Spatio-Temporal Land Use Land Cover Changes in Peri-Urban Areas of Nakuru City, Kenya

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Abstract

Developing countries, including those in Sub-Saharan Africa, continue to register high rates of urbanization, which is associated with significant changes in land use within its peri-urban areas. Nakuru City, in Kenya is not an exception. The city is one of the fastest growing cities in Eastern Africa. This is brought about by the high population growth rate and increased human activities. The growth of the city has caused notable changes in land use land cover in its peri-urban areas. Despite this, factual data on the extent of land use land cover changes is lacking, yet the data is critical for sustainable urban planning. Thus, this study sought to establish the spatio-temporal land use land cover changes in peri-urban areas of Nakuru city since 2003 to 2023. Study area polygon was used to select cloud free images and appropriate off-nadir angle of inclination. Purposive sampling was used to select three study locations out of seven locations which surround the city council of Nakuru. Supervised and unsupervised classification techniques were employed to get thematic information from satellite imagery. Idrisi remote sensing software was used to analyze spatial data on land use land cover changes. The results disclosed that land use land cover in peri-urban areas of Nakuru city changed significantly during the past two decades, between 2003 and 2023. Farmlands, built-up areas, bare lands and water bodies increased from 2003 to 2023. Forest area and shrub land, however, depicted a fluctuating trend with an area decrease in 2014 and then an increase in 2023. The area under grasslands constantly decreased. The findings of the study contribute towards achievement of the Kenya's Vision 2030, which aim at providing high quality life, clean and secure environment to all through inclusive process involving all Kenyans. Appropriate measures need to be employed to reduce the rapid change in land use land cover and to integrate environmental conservation with urban development.

Keywords: Peri-Urban, Land Use, Land Cover Changes, Spatio-Temporal, Fringes

Introduction

The global rate of urbanization is high with more than half (55 %) of the world population living in urban areas in 2018. It is projected that 60% of the world population will live in urban areas by 2030 and 70% by 2050, with high concentration of the urban population in Asia and Africa (UN, 2018). The rapid pace of urbanization has often brought about rapid land use changes, much of it in Africa and Asia. This has been occasioned by the fact that most parts of Africa and Asia are still predominantly rural as opposed to developed countries. As urban areas continue to experience unprecedented land use changes, they also experience problems emanating from such changes. For example, inefficient provision of services, food insufficiency, illegal settlement, environmental pollution, waste dumping, forest destruction, reduction in water surfaces and permanent change in land use (Alsharif et al., 2015). The urbanized land is expected to increase by 1.2 million Km^2 by 2030 (UNDP, 2016).

Rapid urbanization is noticeable in sub-Saharan Africa where so many countries in the region are being urbanized and their fringes are further converted into urban centers (Zasada, 2011). According to Yirsaw et al. (2017), farmlands and wetlands in peri-urban areas of cities have shown a declining trend. A combination of various socio-economic factors are responsible for the land use changes. For instance, in Su-Xi-Chang city, the growth of population and built-up environment show a positive correlation. This implies that the increase in population causes an increase in built environment due to the increase in demand for settlement. Large parts of agricultural lands are changed into residential areas both in rural and urban areas (Yirsaw et al, 2017).

Thus, Land use variation is a major aspect in peri -urban areas and has led to various effects ranging from economic to social to environmental. A change in livelihoods occurs as a result of land use changes in the peri-urban areas as people start to engage in other sources of income. For instance, households work as casual labourers on housing construction, engage in informal trade, or migrate to urban areas as is the case in Accra City of Ghana (Fobil & Atuguba, 2004). Moreover, the existing farmers intensify agricultural activities in urban fringes to be able to cater for the increasing demands of the urban population as witnessed in the peri-urban areas of Kumasi, Ghana (Cobbinah & Amoako, 2012). Further, peri-urban farmers have innovatively responded to the pressure and opportunities attached to their geographical adjacency to urban agglomerations. Peri-urban farming is now characterized by a heterogeneous pattern of holdings with intensive and specialized production, high participation in diversification and lifestyle-oriented farms in the fringes of Nairobi city of Kenya (Thuo, 2013).

