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Prediction of Land Use Land Cover Change: Molusce Plug -Based Technologies an Analysis of Kiambu County Kenya

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ABSTRACT

Land use land cover change is a very important factor that impacts on regional planning, sustainability in environmental and resource management. This study focused on the prediction of Land Use Land Cover changes in Kiambu County in Kenya, deploying MOLUSCE plug-based technologies. The results showed a decrease in cropland from 85,918.90 Ha in 2024 to 62,268.00 Ha in 2044. Vegetation cover is also decline from 45,871.5 Ha to 40,537.00 ha within the same period. Similarly, water bodies reduce from 12,040.50 Ha in 2024 to 10,040.50 Ha in 2044, while bare lands decline from 4,627.0 Ha to 4,050 Ha. Contrarily, built-up areas increased from 105,581.1 Ha in 2024 to 137,454 Ha in 2044. These findings highlight a trend of urban growth at the expense of agricultural and natural land covers. The study demonstrated that predictive models provide valuable insights that guides planners, policymakers, and environmentalists in making informed decisions to promote sustainable land use and environmental conservation in Kiambu County.

INTRODUCTION

Land use and land cover (LULC) change has become one of the most significant global environmental problems because of its strong relationship with population sprawl, urbanization, agricultural growth, and climate change (Intergovernmental Panel on Climate Change, 2019, Afroz *et al.,* 2022, and Eric *et al.,*2006). Transformations in Land Use Land Cover utilizations have impacts on food security, biodiversity conservation, regional planning, and environmental sustainability (Mugari & Masundire, 2022; Abdulai & Owusu,2022). According to Zhang *et al.,* (2025) globally, LULCCs are driven largely by anthropogenic factors such as; urbanization, population growth, industrialization, and economic development. This driver has resulted into increased deforestation, reduction in agricultural land, and increased environmental degradation (Celdric *et al.,* 2025). Technological advancements especially in geospatial fields has enabled researchers to analyze historical land use transformations and forecast future occurrences using Geospatial modeling techniques (Intergovernmental Panel on Climate Change, 2022; Chandra, *et al.,* 2023; S. Liang, 2023). Geospatial technologies allow integration of Land satellite imagery, spatial variables, and predictive algorithms to simulate future scenarios in land use land cover transformations contributing towards insights in sustainable land planning and environmentally sustainable management (Mohammed *et al.,* 2025; Yildirim *et al.,* 2025; Muhammad *et al.,* 2025). African countries are experiencing drastic changes in their landscapes; this has resulted to increased utilization of remote sensing and GIS-based modeling techniques in monitoring the dynamism in land use land cover changes. The deployment of predictive models in land use land cover changes is vital in policy making and understanding the future scenarios. Kenya has witnessed intensified land use changes in the past decades especially in areas surrounding major urban cities. Kenya counties situated in the periphery of Nairobi Metropolitan, such as Kiambu, Nakuru, Machakos, Kajiado, Nyandarua, and Murang'a, are undergoing the transformation. The transformations are due to population growth, infrastructural expansion, industrial development, and urban expansion. These drivers have led to transformations in agricultural land use, vegetation lands, bare lands, and open spaces. Studies have been done on land use and land cover change prediction. For instance, Mwangi *et al.,* (2025) carried out a study on the monitoring and predicting land use and land cover using remote sensing and CA-ANN in Nairobi National Park and its environs. The study deployed Landsat imagery for 2016, 2023 and predicted future scenarios for 2040. Random forest classification method was utilised. The study results showed expansion of built-up areas while vegetative areas were on reduction mode. Mutunga, *et al.,*

