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Land Use Land Cover Changes and their Effects on Agricultural Land: A Case Study of Kiambu County - Kenya

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Abstract

In the last four decades the emergence of new technologies and effects of rapid population growth around the globe have necessitated a tremendous shift by managers and planners on how to tackle land use and land cover (LULC) changes. Geospatial technologies have been used extensively in many areas of the world for generating valuable information on the forest cover, vegetation type, land use change detection and general environmental monitoring. Kiambu County is one of the most affected counties in Kenya by LULC changes due to its proximity to the capital city (Nairobi), good climate, fertile soils and improved infrastructure. This paper analyses the effects of LULC change on agricultural land in Kiambu County and determines the main drivers of LULC changes using geospatial technologies. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper plus (ETM+) satellite images together with other data-sets were used. Satellite images for the years; 1984, 1993, 2002 and 2013 were applied in the time-series analysis of LULC. Digital image analysis was carried out through supervised classification using ERDAS Imagine 2011 by defining the training sites on the respective images. The classes mapped were agricultural land, forests, built-area/urban, water body, wet land, grassland and bare land/rock area. The overall accuracy was in the range of 89.7% to 90.7%. The results obtained showed that Agricultural land reduced over the whole period of study from 39.7% to 15.8% which is an indication that the County is food insecure considering that the population also grew at similar rates. It is also evident that the built-area/urban increased tremendously over the same period, from 1.9% to 33.5%, showing a high demand for houses. A decrease in grassland, Forest, water body and Bare-land/Rocky areas was also observed. The application of geospatial technologies to analyze LULC and related effects was clearly demonstrated.

Key words: LULC change, Landsat, GPS, GIS, Remote Sensing, satellite image analysis, Kiambu County

1. Introduction

Land use land cover (LULC) is a global change driver and has notable implications to many of the international policy issues (Vitousek and Field, 1999). Land Use is the human modification of natural environment or wilderness into built environment. It is basically the human activities on the earth's surface. Land cover on the other hand is simply that which covers the earth surface. The major effect of land use on land cover since 1750 has been deforestation of temperate regions (Nuwagaba and Namateefu, 2013). Over the years, human activities have modified the environment with significant population increase, migration, and accelerated socio-economic activities.

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Land use and land cover are two separate terminologies which are often used interchangeably. It is an important component to understand global land status as it shows present as well as past status of the earth surface (Dimyati et al., 1994). Land use land cover analysis plays an important role in the field of environmental science and natural resource management by helping managers to make informed decisions that pertain to sustainable development. Land cover is a secondary measuring parameter of the content of the earth surface as an important factor that affects the condition and functioning of the ecosystem. It is a biophysical state of the earth surface. Land use/cover pattern of a region gives information about the natural and socio-economic factors, human livelihood and development. Like other resources, land resource is also delimiting due to very high demand of agricultural products and increasing population pressure day by day (Yadav et al., 2012).

Urbanization as a land use is the physical growth of urban areas as a result of rural migration and even sub-urban concentration into cities (particularly the very large ones) and around the small ones in the village depending on the factors that are driving its growth. Urban population is increasing at a much faster rate than was expected. The process of urbanization has been characterized not only by population growth but also by industrial expansion, increasing economic and social activities and intensified use of land resources (Karuga, 1993).

It has mainly exerted intense pressure on existing land uses and the most affected is agricultural land which is diminishing at a very high rate. This is because much of it is being converted into urban/ build-area land use leading to food insecurity (a global problem which has caused governments to spend time and money trying to resolve). Agriculture is the backbone of most economies in developing countries which have good fertile soils and receive adequate rainfall that can support both cash and food crops grown in these areas. Conversion of agricultural land has become a serious problem which is depriving economies foreign exchange income and it has also led to reduced food production.

Urban/build area land use has sharply accelerated with an increasing proportion of the population in many countries concentrating in large urban centers that are accessible and with good infrastructure. Security and availability of good services within the centers has also caused movement hence the growth. This movement has created demand for residential houses and thus building haphazardly without coordinated planning. Property developers are building satellite cities and new housing compounds on the outskirts of some of Africa's largest cities, for example Lagos city in Nigeria, Tatu and Konza cities in Kenya, demonstrating a new trend in African land use/land cover. The environment and social consequences of a growing population in a loosely planned urban/build area system could be dramatic especially when urban areas experience accelerated growth in a short period of time as is being witnessed globally (Mundia and Yuji, 2010).

In Kenya Land is a very important resource which majority of the citizens hold dear to their lives and at times fighting has erupted where people are killed, yet of the total area of 582,646 km², only 17% is suitable for rain-fed agriculture. About 2.2% of the arable land is covered by forest reserves. Arid and semi-arid lands (ASALs) comprising grassland and savannah rangelands cover the remaining 82%. The rangelands are home to 85% of total wildlife population, and 14 million people practicing dry-land farming and pastoralism (Mwichabe, 1996).