Urbanization enhances changes in land use, land transactions and increased rural –urban developments that has given rise to complex rural-urban migration and overall transformation in the peri-urban land. Rapid urbanization of Nairobi city, for example is causing expansion of the city boundaries to the hinterlands of Kiambu, Kajiado and Machakos Counties thus conversion of other land use types into settlements in the peri urban areas is an unending process (Wangai et al., 2019). Areas poorly suited for urban use such as wetlands, steep hillsides, outcrops and rocky shores, estuarine channels, rivers and forest remnants have suffered the effects of intense environmental degradation. This development has occurred in isolation, without taking into account the concept of the ecological balance and how this system is affected (Appiah et al., 2019). Nakuru City, in Kenya is not an exception. The city is one of the fastest growing cities in Eastern Africa, with notable changes in land use land cover in its peri-urban areas. Despite this, factual data on the extent of land use land cover changes is lacking, yet critical for sustainable urban planning. It is

against this background that the study sought to establish the spatio-temporal land use land cover changes in peri-urban areas of Nakuru city since 2003 to 2023, with a view to generate factual data that can be useful for sustainable development of the city.

Literature Review

Land Use Land Cover Changes

Land cover change means a change in the continuous characteristics of land such as vegetation type and soil properties while land use change is the alteration in the way a certain area of land is being managed through human activities. The land cover categories experiencing changes include Water (Water dams, rivers, and lakes), forests such as deciduous, evergreen, mixed forests, agriculture (Cropland, grassland, orchards) and urban estates structures e.g residential, industrial, commercial services, transportation and utilities. Rapid urbanization has been recognized to be in a competition with urban agriculture for space. In this, land cover has changed from natural cover such as water, natural vegetation or bare land to anthropogenic cover such as agriculture and urban estates (Bonye et al., 2020).

Peri-urbanisation is a worldwide phenomenon. In most European countries, peri-urbanization is manifested in different ways, including changes in land use land cover, land management, planning status of an area, socio-economic changes, and environmental changes. While land use changes are often conceptualized as having underlying drivers and leading to one or more impacts, various studies show that peri-urbanization is more complex. The direction or cause of the various processes of urbanization differs across regions. As a result, land use changes sometimes precede socioeconomic changes, while in other areas it follows socioeconomic changes. The multifaceted character of peri-urbanization processes provides challenges for managing peri-urban areas (Shaw et al., 2020). According to Vejre et al. (2010) plans and policies for the peri-urban area around Copenhagen were adjusted to provide cultural and ecosystem services such as landscape aesthetics and recreational value for urban dwellers. Thus, urban lifestyles add a set of demands for land use in peri-urban areas.

Peri-urbanization in developing countries in comparison with developed countries is accelerating. The process has been increasing, and this problem causes physical expansion without any program in cities to combat harmful effects on the natural environment and agricultural lands in periphery of cities (DESA, 2011). In Iran, expansion of cities takes up agricultural lands and gardens in peripheries of cities. Bojnurd city in North Khorasan province is an example where 2,584 hectares were converted into urban land through continuous growth of cities into peripheral lands (Parsipour et al., 2019).

Wangai et al. (2019) observed that rapid urbanization of Nairobi city causes expansion of the city boundaries to the hinterlands of Kiambu County. As a result, the Nairobi-Kiambu peri-urban area is strongly emerging as a human-dominated zone, where new human settlements are replacing other land use land cover (LULC) types such as forests and grasslands. Conversion of other LULC types into settlements in the urban-peri urban-rural gradient is a directional process. That is, the central business district of Nairobi that borders Kiambu in the south acts as an epicenter of spatial expansion of settlements to the suburban and peri-urban area.

Summary of Knowledge Gaps

It is evident from the studies done that urban sprawl in the world cities is unavoidable. In this essence, the land is basically converted from natural biophysical state to a human dominated environment. The agricultural land within the urban fringe will continue to shrink and come with its effects on human livelihoods. This means that providing services and goods to the ever-rising population will, thus, be an unending struggle as the natural resources continue to be strained or exhausted if not diminished in value. Land use changes lead to the development and accessibility of remote areas and increased income to people living in the peri-urban areas while at the same time promoting social cultural benefits. However, unsustainable land use changes have negative implications in natural resource management in urban areas (Munthali et al., 2019). Despite this, information on LULC changes in peri-urban areas of Nakuru City is lacking, yet so critical for sustainable development.