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(2024) carried out a study on spatio-temporal patterns of land use and land cover change in Kibwezi West, Eastern Kenya. The study deployed MOLUSCE plugin in QGIS for prediction the future scenarios for 2051 with spatial variable such as slope, elevation, distance to roads and rivers. The study findings showed an increase in cultivated areas and grassland but a decline in water bodies, forest, and shrublands. A study by Githui *et al.,* (2022) carried out the study on land use and land cover change assessment and future predictions in the Matenchose watershed, Rift Valley Basin, Kenya using CA-Markov simulation. The study deployed satellite images from 1991, 2003, and 2020 to predict future scenarios for 2050. The study used CA-Markov simulation models, and the study results showed increase in cultivated areas and residential areas and a decline in forest and grassland. This study focused on Kiambu County with is located on the northern side of Nairobi city. The county closeness to Nairobi City has seen it undergoing drastic transformations due to urbanization and land subdivision. This transformation has resulted to gradual reduction in agricultural land, water bodies and forests. The transformations threaten the achievement the vision 2030 and the Sustainable Development Goals (SDGs). Therefore, this study focused on predicting Land Use Land Cover change in Kiambu County, Kenya, using MOLUSCE plugin-based technologies.

Statement of the Problem

Land Use Land Cover Changes affect ecological biodiversity, human livelihood, and climatic regulations. Kiambu County is experiencing population sprawl that is increasing the transforming of natural landscapes. The availability of data on inclusive prediction models on land use change dynamics remains limited. Furthermore, the deployment of high-resolution satellite data on LULCCs remains unknown. The limitation of these crucial data creates a gap in vital areas such as decision-making and sustainable land management systems. Therefore, the study addressed this gap by predicting Land Use Land Cover Change: Molusce Plug -Based Technologies Analysis of Kiambu County Kenya.

Main Objective

The main objective of the study was to analyse Prediction of Land Use Land Cover Change: Molusce Plug -Based Technologies Analysis of Kiambu County Kenya.

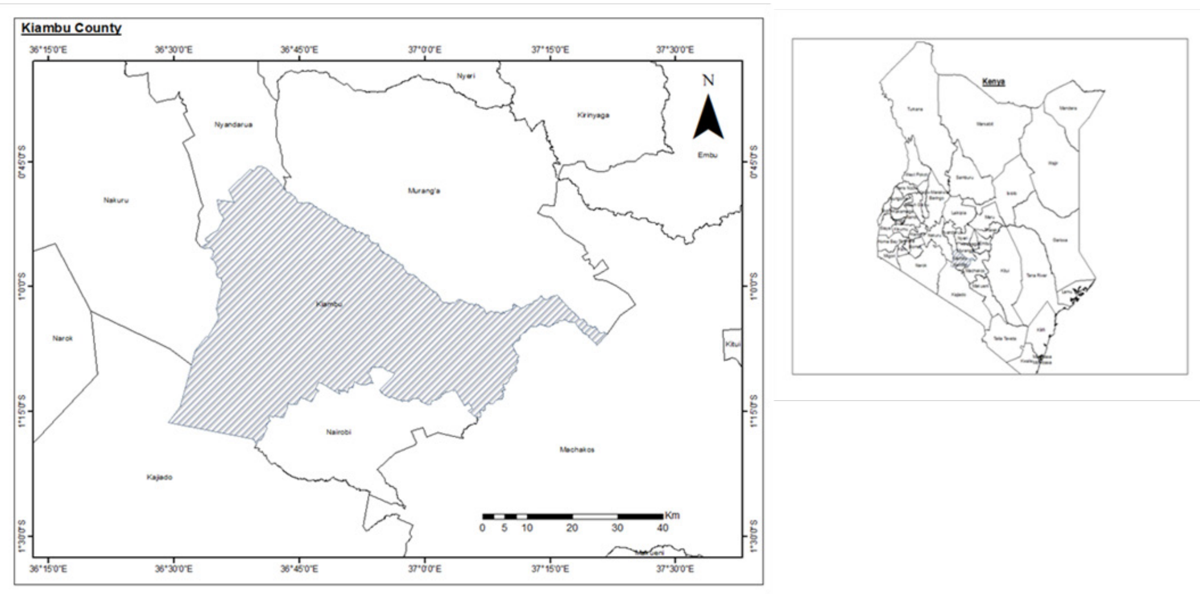

Figure 1: Study Area Map
Source: Google Earth Pro image (2013)

MATERIALS AND METHODS

Study Area Map

The study was conducted in Kiambu County. The County is a pre-urban region located in the central part of Kenya. Its' neighbours include: - Nakuru, Kajiado, Maranga, Machakos and Nyandarua. The county is characterized by red volcanic soils, cool and wet climatic conditions that support various agricultural activities. The county is densely populated with approximately 2.41 million people. The county is rich economically with various activities like; industrial development, agricultural activities, trade, and real estate.

