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Urban Expansion and Loss of Agricultural Land: a GIS based study of Kiambu County

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Abstract: ***Urbanization leads to the outward expansion of cities and results in changes in land use and the dramatic effects are very clear in peri-urban areas. A key challenge of the urbanization process is the rapid conversion of prime agricultural land to urban land use (residential, industrial, and infrastructural construction) in the urban periphery. The present study attempts to understand the spatiotemporal extent of urban expansion and its implications on land use, by using remote sensing and GIS tools to detect land use/cover changes in a peri-urban setting over 28 years. Land use land cover (lulc) maps were derived from Multispectral images of 1986, 2002 and 2014 from Landsat Thematic Mapper, Enhanced Thematic Mapper and Landsat 8. The study revealed significant change of land-use/cover between 1986 and 2014 with the area experiencing a rapid increase in urbanization (41.6%), forest decreased by (10.3%), and a decrease in bare land (1.8%), water (0.22%) and agricultural area (29.3%). Agricultural in 28 years is losing to urbanization with the results showing that 61.5% of agricultural land converted to built-up land. The findings provide a useful support for land-use planning and management. In addition, provides the inputs to decision makers that must balance trade-offs between the positive benefits of land-use change and negative unintended consequences. The study calls for a combined approach, which involves participation of all the stakeholders in management and planning of land as a vital resource. This approach will protect the endangered land use, agricultural land, and controlling urban developments.***

Keywords: Urban expansion; Urban periphery; Agriculture lands; Land use, Land use

1. Introduction

Rapid urbanization is a worldwide phenomenon, fueled by an increase in urban population and economic growth has changed the urban landscape. Rapid urban population growth goes with a lack of equivalent growth in supply of urban land i.e. land is fixed in supply and does not increase with the increasing population [1], leading to the outward expansion of cities resulting to the land use and cover changes. The dramatic effects are very clear in peri-urban areas, as the cities expand, the main zone of direct impact is the peri-urban area, characterized by diverse uses of land, that often vary in relation to their functional linkages to urban and to rural sectors [2]. The pressure exerted deprives other sectors of the needed land. Urban spread out has been blamed for disorganized use of land resources and energy and large-scale intrusion onto the agricultural lands. When sprawl takes place at the periphery of a certain locality, it has a direct or indirect impact on other parts of the same locality within its border or on a neighboring community [2]. The consequences of sprawl on peri-urban areas include changing labor and market conditions, loss of farmlands, changes in social, cultural and lifestyles. This is true in the city peripherals where massive agricultural land is disappearing each year.

A key challenge of the urbanization process is the urban encroachment into valuable agricultural and forest lands and therefore affecting the resilience of social-ecological systems [3], [4]. Losing prime agricultural land to urbanization and associated urban growth can cause problems such as air pollution, competition for water, and conflicts over farm practices and the associated decline in agricultural productivity [5]. While the rate of urban expansion has been reported to be highest in SSA, there is documented evidence that shows the loss of agricultural lands to urban development in other parts of the world. For example, in India, the estimated extent of agricultural land lost to urban between 1955 and 1985 amounted to about 1.5 million hectares, with additional 800,000 hectares transformed into an urban settlement between 1985 and 2000 [6]. In North America, urban growth in Michigan cut cropland from 16.5 million acres in 1982 to less than 10.0 million acres in 1992 [7]. Most times majority of the land lost to urbanization is most productive for agricultural production [8], [9], [10]. China between 1996 and 2002, about 4 million hectares of cultivated land were lost to urban expansion with an annual average reduction of 821,000 hectares [11]. The Beijing–Tianjin–Hebei (BTH) region alone, 74% of the total new urban area converted from agricultural land between 1990 and 2000, and the figure was as high as 81.0% when considering only small cities [12].