Research Methodology

Study Areas

The study area comprised the peri-urban areas of Nakuru City (Figure 3.1) (0º 16 [1] N 36.04 ºE), the headquarters of Nakuru County. Nakuru is Kenya's 4th largest city with a population of 570,674 (NCIDP, 2018). The peri-urban areas of Nakuru city include Barut, Lanet Umoja, Kiamaina, Viwanda, Ngata and Mbaruk sub-locations as indicated in (Figure 1).
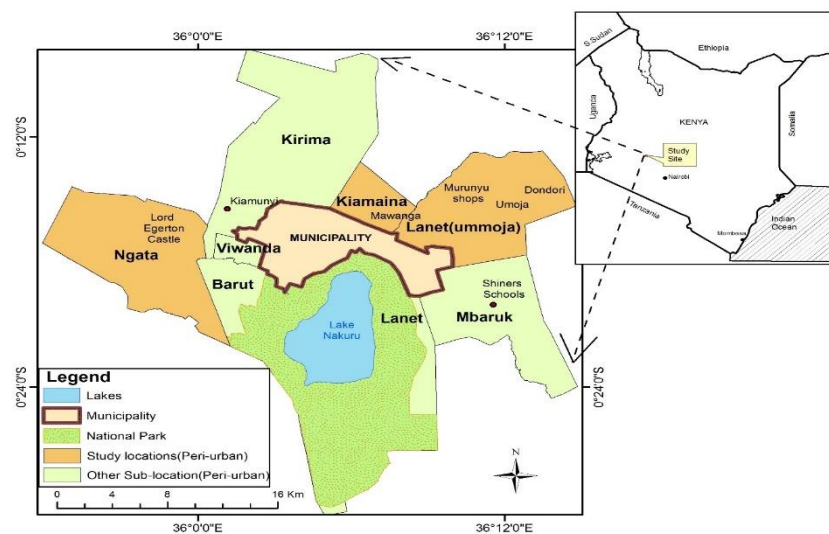

Figure 1: A Map Showing Study Locations in the Peri-urban Areas of Nakuru City

Source: Survey of Kenya (2022)

Research Design

The study adopted a survey research design. It is very useful in obtaining an overall picture of the study as it stands at the time of the study (Cochran, 1963).

Target Area

The peri-urban areas of Nakuru City.

Sampling Procedure

Out of the seven locations surrounding Nakuru city: Barut, Lanet Umoja, Kiamaina,Ngata ,Kiamunyi, Viwanda and Mbaruk, only three locations were selected for study. These include: Kiamaina, Ngata and Lanet-Umoja. The selection of these 3 sub-locations was based on their location along the major tarmac roads. Areas along these major roads depict significant changes in land use because roads facilitate the flow of people, goods and services into and out of a locality. Within the selected study locations, households were randomly chosen for the study.

Instruments

The study area polygon was used to select cloud free images and appropriate off-nadir angle of inclination and date of acquisition from the United States Geological Surveys (USGS) glovis website (https://glovis.usgs.gov/). The LANDSAT imagery was used to cover a period of 10-year intervals starting in 2003 and ending in 2023 for the dry seasons. The satellite images described in (Table 1) were utilized in the study. They included Landsat Thematic Mapper (TM) at 30-meter resolution, Landsat Enhanced Thematic Mapper (ETM+) at 30 meter plus and the 15-meter panchromatic band, Operation Land Imager (OLI) at 15-meter resolution and the Sentinel images at 10-meter resolution.

Table 1: Enhanced Thematic Mapper plus sensor and Operation Land Imager and Sentinel

Satellite Sensor	Acquisition Dates	Resolution(meters)	Website search ID
ETM+	Feb 2003	30m	LE07_L1TP_169060_20030204_20200916
OLi	Jan 2014	15m	LC08_L1TP_169060_20140125_20200912
OLi	Feb2023	15m	LC08_L1TP_169060_20230203_20230209

Source: Survey of Kenya (2023)

Image Processing

Image processing included Preprocessing, transformation, correction, and classification. Pre-processing techniques for satellite images involve false color compositing of multispectral bands to be used to discern the unique features to carry out classification using Idrisi remote sensing software. Concatenation was done to delimit the area of interest from satellite images. Image color stretching and enhancement was also done to improve the contrast and color sharpness in the images.