Kenya's agriculture is determined by factors such as climate, hydrology and terrain. Such agro-ecological factors also determine the suitability of an area for a particular land use. Agricultural potential can be classified into high, medium and low. Intensive cultivation is found in the high-potential highlands comprising of the agro-ecological zones I to III where rainfall is high and soils are fertile. The high to medium potential land is estimated at 5.3 million ha (20% of total land in Kenya) and receives reliable rainfall of above 1200 mm annually. Common crops include tea, coffee, sugarcane, maize and wheat among others. A lot of pressure is being exerted on these two potential areas by the fast growing population from within and without. In Kenya, approximately 59% of the soils have moderate high natural fertility which makes them suitable for growing a large variety of crops. Productivity is curtailed because only 17% of the country receives average rainfall of more than 800 mm per annum which is the minimum requirement for rain fed agriculture (Kenya Land Alliance, 2002).

In the last three decades Kiambu County has experienced rapid growth in terms of population which has put pressure on its limited resources and adversely affected other land uses in the entire county and more so places that are near urban centres because of demand for housing (Figure 1). It is currently the most build/urbanized county after Nairobi, Mombasa and Kisumu counties. Kiambu County falls within the high and medium potential areas in the agro-ecological zones I to III, where the leading income earning and employment generating cash crops like tea, coffee, pine-apples, and sisal are grown. Other crops grown are wheat, beans, maize, bananas, arrow roots, vegetables and now the upcoming flower industry through green houses. This is enough proof that the County is fully agricultural.

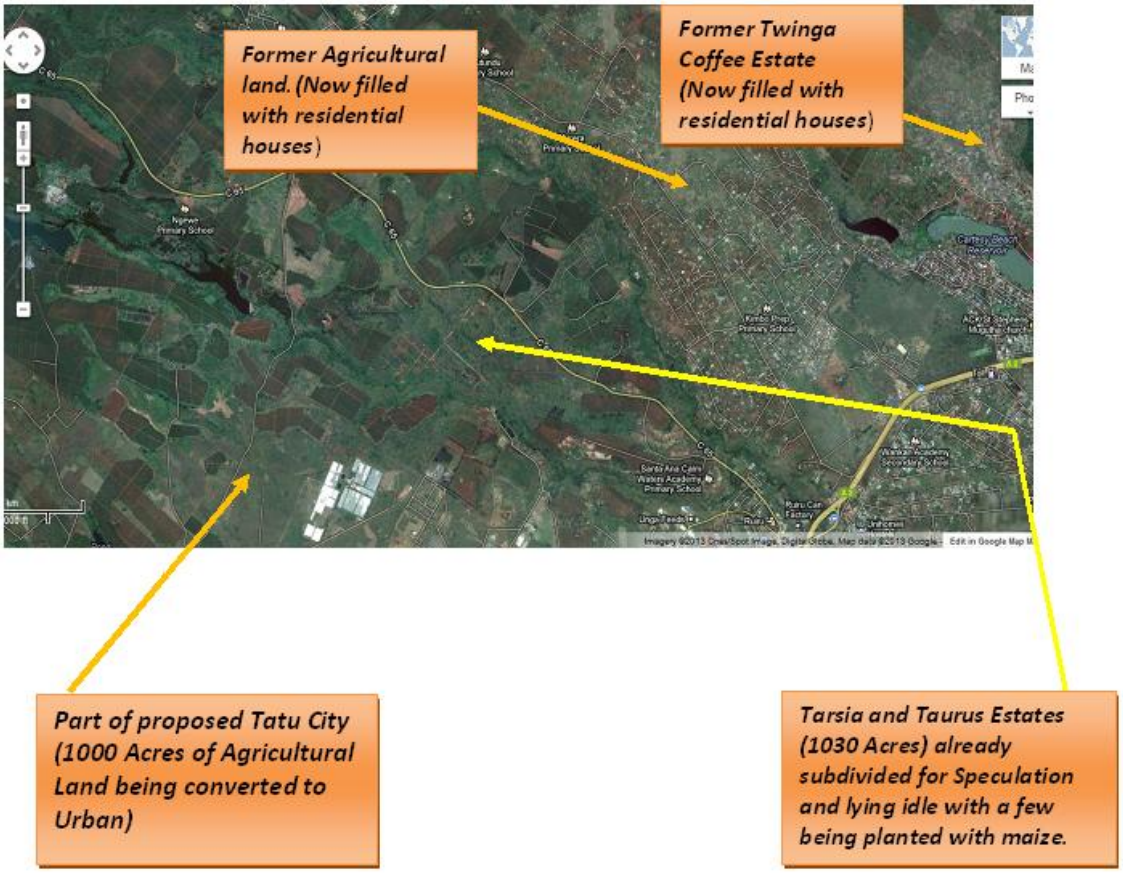


Figure 1: Geo-eye Google Image showing some of the agricultural land farms that have been or are being converted into real estate near Ruiru Town centre. (Source: Field Survey and extraction from high resolution Google maps, 2013)