Data Acquisition and Methodological Flowchart

With the aim of achieving the main goal, the study deployed data from USGS Explorar for Landsat 7 TM and Landsat 8 (OLI / TIRIS), OpenStreetMap for roads and rivers, and SRTM for DEM and slope. The study utilized the methodology below.

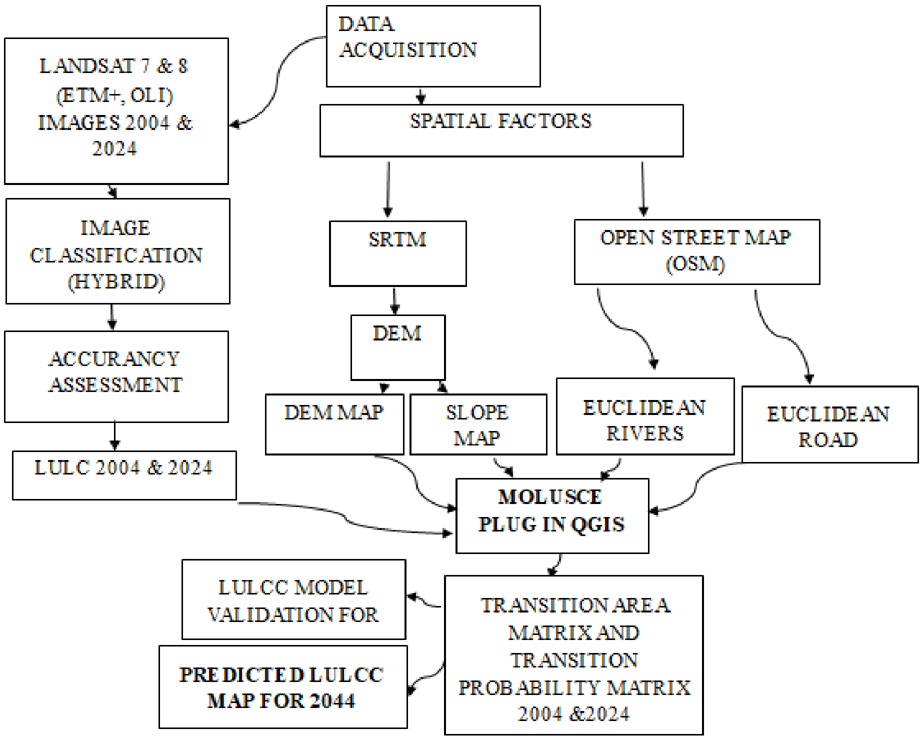

Figure 2: Methodology Flow chart
Source: Adopted and modified Diego et al., (2020)

RESULTS AND DISCUSSIONS

The study used Land sat, SRTM and Open Street Map (OSM) data in the achievement of the primary goal. The data were analyzed using Google Earth Engine (GEE), Eridas Imagine, ArcGIS and QGIS in generating land use land cover classification and factor maps. Accuracy assessment was done to test and validate the classified maps.

Accuracy Assessment

The study carried out accuracy assessment on the classified images for 2004 and 2024. The results were shown in table 1. In the study results, both the overall accuracy and Kappa Accuracy percentage were above 90% showing that the land use land cover change classification was of high accuracy. According to Singh, (2025), in the accuracy assessment, the result of both the overall accuracy and Kappa Accuracy above 90% indicates that the sample in the assessment were correctly classified.

Table 1: Land use land cover change Accuracy Assessment

LULC classes	2004	UA	2024	UA
	PA		PA	
Vegetation	97.61	70.69	100.00	65.63
Cultivated areas		100.00		100.00
Bare lands	100.00	100.00	100.00	84.61
Built -up areas	95.23	100.00	92.85	97.56
Water bodies	97.61	100.00	95.23	97.56
Overall Accuracy %	80.95	94.28	100.00	92.10
Kappa Accuracy %		92.97		98.84

Land Use Land Cover Classification And Spatial Factors

The figure 3 (a) (b) reveals various changes in land use in Kiambu County from 2004- 2024. The study results showed drastic changes in land use types, for instance, the results in 2004 showed a higher percentage in vegetation and cultivated areas while in 2024, saw an increase in built up areas due increased rural urban migration and expansion of Nairobi city population.

