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Assessment of Land Use and Land Cover Change Using GIS and Remote Sensing Techniques: A Case Study of Makueni County, Kenya

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Abstract

The surface of the earth is undergoing rapid land-use/land-cover (LULC) changes due to various socioeconomic activities and natural phenomena. The main aim of this study was to gain a quantitative understanding of land use and land cover changes in Makueni County over the period 2000- 2016. Supervised classification-maximum likelihood algorithm in ERDAS imagine was applied in this study to detect land use /land cover changes observed in Makueni County using multispectral satellite data obtained from Landsat 7 for the years 2000, 2005 and 2016 respectively. The County was classified into seven major LU/LC classes viz. Built up areas, croplands, water bodies, evergreen forests, bush-lands, grassland and bare-land. Change detection analysis was performed to compare the quantities of land cover class conversions between time intervals. The results revealed both increase and decrease of the different LULC classes from 2000 through to 2016. Significant shifts from some classes to others was also observed. Drivers of the observed changes ranged from Climatic factors such as rainfall and drought to socio-economic factors. Consistent LULC mapping should be carried out in order to quantify and characterize LULC changes. This will help establish trends and enable resource managers to project realistic change scenarios helpful for natural resource management.

Keywords: Land use; Land cover change; Change detection; Supervised classification; Makueni county

Introduction

LULC change is a major issue of concern with regards to change in the global environment [1]. The rapid growth and expansion of urban centres, rapid population growth, scarcity of land, the need for more production, changing technologies are among the many drivers of LULCC in the world today [2]. According to Ref. [3], LULCCs respond to socioeconomic, political, cultural, demographic and environmental conditions and forces which are largely characterized by high human populations. LULCC has become one of the major concerns of researchers and decision makers around the world today.

Many researchers argue that LULCC emerged as a major aspect in the wider debate of global change; and that change originates from human-induced impacts on the environment and their implications for climate change [4-6]. The indicators of these changes can be clearly seen in the current major global concerns such as increasing concentrations of carbon dioxide (CO_2) in the atmosphere, loss of biological diversity, conversion and fragmentation of natural vegetation areas and accelerated emission of greenhouses gases [7].

LULC dynamics are widespread, accelerating, and significant processes majorly impelled by human actions and at the same time resulting to changes that impact human livelihood [8]. The LULC dynamics modify the availability of different important resources including vegetation, soil, water, and others [9,10].

Due to rising population over the years, lots of pressure has been imposed on the land resources in Kenya where approximately 75% of the populace engages in agriculture but only 20% of its land is arable. As a result, the shortage of arable land has led to expansion of cultivation into the wetter margins of rangelands, deforestation and decline of grassland as a result of overgrazing, charcoal burning and other unsustainable land uses. These actions have far reaching implications on the integrity of natural resources and ecosystems in the country [11,12].

LULCCs has also taken place in Makueni County over the years. Land has been subjected to a lot of pressure due to over-reliance on its resources. There has also been rapid population growth in the county in the recent past and this has translated to over-utilization of land and its resources. Most communities are farmers and they therefore depend on land for their livelihood well-being and sustenance. However, the county is located in ASALs and thus the environmental and climatic conditions are not favorable for crop production. This has resulted to the locals engaging in other sustenance activities such as charcoal burning, logging and even sand harvesting, all of which result to environmental degradation.

Materials and Methods

Study area

Makueni County covers an area of 8,034.7 Km^2. The county lies between Latitude 1°35´ and 3°00 South and Longitude 37°10´ and 38°30´East [13]. The map boundary for this area stretches in a north west to south east direction (Figure 1). The County boarders Kajiado, to the West, Taita Taveta to the South, Kitui to the East and Machakos County to the North. The county lies in the arid and semi-arid zone in Eastern Kenya. It consists of hills and small plateaus rising between 600-1900 metres above sea level (masl) [13,14].