Urban centers often expand over the most productive agricultural land [13]. An instantaneous consequence is the reduction of agricultural capacity greatly affecting food production which impacts negatively on food security. Food and Agriculture Organization of the United Nations (FAO) defines food security as a solution that exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active and healthy life [14]. Food security encompasses the four dimensions, availability, stability, safety, and access. The first dimension relates to the general availability of sufficient amounts of food. In the future, agriculture will be challenged to meet the demand of a population that is projected to grow and to urbanize [15]. The food availability of every developing city stands threatened. An immediate consequence of rapid urbanization is the crowding out of peri-urban agriculture, which often plays a significant role in supplying perishable foodstuffs to cities. In addition, already weak tenure agreements may be

challenged, and agricultural production may shift to less productive areas, which could, ceteris paribus result in yield losses. Food stability requires that food can be accessed at all times. Food safety is linked to the quality of food and constancy. This will put additional pressure on rural infrastructures, transport, technologies, and food distribution. Since these tend to be insufficient in urban and peri-urban areas of most developing countries, the stability of food supplies may be jeopardized [16].

As the urban population continue to grow and urbanize, the demand for food rises continue to rise the strain of feeding urban populations. Staple food consumption has outstripped production, leading to steadily increasing dependence on world markets for food in sub-Saharan Africa (SSA), a consequence of missed opportunities to promote agricultural growth [17], [18] leading to a rising dependence for food imports. [19] observed that there is a shift in employment within the food system, with fewer people working in agriculture and more working in transport, wholesaling, retailing, food processing and vending because of meet the higher demand for processed agricultural products. The increase of urban encroachment onto farmland has forced farmers to bring lower quality land under cultivation to meet the growing demand for agricultural products [20]. Steady, long-term production is generally unsustainable on lower-quality land and once farmland is bought, farmers cannot just simply move their farms farther away from urban areas and continue their livelihood.

Planning and development control become a problem where existing institutions are not adequately structured to handle consequences of urbanization and which cut across different administrative boundaries leading to land issues not being addressed or, at worst, leading to conflicting land use planning decision [21]. Managing the urban growth in rural-urban fringes is however complex and conflict ridden, and aggravated by the absence of strategic urban planning frameworks to guide land-use conversion, especially in sub-Saharan Africa [22]. In developing countries, rapid urban expansion is associated with unplanned development at the urban periphery that requires a high cost of infrastructure. Similarly, it's clear that even in planned activity the development of infrastructure rarely corresponds to the large tract of land that develops in a low-density pattern. Thus, resulting to social, environmental and economic problems to the society [23]. It is so in developing nations such as Kenya, where legal and policy framework on land use and ownership is weak. As a result, land development is occurring haphazardly resulting into the urban sprawl and thus non-optimal use of land within the controlled areas [24].

The conversion of agricultural land in the urban peripheries is a clear result of the haphazard developments and reflected in the many dormitory and satellite towns. Thus, the problem of expanding of city centers is complex and complicated, land use change is the end result of many interacting factors arising from different levels of associations of human-environment systems, which differs in time and space. The driving forces can be slow with long turnover times, which decide the boundaries of sustainability, generally driven by a combination of factors that work progressively and factors that happen irregularly. Thus, it is necessary to measure and monitor land use changes over space and time for sustainability