Remote Sensing (RS) and Geospatial Information Systems (GIS) with their advantages of handling spatial, multispectral and temporal data, their availability and efficiency in data manipulation, have become very handy tools in analyzing, accessing, monitoring of land use/land cover changes and their effects on food security. Global positioning system (GPS) has also played an important role as a tool for collecting spatial data for the same and in improved farming methods like precision agriculture. Geospatial techniques have been used extensively in the tropics for generating valuable information on the forest cover, vegetation type and land use change detection (Forman, 1995).

In this study we apply GIS, Remote Sensing and GPS tools to analyse the effects of land use land cover changes on agricultural land in Kiambu County. The main objective of this study focuses on the effects of the long-term land use land cover changes in Kiambu County. The study employs the use of time-series analysis of Landsat images for the period 1984, 1993, 2002 and 2013. The study area is shown in Figure 2.

Figure 2: The Study Area (Kiambu County)

2. Materials and Methods

Changes in vegetation pattern were detected using Landsat TM and ETM+ imagery, owing to their good spectral and temporal resolution and moderate spatial resolution (Lillesand et al., 2004; Short, 2004). To carry out this study various data sets were acquired, but in various formats and from different sources. Also different software(s) have been used to integrate the various data sets and to carry out the analysis. Figure 3 shows the methodology adopted in this study.

