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Land Use Change Assessment, Prediction Using Remote Sensing, and GIS Aided Markov Chain Modelling at Eleyele Wetland Area, Nigeria

Opeyemi O TOPE-AJAYI[1], Oludare H. ADEDEJI[1], Clement O. ADEOFUN[1], S. O. AWOKOLA[2]

[1] *Federal University of Agriculture, Department of Environmental Management and Toxicology, Abeokuta, Ogun State, NIGERIA*

[2] *Federal University of Agriculture, Department of Civil Engineering, Abeokuta, Ogun State, NIGERIA*

E-mail: topeajayiopeyemi@gmail.com, adedejioh@funaab.edu.ng, clemluv2000@yahoo.com, osawokola@yahoo.co.uk

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A B S T R A C T

Land use change involves changes in the area extent of a given type of land use or cover and such changes have significant impact on natural and human environment at all geographic scales. We performed a land use classification and analysis by using GIS and Remote sensing technique, and GIS aided 'Markov Cellular Automata' technique was used to model the land use change and determine the magnitude, rate and dynamics of change in the spatial extent of the Eleyele wetland area, Nigeria. We also identified the factor responsible for the observed changes with the objectives of predicting future change in the next 30 years. Four multi-temporal datasets comprising Landsat TM 1984, 2000 and Landsat OLI/TIRS 2014 imageries were classified using ArcGIS 10.0 version with support of ground truth data. Post-classification comparison with GIS overlay to map the spatial dynamics of land use/cover change was conducted. Land use Change Modeller (LCM) and Markovian processes were employed to analyze the pattern and trend of change. Based on the past trend of land use changes (from 1984 to 2014), the future land use map of Eleyele wetland area for the year of 2044 was generated using the neural network built-in module in the Idrisi Selva. The study revealed that the lake area decreased from 1.28 km^2 in 1984 to 0.99 km^2 in 2000 and further to 0.60 km^2 in 2014. The study concluded that the increase in built area around the lake has resulted in the loss of vegetal cover, which has negative implication for biodiversity conservation in the study area. This type of research will help shaping the urban form of the city in a planned manner.

1. INTRODUCTION

To understand and quantify the spatio-temporal dynamics of urban land use and land cover changes and its driving factors it is essential to put forward the right policies and monitoring mechanisms on urban growth for decision making [1], [2]. These changes can lead to land use conflicts due to the need for resources and space and the capacity of the land to absorb and support these needs [3], [4]. Rapid expansion of Ibadan city, Nigeria, due to population increase have encroached on many outlying non-urban areas such as the Eleyele lake area creating problems such as reservoir siltation, bed loading and water quality degradation etc [5]. With is an increase demand for land for urban development, gradual deforestation of the watershed sets in for replacement many unauthorized buildings and other anthropogenic activities [6]. Urbanization is an increasing proportion of population living in settlements defined as urban centres [4], [7], [8]. According to the United Nations Population Fund (2013), rapid population growth has been concentrated in towns and cities of the world and on a global scale, population growth can be considered the main historical reason for land use change [9]. It could lead to the concentration of population in hazard- and risk-prone areas such as wetlands and flood plains [10], [11].

Urbanization brings about the conversion of fertile agricultural area, vegetation and wetlands to urban areas, increase in impervious surfaces and even the extinction of few land use/cover features e.g. natural drainages [12], [13]. Wetland degradation and forest clearing have attracted attention because of the potential effects on biodiversity loss, erosion, increased run-off and flooding, increasing CO_2 concentration and climate changes [14], [15]. It has become urgent to understand the change in spatial extent that has taken place in the study area because the wetland is rapidly diminishing and lake is gradually shrinking. Adeniyi and Omojola (1999) had earlier submitted that information based on urban land use changes could shed more light on the growth process, since physical changes in the distribution of urban land uses are direct indications of social and economic changes [16]. Mayaux et al (2008) posited that global change studies require accurate, relevant and consistent information on land cover dynamics to enhance our understanding of how the different elements of the global system currently operate, the ways in which they interact and how is best to reduce the uncertainty in the predictions of change [17].

According to Mejebi (2008) change detection is the concept of identifying contrasts or discrepancies in the state of an object or phenomenon by observing it at different times [18]. One of the most common applications of change detection is determining urban land use change and assessing urban sprawl. This would assist urban planners and decision makers to implement sound solutions for environmental management [19]. In order to study the dynamics of land cover, it is necessary to have maps that reflect the status of land cover at different times [20], [21].

This involves the ability to quantify temporal alteration and transformation using multi-temporal data sets. Spatio-temporal analysis of landscape dynamics is crucial in formulating an appropriate set of actions in landscape management [1], [22].