2. Study Area

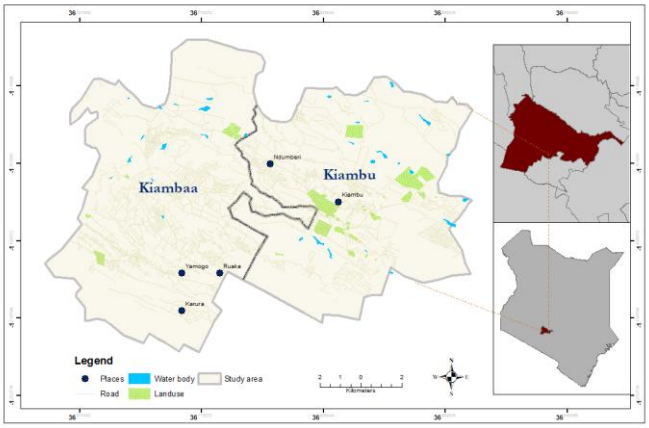

Figure 1: Map of study area

The study area covers two sub counties namely, Kiambaa and Kiambu sub-counties. The two sub-counties are located in the southern portion of Kiambu County and lies directly Northwest of the city of Nairobi which defines its Eastern and South-Eastern boundaries. It borders the city of Nairobi to the south for about 20 km from Nairobi City, Karuri Town Council to the West, Limuru Municipal Council to the north and Kiambu Municipal Council to the east. Kiambaa and Kiambu Municipality sub counties have a population of 158,918 and 94,883 respectively [25].

The area experiences a bi-modal type of rainfall. Long rains fall between Mid-March to May followed by a cold season with drizzles and frost during June to August and the short rains from Mid-October to November. Annual rainfall varies with altitude, with higher areas receiving as high as 2,000 mm and lower areas receiving as low as 600 mm. Mean temperature in the study is 26^0 C with temperatures ranging from 7^0C to 34^0C, with the lowest temperatures experienced in July and August, whereas in January to March temperatures rise. whereas in January to March temperatures rise. The average relative humidity ranges from 54 percent in the dry months and 300 percent in the wet months of March up to August. The area is covered by high-level upland soils, which are from volcanic rocks, being very fertile. Their fertility is conducive for livestock keeping and growth of various cash and food crops such as tea, coffee, horticultural products, pyrethrum, vegetables, maize, beans, peas, and potatoes. It also experiences bi-modal type of rainfall with the long rains between Mid-March to May followed by a cold season with drizzles and frost during June to August and the short rains from Mid-October to November [26].

3. Methodology

3.1 Data

We developed study area map using the Survey of Kenya topo sheets from sheet number, 134/4, 135/3, 148/1, 148/2, 148/4 and 149/1, at a scale of 1:50,000 by geo-referencing for further analysis. Three Landsat imageries for the years

1986, 2002 and 2014 to identify the land use land cover changes. Acquired Landsat data from the United States Geological Survey (USGS, 2014). The images comprise a thematic mapper (TM), an Enhanced Thematic Mapper plus (ETM +), and an Operational Land Imager (OLI) as shown in Table 1.

Table 1: Characteristics of Landsat Imagery

Data Type	Date	Spatial Resolution
Landsat TM	1st Jan.1986	30 meters
Landsat ETM+	10th Feb. 2002	30 meters
Landsat (OLI)	3rd Feb.2014	30 meters

3.2 Urban expansion detection and analysis

All Landsat images were captured under clear conditions (0% cloud coverage for three images), uniform atmospheric conditions within the images were assumed and applied no atmospheric corrections. A false color composite operation performed using Erdas Imagine Spectral toolbox and the Landsat bands were combined in the order of band 4, band 5 and band 1 for Landsat TM and ETM+ while Landsat OLI was composited in the order of band 5, band 6 and band 2. A modified -5 class classification system was designed with the consideration of the land use properties of the study area as urban/built-up, agricultural land, forest/trees, water body, and bare lands /others adopted from the AFRICOVER classification scheme applied in East African Countries as presented in Table 2. A supervised classification was performed to cluster pixels in data sets into classes corresponding to user defined training classes using maximum likelihood classifier (MLC) classification technique. The classified maps were generated for the years 1986; 2006 and 2014. To verify the result, thorough ground-truthing of the study area was carried out. The accuracy of the classification was verified by field checking or comparing with existing land use and cover maps that were field-checked. In performing land use/cover change detection, a cross-tabulation detection method was used. A change matrix was produced with the help of Erdas Imagine software. Quantitative areal data of the overall land use/cover changes and gains and losses in each category between 1986, 2002 and 2014 were then compiled.