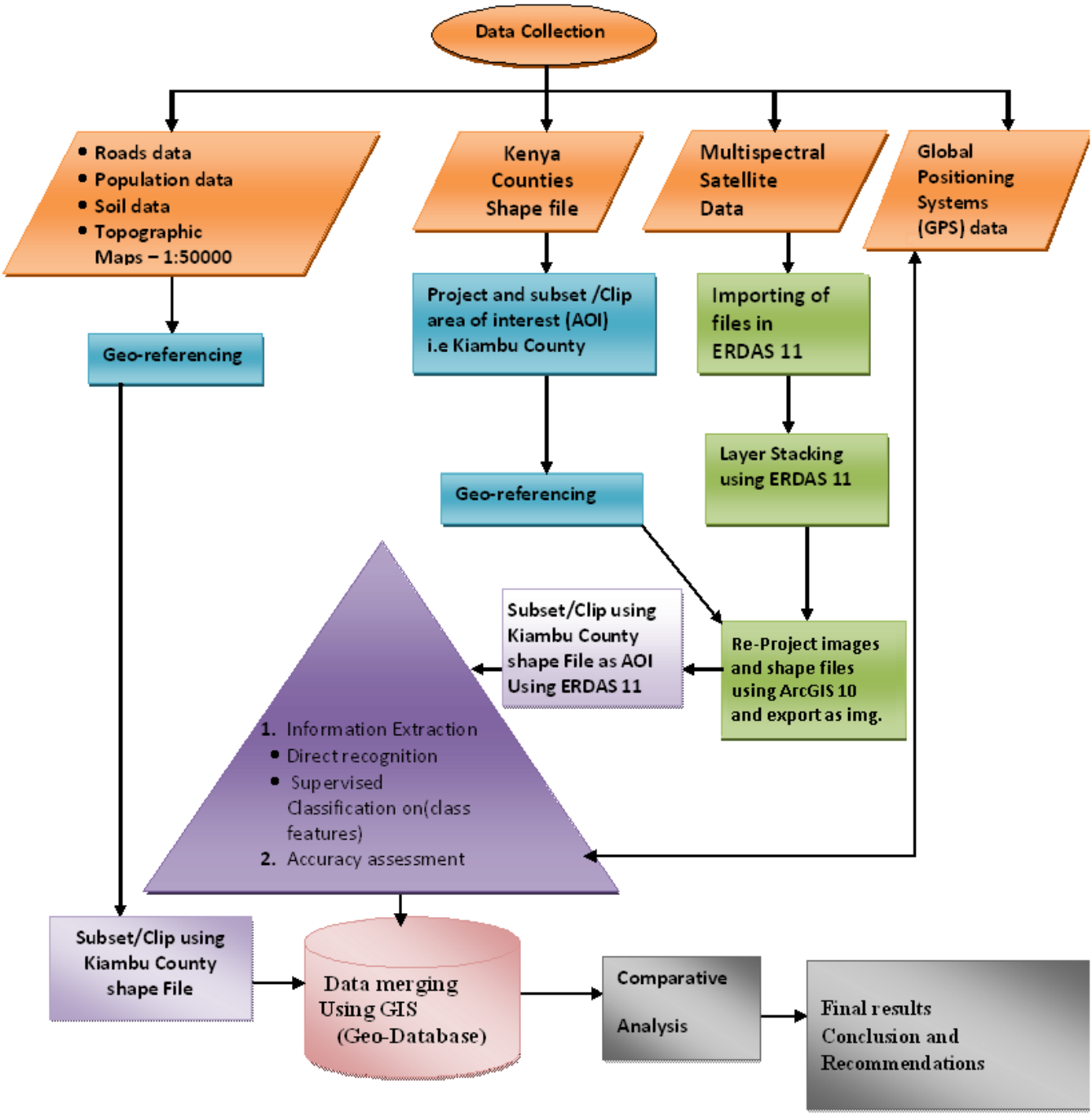


Figure 3: General methodology

2.1 Sources of Data

Data type, source and description of data used in this research are given in Table 1. The Software used in this study include, ArcGIS 10.1 for preparation of thematic map, Database generation, analysis and sub-setting/clipping of images; ERDAS Imagine 2011 for layer stacking, mosaicking, sub-setting, image classification, recording of features and accuracy assessments;

Quantum GIS 1.6 for conversion of KML files to shape files and ArcPad 10 for Handheld GPS data collection.

Table 1: Data type, source and description

Data Type	Source	Description
Multispectral Images	RCMRD	Landsat ETM+ (1984, 1993,2002 & 2013)
Kenya soils	ILRI	Shape file
Road Network	Road data Thro' RCMRD	Classified roads for Kenya
Kenya Population	Population census (thro' RCMRD)	1979, 1989, 1999 & 2009
Kenya Counties	Kenya Data (thro' RCMRD)	Shape file
Topographic Maps Scale 1: 50,000	Survey of Kenya	Scanned and covering the area of study
GPS	Field Surveys	Co-ordinates

Imagery data with the least cloud cover and sun glint covering the area of study was selected. Hence the use of slightly non uniform data i.e. 1984 and 2002 instead of 1983 and 2003 respectively. This difference of one year does not have significant error in our results. The imagery data-sets are given as follows.

- Epoch 2013: Landsat 7 (ETM+) Enhanced Thematic Mapper plus image (spatial resolution 30m) of 2001-04 of 10th Feb 2013. Covering the entire County.
  - LE7 1680612013055SG100 Downloaded on 22nd June 2013. (http://www.earthexplorer.usgs.gov)
- Epoch 2002: Landsat 7 (ETM+) Enhanced Thematic Mapper plus image (spatial resolution 30m) of 2001-04 of 10th Feb 2002 covering the entire county.
- LE7 1680612002153SGS00 Downloaded on 22nd June, 2013. (http://edcsns17.cr.usgs.gov/NewEarthExplorer/)
- Epoch 1993: Landsat 4 Thematic Mapper (TM) image (spatial resolution 30m) of 1990-94 of 17th Feb, 1993 covering the entire county. - LT4 1680611993048xxx02
  - Downloaded on 22nd June, 2013. (http://edcsns17.cr.usgs.gov/NewEarthExplorer/)
- Epoch 1984: Landsat 5 Thematic Mapper (TM) image (spatial resolution 30m) of 1980-84 of 17th Dec, 1984 covering the entire county. - LT5 1680611984352xxx13
  - Downloaded on 22nd June, 2013. (http://edcsns17.cr.usgs.gov/NewEarthExplorer/)