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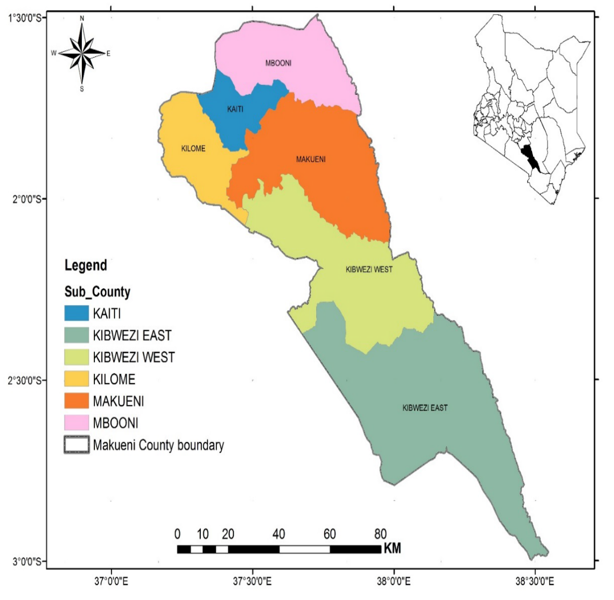

Figure 1: Makueni County.

Data collection

Two types of data were used in this research. Satellite data that comprised of three years multi- temporal satellite imageries (LANDSAT 7 imageries of 2000, 2005 and 2016) for the month of February acquired from the USGS GLOVIS website (Table 1). Ancillary data included the ground truth data for the LU/LC classes. The ground truth data was in the form of reference points collected using Geographical Positioning System (GPS) for the 2016 image analysis, used for image classification and overall accuracy assessment of the classification results.

Image pre-processing and classification

Pre-processing of satellite images before detection of changes is a very vital procedure and has a unique aim of building a more direct association between the biophysical phenomena on the ground and the acquired data [15]. Data were preprocessed in ERDAS imagine for geo-referencing, mosaicking and sub-setting of the image on the basis of Area of Interest (AOI). The main objective of image classification is to place all pixels in an image into LU/LC classes in order to draw out useful thematic information [16]. Image classification was done in order to assign different spectral signatures from the LANDSAT datasets to different LULC. This was done on the basis of reflectance characteristics of the different LULC types. Different color composites were used to improve visualization of different objects on the imagery. Infrared color composite NIR (4), SWIR (5) and Red (3) was applied in the identification of varied levels of vegetation growth and in separating different shades of vegetation. Other color composites such as Short Wave Infra-red (7), Near Infra-red (4) and Red (2) combination which are sensitive to variations in moisture content were applied in identifying the built-up areas and bare soils. This was supplemented by a number of field visits that made it possible to establish the main land use land cover types. For each of the predetermined LU/LC type, training samples were selected by delineating polygons around representative sites. Spectral signatures for the respective LU/LC types derived from the satellite imagery were recorded by using the pixels enclosed by these polygons. A satisfactory spectral signature is the one ensuring that there is 'minimal confusion' among the land covers to be mapped [17]. Maximum Likelihood classifier (MAXLIKE) scheme with decision rule was used for supervised classification by taking 89 training sites for seven major LU/LC classes. The number of training sites varied from one LU/LC class to another depending on ease of identification and the level of variability. The Maximum Likelihood Classification is the most widely used per-pixel method by taking into account spectral information of land cover classes [1]. The delineated LU/LC classes were; built up areas, water bodies, croplands, evergreen forests, bush-lands, grasslands and bare-lands as described in Table 2.

Post classification

Post-classification refinement is done to improve classification accuracy and reduction of misclassifications [18]. After classification, ground verification was done in order to check the precision of the classified LU/LC map. Based on the ground verification necessary correction and adjustments were made. The map from t_1 (e.g., 2000) (Figure 2) was compared with the map produced at time t_2 (2005) (Figure 3) and a complete matrix of categorical change obtained

Accuracy assessment

If the classification data are to be useful in detection of change analysis, it is essential to perform accuracy assessment for individual classification [19]. Accuracy assessment is an essential and crucial part of studying image classification and thus LULCC detection in order to understand and estimate the changes accurately. It reveals the extent of correspondence between what is on the ground and the classification results. It is important to be able to derive accuracy for individual classification if the resulting data are to be useful in change detection analysis [19]. In this study, accuracy assessment was done for the Landsat 7 ETM+ 2016 satellite image, for which the ground truth data likely equates. An overall accuracy was calculated by dividing the sum of the correctly classified sample units by the total number of sample units.