Table 2: Land use land cover classification scheme

No.	Land use/land cover	Descriptions based on the AFRICOVER land cover classes
1	Urban/Built-up Areas	Continuous and discontinuous urban fabric, Residential, industrial and commercial units, road and railway networks and other associated lands.
2	Agricultural Lands	Irrigated and rain fed arable lands, crop land with permanent crops, farming and fallow fields
3	Forest	Natural and man-made forests, natural grasslands, sparsely planted trees.
4.	Bare Fields/others	All vacant spaces, sands, rocky areas, cleared lands
5.	Water bodies	Rivers, dams

4. Results and Discussion

Land cover maps from Landsat imageries of 1986, 2002 and 2014 were produced and trend analysis was carried out to compare the land cover type (Fig. 2, 3 and 4; Table 2).

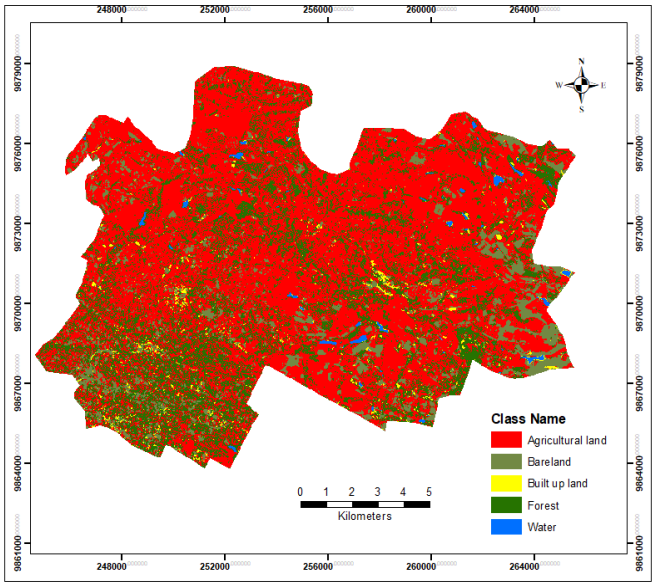

Figure 2: The land use and land cover map in 1986

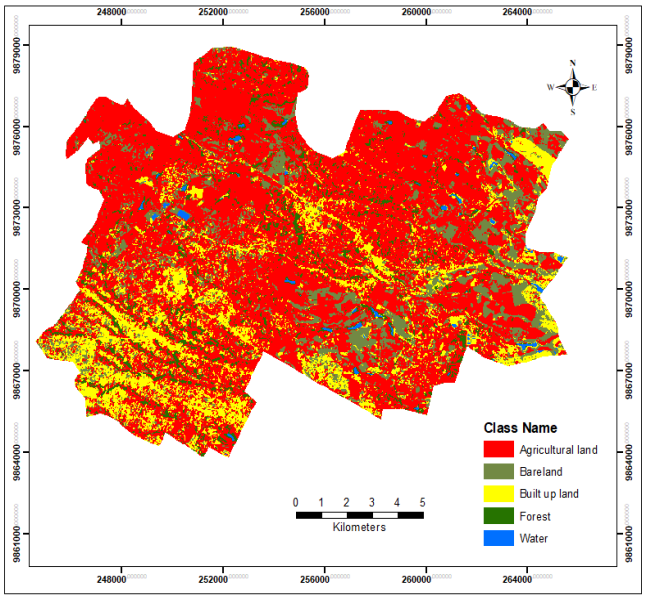

Figure 3: The land use and land cover map in 2002

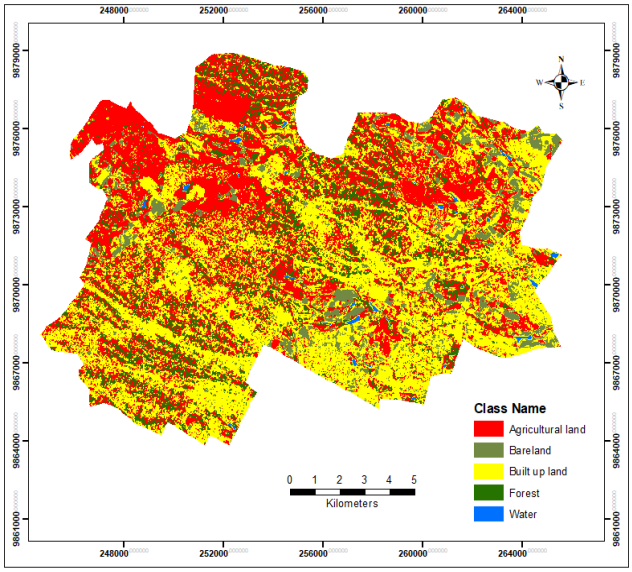

Figure 4: The land use and land cover map in 2014

Table 3: Area of land occupied by the five-land use land cover classes

Class	1986 Area (Ha)	2002 Area (Ha)	2014 Area (Ha)
Forest	4749	1210.3	2660.0
Agricultural	13,061.8	12,993.3	7130.7
Built-up	280.6	3140.8	8717.6
Water body	135.6	134.1	90
Bare land	2010	2758.5	1638.7

From the above maps and statistics, significant changes have been observed between 1986 to 2014. Built up has increased of the years indicating urbanization. An increase of 8,437 hectares. Forest/plantations, shrubs and grassland have reduced over the time, with agricultural land being the most affected with 61.5% of its total area being converted to built-up area within 28 years as seen in Table 4.

Agricultural land comprising irrigated and rain fed arable lands, cropland with permanent crops, farming and fallow fields occupied the largest area at 13,061.8 hectares in 1986 attributed that the land was still under large-scale farming with the majority holding large being tea and coffee plantations [27]. (Maina, 1994). At independence, large-scale farm production was the mainstay of the country's economy and these had to remain intact to safeguard the economy. Further, the period between 1985-1995 experienced slow economic development which explaining the low rate of urban expansion in 1986 in the two sub -counties [28]. Rapid urban population increase means an increasing demand for urban land, particularly for housing, but also for other various urban uses. The increase in area coverage of built-up land between 2002 and 2014 is attributed to an increase in the human population density coupled with an increase in residential, industrial and institutional building at the expense of bare lands and agricultural land.