Image Classification

The images were subjected to both supervised and unsupervised classification for spectral signature of features in order to distinguish various classes such as closed forest, open forest and highly degraded areas and shrub land. Ground-truthing to validate information gathered from satellite images was carried out. The classified raster and vector data was exported to the Geographical Information System (GIS) software

Arcgis10.7 for analysis and map design. GIS images were produced to show the change in land cover area for the period from 2003 to 2023

Results and Discussion

Results in Figure 2, 3, 4 show that classified Landsat images depict various land use land cover changes in the study areas. Seven land use land cover categories were classified. The study area was defined to have seven land use land cover categories namely forests, shrub land, grassland, farmland, built-up areas, bare area and water bodies.
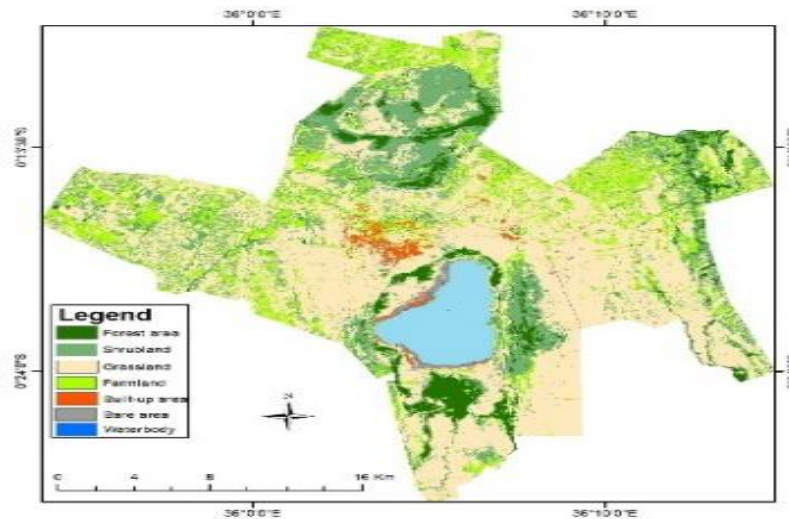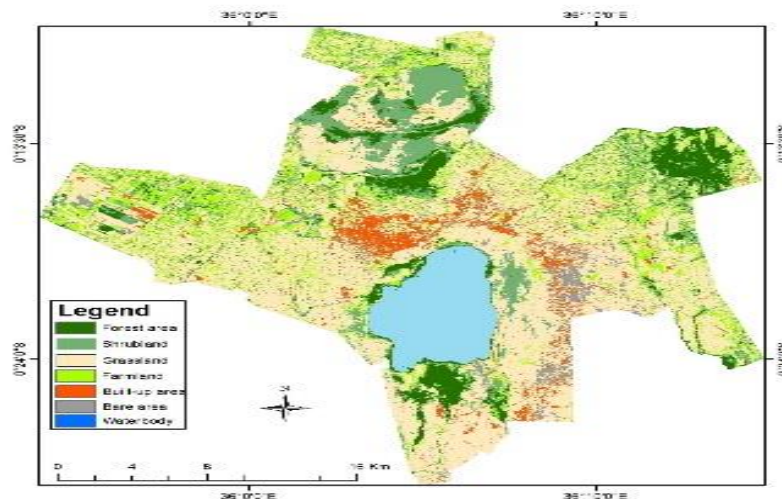

Figure 2: Land Use Land Cover for the Year 2003
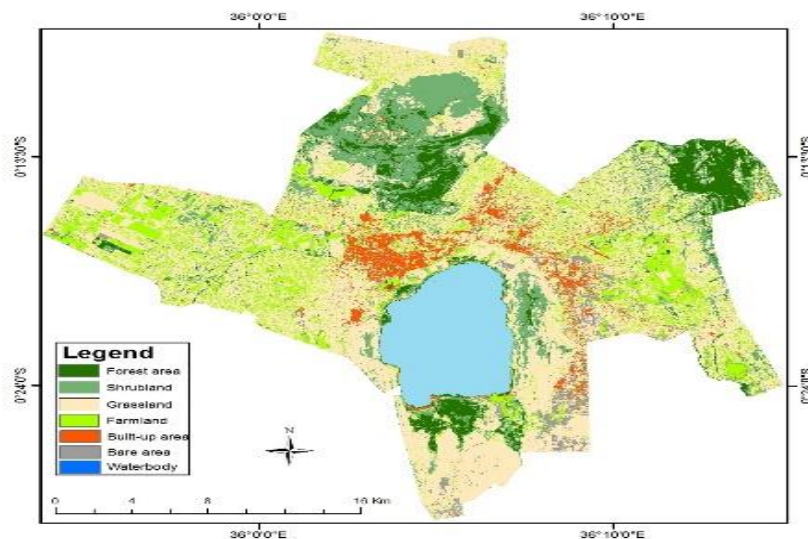

Figure 3: Land Use Land Cover for the Year 2014

Figure 4: Land Use Land Cover for the Year 2023

LULC Changes in the Peri-Urban Areas of Nakuru City

The Landsat and peri-urban household interview results confirmed that land use land cover changes have been ongoing during the study period but reached a noticeable peak in the period of 2003-2014 where most areas of land were converted into built-up areas and farmlands. This is attributed to the 2007 post-election violence, where majority of the people displaced from other regions migrated and settled in Nakuru town and its environment as revealed by the respondents in a ground truthing exercise.