The study utilized spatial variables that included; Digital Elevation Model (DEM), Slope, Euclidean distance from the roads, and Euclidean distance from the rivers.

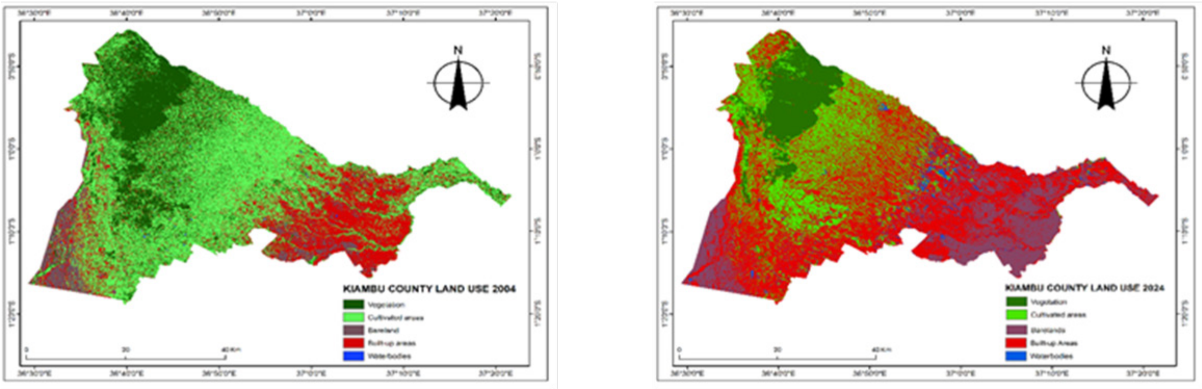

Figure 3: (a) LULC 2004 (b) LULC 2024

Digital Elevation Models (DEMs) data was obtained from Open Topography DEM Downloader a QGIS plug and was converted into raster through rasterization. The raster was reprojected to UTM Zone 37S and snapped to align it with the land use land cover raster maps of 2004 and 2024. Utilizing the DEM data the slope dataset was extracted using terrain analysis. The slope dataset was snapped and reprojected to UTM Zone 37S to align with land use land cover datasets. The study also deployed Euclidean distance from the roads and Euclidean distance from the rivers which was obtained from OpenStreetMap (OSM). The datasets were rasterized; Euclidean distance was generated and reprojected to UTM Zone 37S to align with LULC datasets. The study deployed Molusce (Modules for Land Use Change Evaluation) a QGIS plugin in carrying out the predication process. From the study results of the spatial factors, Figure 3 (a) and (b) shows land use land cover maps. Figure 4 (c) shows DEM with the lowest elevation of 1278 m and the highest 2727 m. Figure 4(d) shows Kiambu slope which was extracted from Kiambu DEM. The slope showed variations in the elevation in Kiambu county. Figure 5 (e) shows