Table 4: Land-use/Land-cover class conversion to Built-up area in hectares

LULC	1986-2014	
	Area (Ha)	%
Agri. to Built-up	5234.81	61.5
Forest to Built-up	2205.34	26.0
Water body to Built-up	39.44	0.5
Bare land to Built-up	1032.27	12.0

5. Conclusion

From the research results, it's confirmed that there has been significant land use/cover change in the study area. Agricultural land being on a continuous decline, paving way for urban developments, mainly associated with expansion of settlements because of population increase and proximity to Nairobi city. These changes have had negative effects and positive outcomes on agricultural land use. With increased high demand for land for construction of both commercial and residential developments also infrastructure such as road networks. The results also revealed that more land-use and cover changes are likely to take place as more land is converted over time, forest to agricultural land, and agricultural land to built-up land, which threatening the existence of agricultural land and the overall environment.
Urban expansion at the expense of agriculture land reveals that the urban containment policies have been ineffective. Agriculture is crucial in terms of employment, food security. The continuous conversion and fragmentation of farms is resulting to the loss of traditional economic base. In the growing population it's important to conserve and protect the potential farmlands, vertical expansion should be promoted. Good planning and a total paradigm shift in space management are necessary in the study area, and the county at large, for sustainable development and food security. Agricultural land with good red volcanic soils should not be converted for urban and other land uses. Instead, innovative space optimization techniques should be adopted in locating residential and commercial buildings.

With the research study results showing a strong linkage between urbanization and loss of agricultural land, we can conclude it that if the current trends continue, there will be an increase in declining of land under agriculture. Therefore, this shows the importance of the research findings to planners, urban managers and decision makers and of particular importance to the county government of Kiambu to take up actions and draft of policies to further control the rate of urbanization to minimize and reduce its impact on existing land uses/cover.

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Author Profile

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