Results and Discussion

Classification

The overall classification accuracy was 88.0%. The study area was defined to have seven land use and land cover categories, which were: Water Bodies, Grassland, Forest, Cropland, Bush-land, Built up Area and Bare-land. The land use land cover classification for 2000 is shown in Figure 4.

Gross percentage change in LU/LC classes between 2000-2016

Generally, over sixteen years (2000- 2016), the gross changes in area coverage varied from one LULC class to another with bush-land experiencing the most increase and evergreen trees undergoing the most decrease in area coverage as shown in Figure 5.

LULC change detection for the years 2000, 2005 and 2016

Change detection between 2000 and 2005: 95%, 78%, 36% and 35% of land under Evergreen forests, water bodies, bare-lands and croplands, respectively in 2000 remained under the same LULC categories in 2005. This was also the case with land under built up areas (33%), bush-lands (20.4%) and grasslands (10.7%). However, there were also significant conversions from one land cover category to another within the same period. There were significant conversions from evergreen forests to bush-land (58.2%) and to croplands (51%). 9% and 8.7% of what was croplands in 2000 was converted to bare-lands and grasslands respectively. 42.4% of bush-lands, 22.6% of

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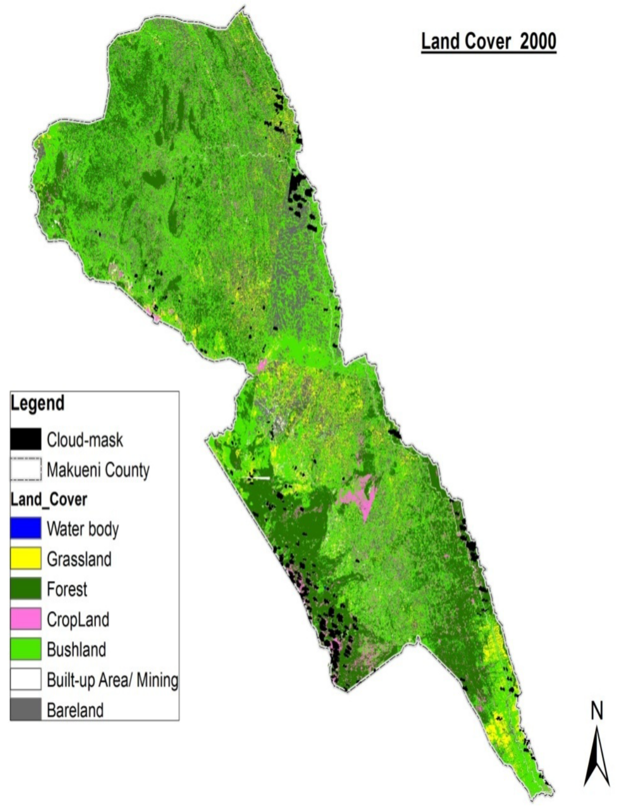

Figure 2: LU/LC Classification map of the study area for the year 2000.

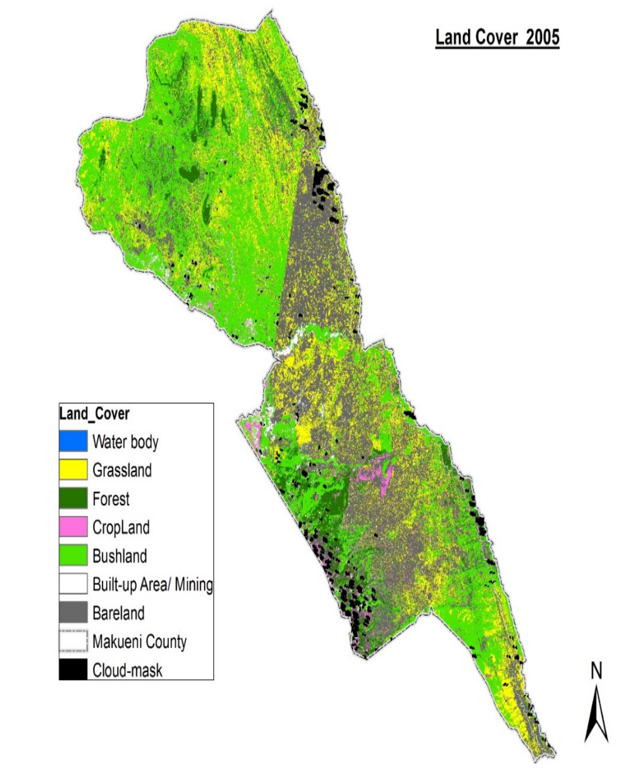

Figure 3: LU/LC Classification map of the study area for the year 2005.