The main aim of this study is to assess and predict the land use changes in Eleyele wetland area, Ibadan, Nigeria using remote sensing and GIS aided Markov chain modelling.

The objectives of the study are:

- to analyze the dynamics of urban land use changes within the selected times;
- to quantify gain and losses of land cover classes, examine land use transitions and assess spatial trends of changes in built up areas using Land Change Modeller;
- to predict future changes in land use/land cover in 2044 in the study.

2. THEORY AND METHODOLOGY

2.1. Study area

The general characteristics of the study area are described below:

The Eleyele Lake area lies between 7°23'N and 7°31'N latitude and 3°25'E and 3°35'E longitude (Fig. 1).

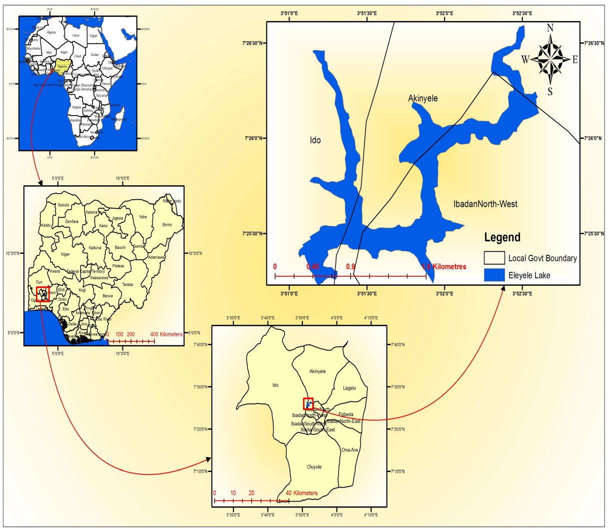

Fig. 1. Map of the Eleyele Lake area and environs.

It is situated north-east of Ibadan, Nigeria. Ibadan is one of the six towns in Nigeria that registered a population of more than 40,000 people by the mid 19th century [22]. The city was created in 1829 as a war camp for warriors coming from Oyo, Ife and Ijebu. It is a major centre of bulk trade owing to its central location and accessibility from the capital city of Lagos at the Atlantic coast.

The population and spatial extent of the city has increased several folds during the past four decades. The population of Ibadan city was estimated to vary from 2 to 5 million inhabitants [23]. Population increase has brought about social transformation and economic development resulting into rapid land transformation in the city including the study area. According to Fourchard (2003) the built-up area of Ibadan was of 38.85 km² in 1935 [24]. In 1952, it was estimated that the total area of the city was of approximately 103.8 km² of which only 36.2 km² was built-up [25].

However, the built-up area increased to 46.40 km² in 1955 [24]. During the 1960s, the *"non-urban land uses"* such as agricultural lands, forest reserves and wetland areas started disappearing at a faster rate and the urban landscape spread over about 100 km², and later increased to 136 km² in 1981 and subsequently to between 210-240 km² in 1988-89 [25].

However, Onibokun (1998) estimated that, by the year 2000, Ibadan city would be made up of about 400 km² of built-up area [26]. Rapid urbanization and population increase due to rising importance of the city have propelled the expansion of the city in all directions especially along major highways including the Ibadan-Lagos expressway (east and north of the city), followed by the Eleyele expressway (west of the city) [22].

The Eleyele lake area of Ibadan, which is the focus of this study, is one the many erstwhile non-urban areas that have been drastically affected by the urban sprawl in Ibadan dramatically altering the morphology of the wetland area. Eleyele wetland area is of about 14.86 km² and also consists of the Eleyele Forest reserve, which covers the water storage area itself plus a strip of dry land surrounding the reservoir and varying in width from 30.48 m to 365.76 m.

The elevation is relatively low ranging between 100-150 m above sea level and surrounded by quartz-ridge hills toward the downstream section where the Eleyele dam barrage is located. A number of stream channels serve as feeding/recharge streams to the Eleyele wetland basin.

In 1942, the quest to create a modern water supply system to meet the challenge of water scarcity for the emerging Ibadan metropolis led to the construction of Eleyele Dam on River Ona with a reservoir storage capacity of 29.5 million litres.

The Lake and the associated dam at Eleyele also receive water from River Alapata, the headstream of River Ona. The strip of dry land surrounding the water storage area was planted with teak plantation in 1941 and was constituted as a forest reserve in 1956 [27]. The total area of the reserve then was of about 526.09 hectares. The areas and their population surrounding the Eleyele Lake include the local government areas of Ibadan North-West (154,029 pers.), Akinyele (211,811 pers.) and Ido (104,087 pers.) [28].

