolved units of governance after the promulgation of the new constitution in 2010 has acted as a push and pull factor to attract more people to work and live in rural areas. This has created an increased demand for new buildings to support an upsurge in demand for residential, commercial, and social amenities

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like schools, churches, and new administrative centres like Kathwana Town. The establishment of Tharaka Nithi County headquarters in a new, underdeveloped area led to rapid expansion and the construction of new buildings to provide administrative offices, commercial, residential, and social amenities to serve the local population. The expansion of built-up areas has led to a significant loss of forest and trees from private farmlands to provide timber, construction materials, and other products from the trees. This finding is in line with the findings of Kogo *et al*. (2021) that the creation of the County Governments in Kenya as devolved units of governance under the new constitution of 2010, led to an increase in residential and commercial establishments in towns like Eldoret, Kitale, and Kapsabet.

During the study period, forest and tree cover dynamics varied between phase one (2001-2014) and phase two (2014-2023). The most noticeable change was an increase in forest cover by 38%. This could have been attributed to the implementation of the Forest Act of 2005 and the Agriculture (Farm Forestry) Rules of 2009, which had a goal of promoting and maintaining farm forest cover of at least 10% within the agricultural land. However, the status of forest and tree cover paints a different picture from 2014 to 2023. There was a decline in the forest and tree cover LULC category by -25.74% in the study area. This can be attributed to increased demand for firewood, timber for building and construction, and the expansion of rural and semi-urban settlements and farmlands. This phase coincides with the introduction of county governments in the country.

The research findings based on key informant interviews, the settlement areas, and the growth of urban and market centres had increased within the studied period. Other factors that were perceived to have contributed to the decline in forest and tree cover land categories in the study area included overharvesting of trees for firewood, charcoal burning, and expansion of agricultural lands. The use of key informants who were over 60 years old and had lived within the study area for over 30 years provided a historical perspective of LULC changes. The historical information was positively corroborated with LULC results that were analyzed using remote sensing and GIS technology. These results show that LULC drivers are influenced by environmental, social, economic, and policy factors (Geist, & Lambin, 2002).

Research findings from other researchers show that LULC change and dynamics occur differently in various geographical settings. The findings from this study are consistent with other studies that were carried out in different parts of the globe. For example, a study conducted by Anwar *et al*. (2022) in Abbotta in the Lower Himalayan Region in Pakistan to compare LULC change for two decades (1989 -1999 and 1999-2009), found that built-up areas had grown by 0.71% and 0.722%. During the same period, the agricultural LULC category had declined by 0.208% and 0.284%, respectively. However, during the same period, the forest land category had an overall net change of 2.94% while water bodies reduced by 0.58%. LULC cover in this region was attributed to proximate drivers like the expansion of rural infrastructure and planned and unplanned settlements, while underlying drivers included changes in demographic variables, economic opportunities, and policy change. Another study carried out in Fagita Lekoma District in Ethiopia by Belayneh *et al*. (2020), reported an increase in forest lands by 18.3% and built-up areas by 7.1% during the studied period of 2003 to 2017. During the same period, there was a decrease in wetlands by -7.1% and cultivated land by -1.9%. The dynamics of LULC in the study region were attributed to the interplay of biophysical, socio-economic, and demographic factors.

The research findings from this study corroborate with the above researchers who found an increase in built-up areas and forest and a corresponding decrease in water bodies and agricultural land cover categories in their study areas. However, the

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findings in this study contrast with the findings by Bekele *et al*. (2019) and Patel *et al*. (2019), who in their research work found that the agricultural land cover category had increased by 42.4% and 39% respectively. Other studies on LULC change have revealed varied results with an increase in built-up and agricultural areas and a decrease in forest land and other vegetation and other land categories (Hassan *et al*., 2016; Tolessa *et al*., 2017; Mutuku *et al*., 2018; Munthali *et al*., 2019; Maina *et al*., 2020; Oloo *et al*., 2020; Kogo *et al*., 2021). The findings from this study exemplify that LULC changes are dynamic and influenced by different factors that ensue at different temporal and geographic scales (Geist, 2002; Li *et al.*, 2009; Sandel, & Svenning, 2013; Sannigrahi *et al*., 2018). Therefore, knowing and understanding the complexity of location-specific drivers of LULC change is critical in forecasting future trends of human-induced drivers and developing sustainable strategies to mitigate the consequences (Assédé *et al*., 2023), for instance, like promotion and adoption of Green Infrastructures (GI) practices like tree planting to support landscape restoration activities.

CONCLUSIONS

Based on the findings from the study, the changes in the landscape are driven by an interplay of different factors. The study area experienced a dynamic LULC change during the studied period. Tree and forest cover had the most dynamic changes with tree and forest cover increasing by +38% between 2001 and 2014 and having a sudden decline by -25.74% between 2014 and 2023. Built-up areas increased by +139.18% during the study period while agricultural and water bodies remained almost stable. Multiple factors are driving forest and tree loss in the study area. Tree and forest cover loss within the farmlands is influenced by both direct and indirect factors. Direct factors that were identified include: harvesting of trees for fuelwood domestic and institutional uses, timber and other construction materials; expansion of farmlands to support cash crops, food crops and livestock keeping and expansion of settlement areas. Indirect causes included: an increase in population, poverty levels and over-dependence on tree biomass as the major source of household energy. These drivers of change can be used to predict future changes to make informed decisions for policy formulation to promote sustainable landscape management in the study area and geographical locations with similar settings. The study provides useful information that can act as a guideline to future planners on issues to focus on when tackling issues that arise due to drivers identified to cause landscape changes in the study area.

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