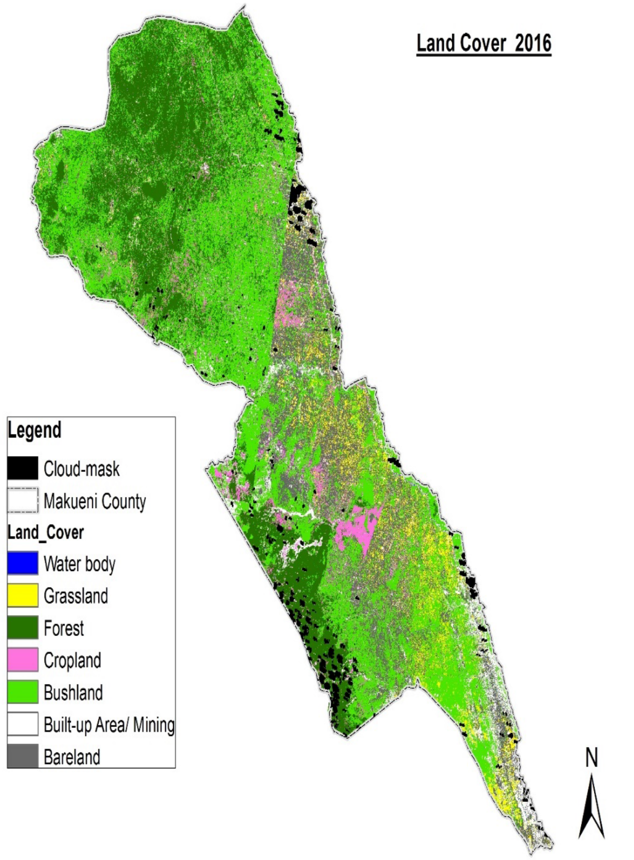

Figure 4: LU/LC Classification map of the study area for the year 2016.

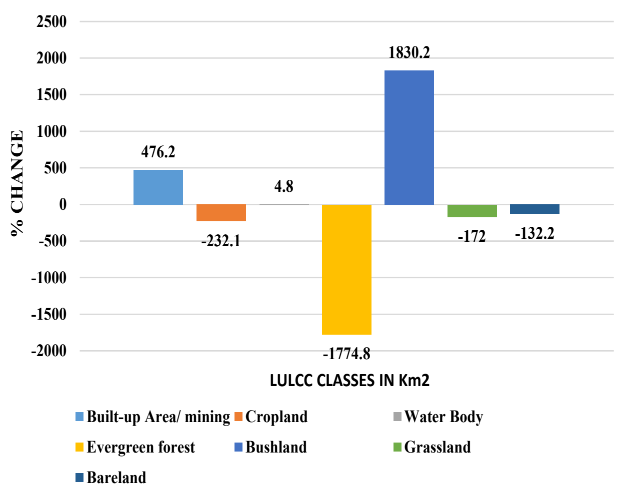

Figure 5: Gross percentage change in LULC categories from 2000-2016.

evergreen forests, 15.4% of bare-lands and 8.7% of croplands were converted to grasslands while 36% of bare-lands, 30% of bush-lands and 15% of evergreen trees were converted to bare-lands by the year 2005. Bush-lands were majorly converted to grasslands (42.4%) and bare-lands (30%) (Table 3).