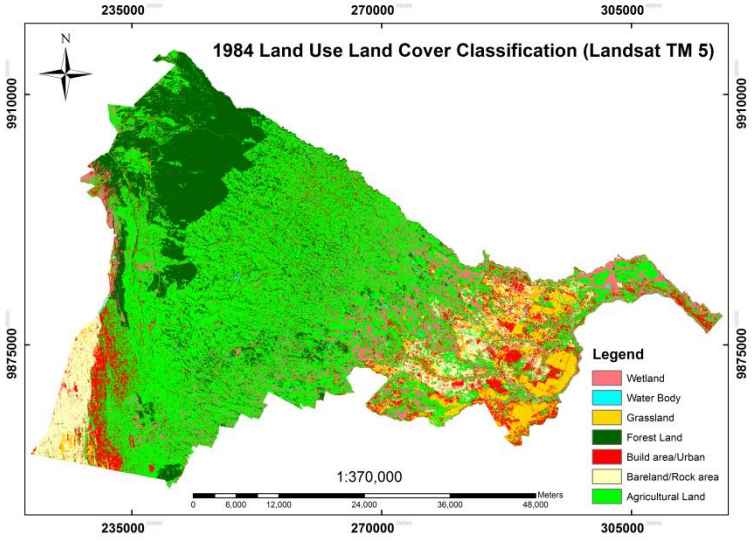
2.2 Image Processing

Data collected was harmonized to make it compatible with other data-sets and enable its usage in other software. This was achieved through projections and geo-referencing of the various data sets. Using Erdas imagine 11; multispectral satellite images were imported into the software. They were layer stacked, re-projected and clipped (see Figure 3), using the Kiambu County

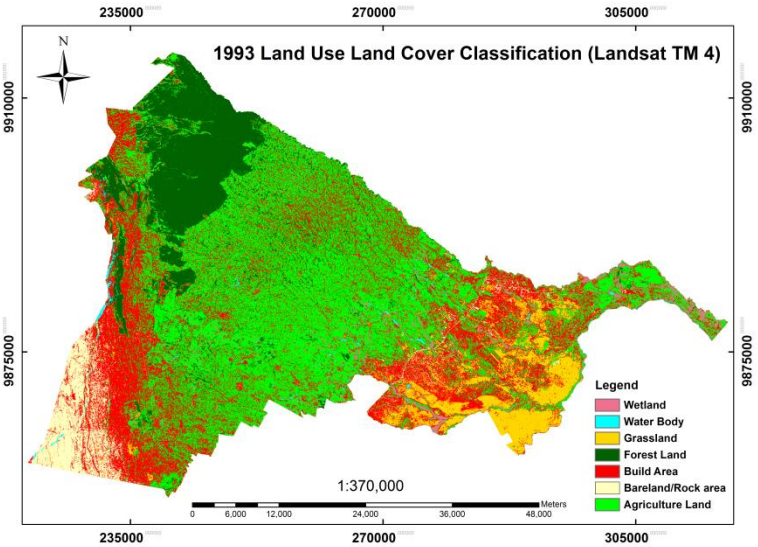
shape file. Information extraction was then carried out through supervised classification and direct recognition of features where seven classes were established. Using GPS co-ordinates, informed knowledge of the area and historical Google earth images, accuracy assessment was carried out. The analysis for the land use land cover changes were carried out at this stage. Data Merging was then carried out using the ArcGIS 10 software which has the capability of integrating the other data with the extracted information. It was also used to prepare the various maps for the respective land use land cover changes for the years 1984, 1993, 2002 and 2013.

3. Results and Discussions

After carrying out the supervised classification, seven main land use classes were obtained. These are wet-land, water body, grassland, forest land, built area/urban, bare land/rock area and agricultural land. Figure 4 (a, b, c and d) shows land use land cover for the years 1984, 1993, 2002 and 2013 respectively.



(a)



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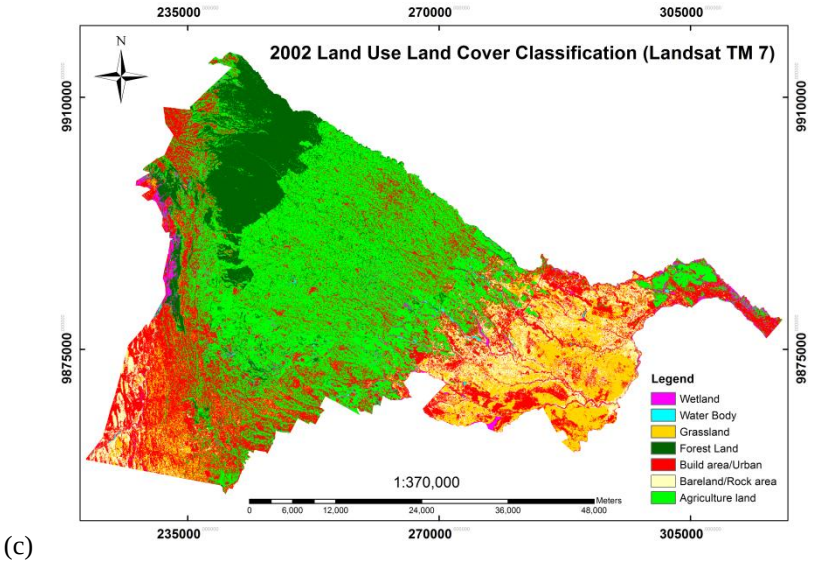