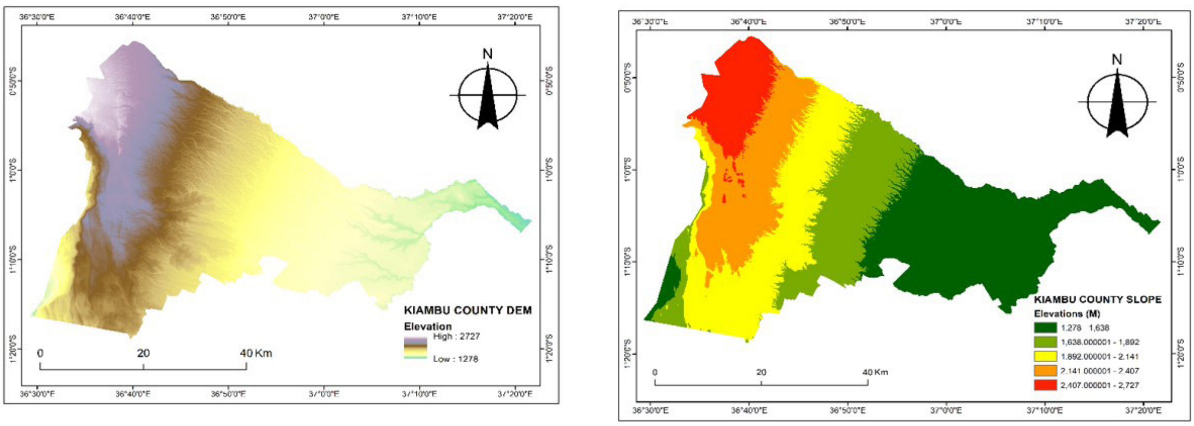

Figure 4: (c) DEM (d) Slope

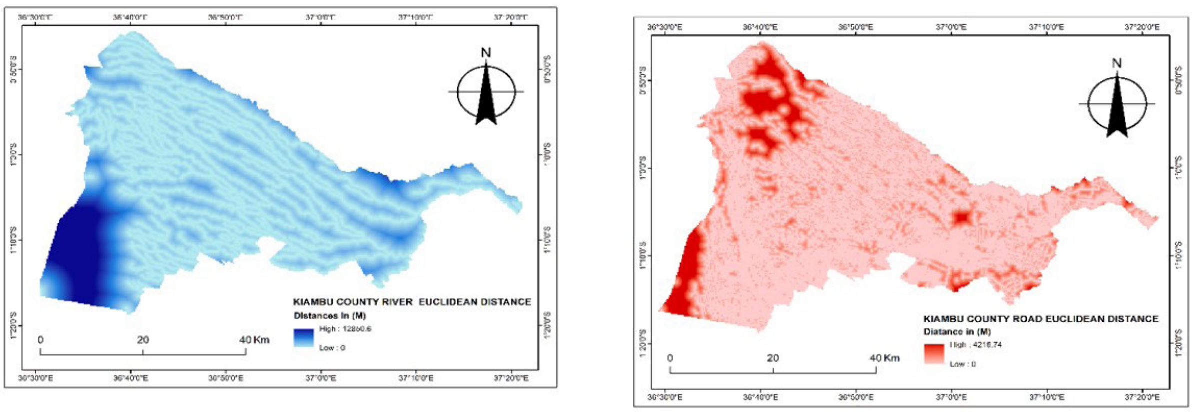

Figure 5: (e) River Euclidean distance (f) Road Euclidean distance

Euclidean distance from the rivers with the lowest at 0 m and highest at 12,850.8 m. This means that 0 m are areas directly located on the river channel, they are suitable for agricultural practices and prone to flooding. At the point 12,850 m are areas far from the water point and have limited land use changes. Lastly, Figure 5 (f) shows Euclidean distance from the roads with the lowest at 0 m and highest at 4,216.74 m. 0 m shows road corridors and immediate surroundings while 4,216.74m shows areas that attract land use land cover changes.

Transition Area Matrix And Transition Probability Matrix 2004 & 2024

The study deployed a formula (J. Ronald ,2016) $Pij=Aij/(\sum^{n}_{j-1} Aij)$ Where:
The study obtained area transitional changes for 2004 and 2024 by updating the tables and generating an area change. Table 2 shows land use land cover changes for 20 years across the five classified classes. Bare lands result showed a gradual increase by 3.64%, built-up areas increased drastically by 46.36%, cultivated areas reduced drastically by 26.96 %, vegetation and water bodies reduced slightly by 18.4 % and 4.62% respectively.