Change detection between 2005 and 2016: The second comparison made during 2005 to 2016, 66%, 46%, 27.9%, 25%, 8% and

7% of land under bare-lands, bush-lands, grasslands, evergreen forests, built up areas and croplands respectively in 2005 remained under the same LULC categories in 2016. Some area under evergreen forests were converted to water bodies (14%), croplands (4%) and built-up areas (4%). Despite the conversion of evergreen forests to other LULC classes, there was also the conversion of 50% of bush-lands, 8% of grasslands and 4% of croplands to evergreen forests. Significant conversion to croplands emanated from bare-lands (45%) and bush-lands (25%). The table also shows that 25% and 22.8% of grasslands in 2005 was converted to bush-lands and bare-lands respectively in 2016. There was a strong conversional relationship from bare-lands to other classes such as grasslands (54%), croplands (45%) and built up areas (36%). 50% of bush-lands were converted to evergreen trees while 36% was converted to both water bodies and built up areas (Table 4).

Land use and land cover analysis: The result of this study showed that built up areas, water bodies and bush-lands increased from 160.7 km^2, 1.1 km^2 and 2159.77 km^2 in 2000 to 644.57 km^2, 5.77 km^2 and 3893.27 km^2 in 2016 respectively. Croplands, evergreen forests, grasslands and bare-lands decreased during this period with evergreen forests decreasing the most from 39% coverage in 2000 to 17% coverage in 2016 (Table 5). These changes took place at the expense of other LU/LC classes as seen in the change detection matrices (Tables 3 and 4). LU/LC changes are complex and at the same time interrelated such that the expansion of one LU/LC type occurs at the expense of other LU/LC classes [20,21]. The results of this study agrees with the results of other studies. In their study in Dembecha area, northwestern Ethiopia, Ref. [22] found out that the expansion of cultivated land took place at the expense of forest land between 1957 and 1982. Similarly, recent researches have revealed that the expansion of agricultural land has been at the expense of lands with natural vegetation cover [6,23-26].

Conclusion

In this work, it was proven that the supervised classification of multi-temporal satellite images is an effective tool to quantify current land use as well as to detect changes in a changing environment. Landsat 7 satellite images of 2000, 20005 and 2016 were used for the

Year	Day and Month	Scene/Tile	Entity Id
2000	1/ March	167/061	LE71670612000061SGS02
	1/ March	167/062	LE71670622000061SGS02
	21/ February	168/061	LE71680612000052EDC00
	21/ February	168/062	LE71680622000052EDC00
2005	12/February	167/061	LE71760612005042PFS00
	12/February	167/062	LE71670622005042PFS00
	19/February	168/061	LE71680612005049ASN00
	19/February	168/062	LE71680622005049ASN00
2016	26/ February	167/061	LE71670612016057SG100
	26/ February	167/062	LE71670622016057SG100
	17/ February	168/061	LE71680612016048SG100
	17/ February	168/062	LE71680622016048SG100

Table 1: Dates and scene ID numbers of Landsat Images used.

	Land Cover	Description
1.	**Forest**	This describes the areas with evergreen trees mainly growing naturally in the reserved land, along the rivers and on the hills.
2.	**Bush land**	Describes areas with sparse trees and shrubs.
3.	**Crop land**	The land which is mainly used for growing food crops such as maize, green grams, beans, cassava, mangos. Crops in this land are either grown by irrigation or rain-fed.
4.	**Water bodies**	This class of land cover describes the areas covered with water either along the river bed or man-made earth dams, filled sand dams and ponds.
5.	**Bare-land**	This describes the land left without vegetation cover. This result from abandoned crop land, eroded land due to land degradation and weathered road surface.
6.	**Grassland**	This class of land cover defines grass as the main vegetation cover.
7.	**Built-up area**	This class describes the land covered with buildings in the rural and urban. It includes commercial, residential, industrial and transportation infrastructures.

Table 2: Land class and definitions for supervised classification.