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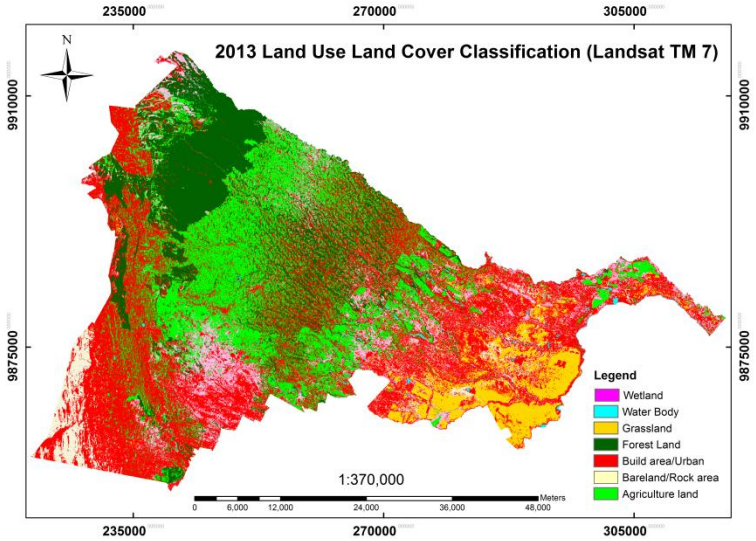

(d)

Figure 4: Land use land cover of Kiambu County for the years 1984, 1993, 2002 and 2013

Accuracy assessment was performed for the years 1984, 1993, 2002 and 2013 land use land cover change maps (Figures 4a, b, c and d) using GPS co-ordinates, Google maps at different times of the year and knowledge of the local area. The results obtained were within 85%. This accuracy is within stipulated accuracy standards by the USGS. Table 2 shows the area and percentages of the seven land use land cover classes. A graphical representation of the areas occupied by the seven land use and land cover classes in Kiambu County during the study period is given in Figure 5. There is a near direct relationship between agricultural land and built area (Figure 5). This shows that agricultural land is being converted into residential and commercial uses. There is also a general decrease in grassland, forest land and wetland (with the exception of 1984). It is worth noting that in general, only built area increased significantly from 1.9% in 1984 to 33.5% of the total area of Kiambu County in 2013. In the same period the most

diminished land cover/land use are agricultural land (from 39.7% in 1984 to 15.8% in 2013) and grassland (from 19.7% in 1984 to 2.0% in 2013). Considering actual land area, agricultural land is the most reduced.

Table 2: Area and percentage of land occupied by the seven land use land cover classes in Kiambu County for the years 1984, 1993, 2002 and 2013

Class	*Area in Ha (1984)*	*% area*	*Area in Ha (1993)*	*% area*	*Area in Ha(2002)*	*% area*	*Area in Ha(2013)*	*% area*
Agriculture Land	101192.00	39.69	76190.50	29.88	59136.70	23.19	38901.07	15.75
Build Area/Urban	4803.66	1.88	34502.90	13.53	66166.10	25.95	82720.42	33.50
Forest Land	33245.00	13.04	50331.10	19.74	36989.00	14.51	29183.71	11.82
Grassland Area	50342.60	19.74	17998.60	7.06	9415.98	3.69	4925.98	1.99
Water Body	14097.70	5.53	1981.8	0.78	4586.40	1.80	6027.72	2.44
Wetland	427.23	0.17	58142.90	22.80	51387.60	20.15	45417.16	18.39
Bare land /Rock area	50858.10	19.95	15818.10	6.20	27284.10	10.70	39777.31	16.11
Total Area	254966.29	100.00	254965.90	100.00	254965.88	100.00	254965.92	100.00