Land Use Land Cover Change Detection between 2003 and 2014

Results in Table 2 show that 6.65%, 20.33%, 50.28%, 15.21%, 1.56% 1.2% and 4.77% of land was under forests, shrub land, grassland, farmland, built-up areas, bare area and water bodies respectively in 2003. In 2014 there were significant conversions from one land use to the other where 7.85%, 14.85%,49.77%, 13.33%, 3.72%,2.774% and 7.7% were covered by forests, shrubs, grassland, farmland, built-up areas, bare area and water bodies respectively. This depicts the highest increase in built-up area by 38.64% and the highest decrease in shrub land by 26.94%. There were also significant conversions from one land cover category to another within the same period of time. There were significant conversions of 2.1% of farmlands to built-up areas and 5.4% of shrub land to bare area. Some patches of bare land were converted into forest area. Most areas covered by grass in 2003 had been converted into farmlands and bare lands in 2014 (Table 2). This is attributed to the increase in socio-economic opportunities which encouraged people to move from rural areas to Nakuru town in search of formal employment and education. In return, the population pressure and high demand for farm produce from the city catalyzed the rate of conversion of grassland and bare areas into farmlands.

Land Use Land Cover Change Detection between 2014 and 2023

The second comparison was made between 2014 and 2023. 7.85%, 14.85%, 49.77%, 13.33% 3.72%, 2.77%, and 7.7% was covered by forests, shrubs, grassland, farmland, built-up areas, bare area and water bodies respectively. All the land cover categories in the study area were converted to various uses in the

years between 2014 and 2023 such that 7.18 %, 15.24%, 45.81%, 15.35%, 4.22%, 3.08%, and 9.10% were covered by forests, shrubs, grassland, farmland, built-up areas, bare area and water bodies respectively. Some areas under shrub land were converted to farmlands and built- up areas. There was also the conversion of shrub-lands, grasslands and farmlands to forests. Bare-lands and shrub- lands were also converted to farmlands and built-up areas. Grasslands and farmlands were significantly converted into bare-lands in 2023 (Table 2).

This study showed that generally farmlands, built-up area, bare lands and water bodies increased from 2003 to 2023. Forest area and shrub land, however, depicted a fluctuating trend with an area decrease in 2014 and then an increase in 2023. Area under grasslands constantly decreased (Table 2). The changes in LULC are attributed to population growth which lead to the increasing demands for housing and business premises, these have been increasing at the expense of natural vegetation and agricultural lands from the year 2003 to 2023. The results are in agreement with the findings of Kamwi and Chirwa et al. (2015) who found out that the drivers of land use land cover change in Zambezi region of Namibia are agricultural expansion, population increase and illegal logging in attempt to obtain livelihood coping strategy

Table 2: Land Use Land Cover Change Analysis per Hectare

	2003 (Area Ha)	**2014 (Area Ha)**	**2023 (Area Ha)**
Forest area	4633	5473	5008
Shrub land	14171	10354	10622
Grassland	35048	34689	31933
Farmland	10603	9294	10703
Built-up area	1087	2594	2945
Bare area	838	1934	2149
Water bodies	3325	5367	6345
Total area	69705	69705	69705

Conclusion

Spatio-temporal analysis indicates that land use and land cover (LULC) in the peri-urban areas of Nakuru City have changed significantly over time. The extent of various land use categories shifted between 2003, 2014, and 2023, with no category maintaining a constant coverage throughout the entire study period. These changes varied across LULC types, with some exhibiting consistent trends, either increasing or decreasing across both time intervals (2003–2014 and 2014–2023). These patterns are largely attributed to population growth, which has driven rising demand for housing and commercial spaces, often at the expense of natural vegetation and agricultural land.

Recommendations for Further Research

- Investigate the effects of land use land cover changes in peri-urban areas of Nakuru city on carbon footprint, urban climate change (urban heat-island) and household resilience.
- Assess the influence of land use land cover changes on sustainable utilization of resources in peri-urban areas of Nakuru City.

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Disclosure of Conflict of interest

There is no conflict of interest declared by the authors in regard to the findings of this research.

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