		2005													
	LULC Type	**Built-up Area**		**Cropland**		**Water Body**		**Evergreen Trees**		**Bush-land**		**Grassland**		**Bare-land**	
		Area (km^2)	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
2000	**Built-up Area**	**82.5**	**33%**	1.4	1%	0.0004	16%	0.5	0%	32.2	1.1%	4.4	0.3%	63.1	3%
	Cropland	19.2	8%	**49.4**	**35%**	0.0000	0%	10.2	2%	248.7	8.2%	141.3	8.7%	236.5	9%
	Water Body	0.2	0%	0.0	0%	**0.0021**	**78%**	0.1	0%	0.6	0.0%	0.0	0.0%	0.0	0%
	Evergreen Forests	55.4	22%	73.1	51%	0.0002	6%	**464.7**	**95%**	1756.9	58.2%	368.4	22.6%	373.0	15%
	Bush-land	54.4	21%	12.4	9%	0.0000	0%	6.9	1%	**615.5**	**20.4%**	693.2	42.4%	741.0	30%
	Grassland	24.9	10%	4.8	3%	0.0000	0%	1.4	1%	157.7	5.2%	**174.2**	**10.7%**	194.5	8%
	Bare-land	16.8	7%	1.4	1%	0.0000	0%	3.3	1%	207.1	6.9%	251.8	15.4%	**894.6**	**36%**
	TOTAL	**253.4**	**100**	**142.5**	**100**	**0.003**	**100**	**487.1**	**100**	**3018.8**	**100**	**1633.3**	**100**	**2502.7**	**100**

Table 3: Change detection matrix of 2000 to 2005.

	2016														
	LULC Type	**Built-up Area**		**Cropland**		**Water Body**		**Evergreen Forests**		**Bush-land**		**Grassland**		**Bare-land**	
		Area (km²)	**% Area**	**Area (km²)**	**% Area**	**Area (km²)**	**% Area**	**Area (km²)**	**% Area**	**Area (km²)**	**% Area**	**Area (km²)**	**% Area**	**Area (km²)**	**% Area**
2005	**Built-up Area**	**50.1**	**8%**	23.9	5%	1.0	17%	74.7	5%	84.3	2%	1.1	0.3%	16.6	1.3%
	Cropland	10.7	2%	**32.8**	**7%**	0.1	1%	48.8	4%	41.2	1%	3.4	0.9%	6.0	0.5%
	Water Body	0.0	0%	0.0	0%	**0.0**	**0%**	0.0	0%	0.0	0%	0.0	0.0%	0.0	0.0%
	Evergreen Forests	25.6	4%	17.3	4%	0.8	14%	**345.9**	**25%**	87.5	2%	2.0	0.5%	4.2	0.3%
	Bush-land	233.3	36%	122.1	25%	2.1	36%	684.3	50%	**1799.6**	**46%**	64.5	16.4%	112.9	9.1%
	Grassland	95.8	15%	70.1	15%	1.1	20%	104.1	8%	969.2	25%	**109.8**	**27.9%**	284.0	22.8%
	Bare-land	229.1	36%	214.7	45%	0.7	13%	115.2	8%	911.4	23%	212.6	54.0%	**823.5**	**66.0%**
	Total	**644.5**	**100**	**480.9**	**100**	**5.7**	**100**	**1373.0**	**100**	**3893.2**	**100**	**393.4**	**100**	**1247.1**	**100**

Table 4: Change detection matrix of 2005 to 2016.

LULC Type	**2000**		**2005**		**2016**	
	Area (km²)	**% Area**	**Area (km²)**	**% Area**	**Area (km²)**	**% Area**
Built-up Area	160.7	2	253.4	3	644.5	8
Cropland	723.1	9	142.5	2	480.9	6
Water Body	1.1	0.01	0.0	0.0	5.7	0.1
Evergreen forest	3105.8	39	487.1	6	1373	17
Bush-land	2159.7	27	3018.8	38	3893.2	48
Grassland	562.9	7	1633.3	20	393.4	5
Bare-land	1324.5	16	2502.7	31	1247.1	16

Table 5: Area transition for Land Cover classes between 2000, 2005 and 2016.

GIS and RS image analysis. The observed changes varied from one LU/LC category to another with some maintaining a constant change (increase or decrease) over the two analysis periods (2000-2005 and 2005-2016). Some classes underwent decrease in the first period and an increase in the second period and vice versa was true for other LULC categories. This study advocates that multi-temporal satellite data is very useful to detect the changes in land use and land cover comprehensively. Land use and land cover changes have wide range of consequences at all spatial and temporal scales. The study reveals that the LULC pattern and its spatial distribution are the major rudiments for the foundation of a successful land-use strategy required for the appropriate development of any area.

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