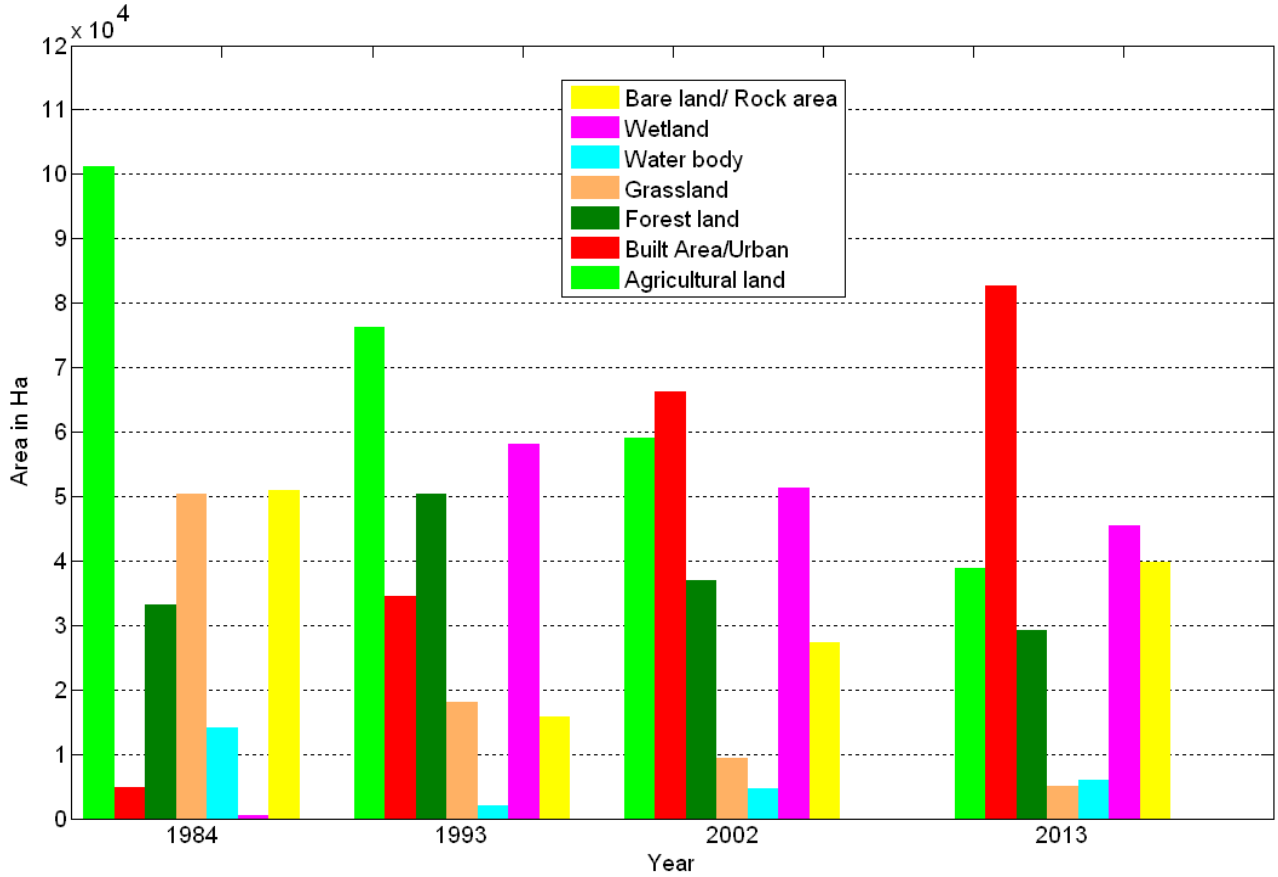

Figure 5: Areas occupied by the seven land use and land cover classes in Kiambu County for the years 1984, 1993, 2002 and 2013

We observe a general shift in land use/land cover from agriculture to residential and commercial buildings. Whether this shift is economically justifiable is beyond the scope of this study. However, the need for more buildings over the years has been due to the increase in population in Kiambu County. For approximate comparison we plot agricultural land and populating trend in Kiambu County in Figure 6. We note that the agricultual land and population data sets are not of the same epochs but they generally cover the same study period, hence it is possible to use them for approximate comparison.

Considering population data of Kiambu County in four epochs (1979, 1989, 1999 and 2009), a near direct relaionship can be established between population increase and decrease in the agricultural land over the same period of study (Figure 6). Agricultural land decreased significantly from 1984 to 2013 (i.e. from 39.7% to 15.8% of the total area of study). At the same time population increased significantly in the same period from 686,290 in 1979 to 1,623,282 in 2009. The trend in agricultural land indicates that agricultural food production in Kiambu Cunty will significatly diminish by the year 2030 if no remedial action is taken to improve crop farming. One of the remedial actions that can be taken is space optization to accommodate land use and land cover classes in an optimal manner. We recommend that a comparative analysis of returns from agricultural products and other alternative investments (e.g. residential/commercial buildings among others) be carried out to explain the observed fundamental shift from agriculture in Kiambu County.