Prediction for 2044

Figure 6 shows the projected land use and land covers distribution for the year 2044, while table 3 gives a summary of the anticipated dynamics of land use changes across the five classes. The study findings showed a continuous and pronounced expansion of built-up areas in Kiambu County, with their proportion increasing from 46.36% between 2004–2024 to 50.70% in the years between 2024–2044 a projection. period. The resulted trend shows continuous urban growth and intensification of anthropogenic activities within Kiambu county. However, cultivated areas displayed a notable decline in its relative proportion. Despite the fact previously accounting for 26.98% change between 2004 and 2024, it is projected to shift to 37.62% in the years between 2024–2044. This indicates a significant transformation in cultivated land dynamics. In Kiambu County, the vegetation cover class is projected to have the most substantial decrease from 18.40% in the years 2004–2024 to 8.53% in the years 2024–2044. In general, the projection of 2044 highlights Kiambu county as a trajectory characterized by urban sprawl at the expense of both agricultural land use and natural vegetation protection. This underscores the call for sustainable land management strategies and policy interventions.

Table 2: Area Changes

		Land Use Land Cover Change for 2004 to 2024			
Classes	**Colours**	**2004 (Ha)**	**2024 (Ha)**	**Area Change**	**% Change**
1		229.96	4,627.00	4,397.04	3.64
2		49,582.84	105,581.10	55,998.26	46.36
3		118.505.78	85,918.90	-32,586.88	-26.96
4		68,102.22	45,871.50	-22,230.72	-18.4
5		17,619.16	12,040.50	-5,578.66	-4.62

CONCLUSIONS

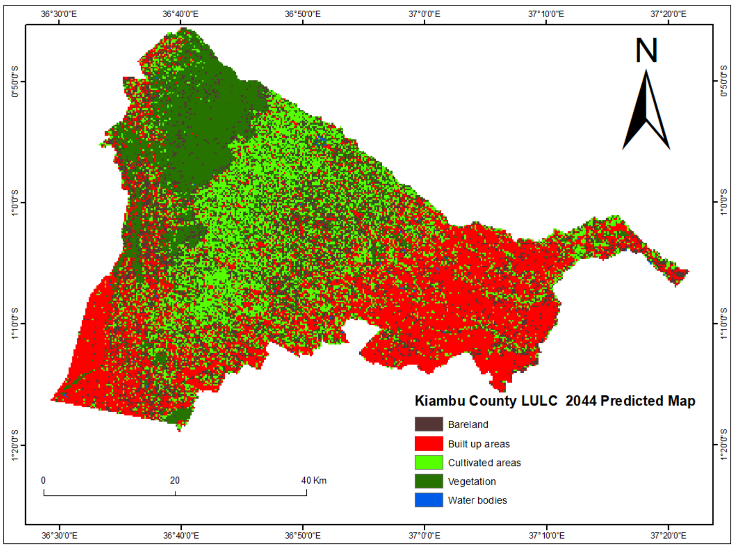

Figure 6: Kiambu County Predication Map 2044

Table 3: LULC pattern and change in Kiambu 2004, 2024 &2024

LULC Types	2004		2024		2044		LULC dynamics			
							2004-2024		2024-2044	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Vegetation	68,102.22	26.81	45,871.5	18.06	40,537.00	15.94	-22,230.72	-18.40	-5,334.5	-8.53
Cultivated areas	118,505.7	46.65	85,918.90	33.82	62,268.00	24.48	-32,586.88	-26.98	-23,650.9	-37.62
Water bodies	17,619.16	6.94	12,040.50	4.74	10,040.50	3.94	-5,578.66	-5.43	-2.000	-3.18
Built-up areas	49,582.84	19.52	105,581.1	41.56	137,454	54.04	+55,998.2	+46.3	+31,869.9	+50.70
Bare lands	229.96	0.090	4,627.0	1.82	4050.00	1.59	+4,397.04	+3.64	-577.00	-0.912

This study concludes that Molusce Plug -Based Technologies is able to predict effectively the changed in land use. The study results showed the year between 2024 and 2044 cultivated areas will decrease by -37.62 %, vegetation by – 8.53 %, water bodies by – 3.18, bare lands by – 0.912 %, and built-up will increase by + 50.70 %.

Recommendations

The study recommends in cooperation of Geospatial technologies in land use management especially the predictive models such as Molusce Plug -Based Technologies. This will give a leeway for early mitigation of the unseen eventualities such as floodings, fire outbreaks, and drought in the regions.

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