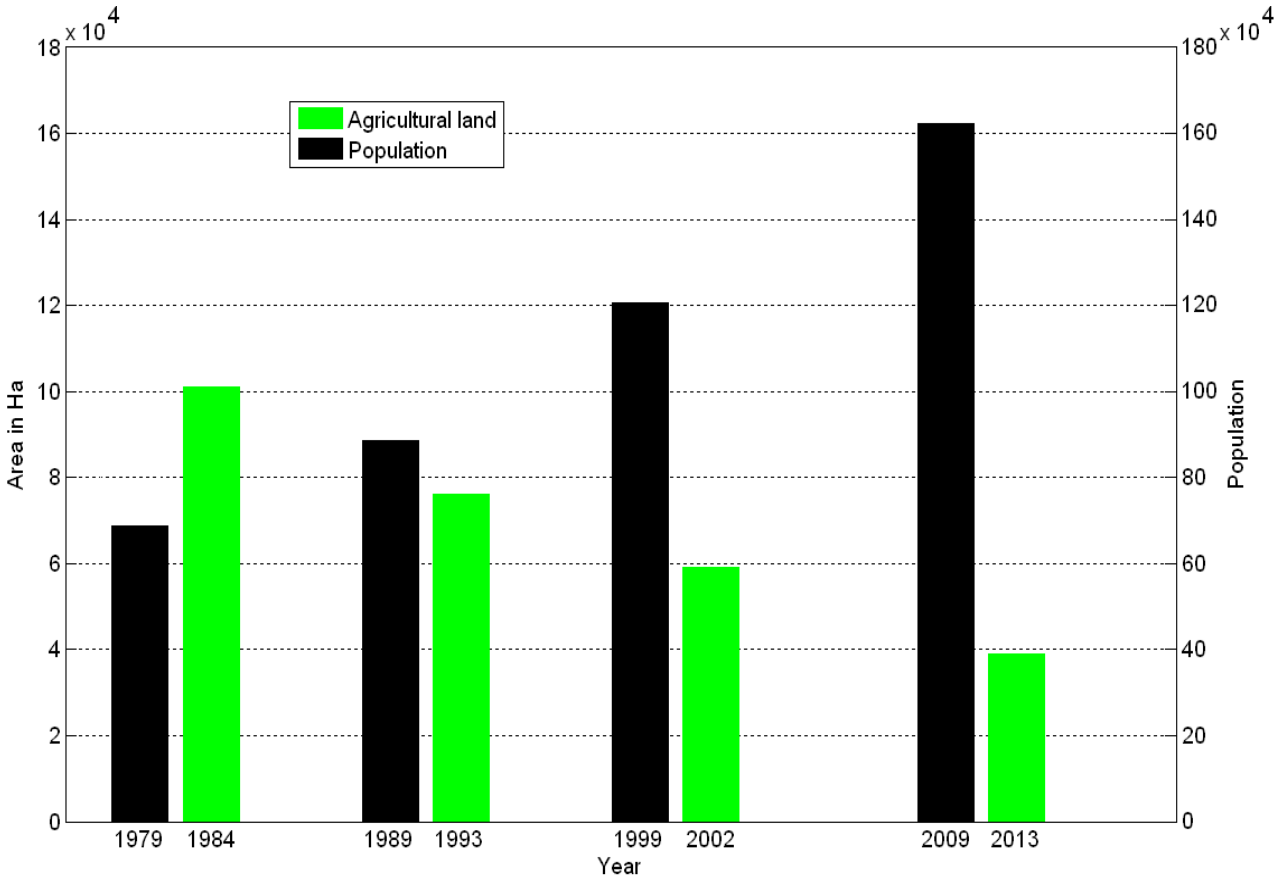

Figure 6: Agricutural land and population trend in Kiambu County from 1979 to 2013

4. Conclusions

The objective of this study was to analyze the effects of land use and land cover change on agricultural land which is related to food security in Kiambu County and to determine the main drivers of these changes using geospatial technologies. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper plus (ETM+) satellite images and other auxiliary data were used. Images for the season between Oct-Feb in the years 1984, 1993, 2002 and 2013 respectively were used. This data was used because it was readily available and considerations were made to use imagery data with the least cloud cover and sun-glint.

Digital image analysis was carried out through supervised classification using ERDAS Imagine 2011 by defining the training sites on the respective images. The classes mapped were agricultural land, forest land, built area/urban, water body, wetland, grassland and bare land/rock area. Accuracy assessment was carried out which gave accuracy levels within the acceptable limits per the USGS requirements. The results obtained showed that Agricultural land reduced over the whole period of study from 39.7% to 15.8% which is an indication that Kiambu County is gradually becoming food insecure considering that the population is also increasing at a very high rate. It is also evident that the built-area/urban increased tremendously over the same period from 1.9% to 33.5%.

Good planning and a total paradigm shift in space management are necessary in Kiambu County for sustainable development and food security. Agricultural land with good red volcanic soils should not be converted into build area/urban and other land uses. Instead, innovative space optimization techniques should be adopted in locating residential and commercial buildings. We also recommend that a comparative analysis of financial returns from agricultural products and other alternative investments (e.g. residential/commercial buildings among others) be carried out to understand cause(s) of the observed fundamental shift from agriculture to other investments in Kiambu County. Investigations on climate change(s) over the years are also necessary. Finally the application of geospatial technologies in the analysis of LULC and related effects should be adopted to help in future planning and monitoring to ensure sustainable development in the County.

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