2.2. Data source

Detailed characteristics of the sources of data used for the study are shown in Table 1. The images were downloaded from the official website of Global Land Cover Facility (GLCF) – (http://www:glcf.umiacs.umd.edu).

Table 1. Characteristics of the Landsat images used in the study.

Sensor	Date of acquisition	Spatial resolution (m)	Path/ Row	Producer
Landsat TM	18.04.1984	30	190/055	GLCF
Landsat TM	06.02.2000	30	190/055	GLCF
Landsat ETM+	07.12.2006	30	190/055	GLCF
Landsat ETM+	05.03.2014	30	190/055	GLCF

The imageries were then processed in the Geographic Information System (GIS) and were combined with ground truth information to assess the accuracy of image classification. All data were developed into Universal Transverse Mercator (UTM) coordinate system, zone 31N, with World Geocoded System (UTM WGS 84) projection parameters. Figure 2 shows the flowchart of the methodology of the study.

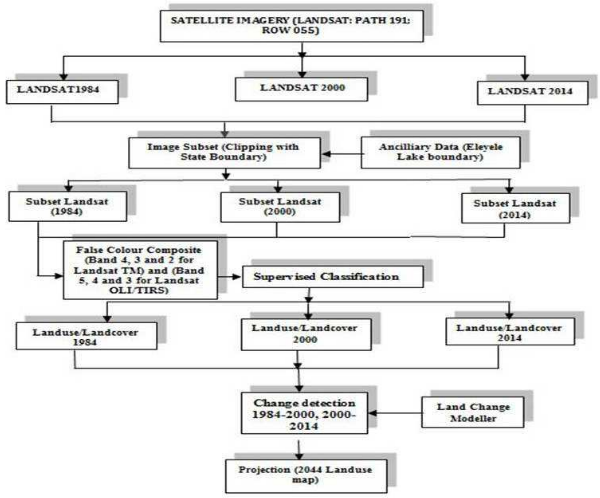

Fig. 2. Flowchart of methodology.

2.3. Image processing

The Landsat were geo-referenced and geo-corrected images for effective image processing, which is critical to successful urban land use land cover mapping and change detection. Image pre-processing allow for conformity between multi-temporal imagery necessary for quantification and spatial comparisons [29]. Satellite imageries were stacked into different bands to produce a false colour composite (FCC) which uses an RGB combination of 432 for Landsat TM and 543 for Landsat OLI/TIRS. In this band, combination band 4 represents the NIR infrared, band 3 belongs to red and band 2 to green (Fig. 3).

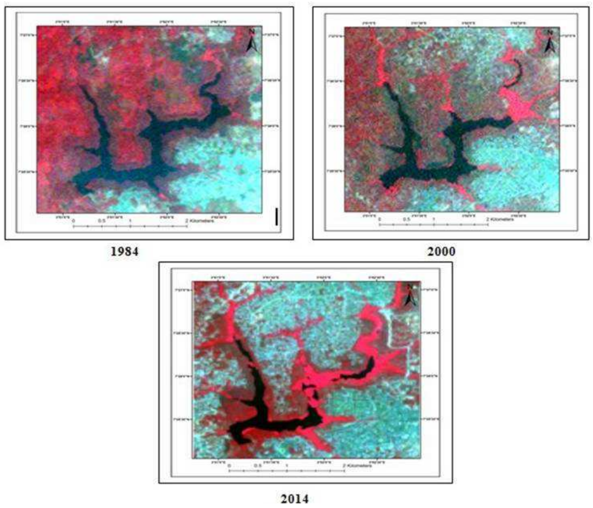

Fig. 3. False Colour Composite (FCC) of satellite imageries of 1984, 2000 and 2014.

2.4. Nomenclatures of land cover classes

Land cover classes are important to make the classification easier [30]. Land cover classes adopted in the study were based on the categories proposed by the Coordination of Information on the Environment (CORINE). CORINE land cover is a map of the European environmental landscape based on interpretation of satellite images. It gives useful geo-referenced information for disaggregation [31]. The Level 1 classification system was followed and the data was classified into four land use / land cover classes spread over the study area. The classes are shown in the Table 2 below:

Table 2. Land cover classes.

Land cover classes	Description
Built-up	Consists of urban fabric, industrial, commercial and transport units, construction sites and artificial non-agricultural areas
Agro-forestry	Arable land, permanent crops, pastures, plantation (*Gmelina*) and heterogeneous agricultural areas
Wetland Forest	Forest, water hyacinth, shrubs and/or herbaceous vegetation association
Water body	Water courses and lake

2.5. Image classification

Image classification refers to the extraction of differentiated land cover and land use categories classes from raw remotely sensed digital satellite data [32]. This involves the process of sorting pixels into finite number of individual classes, or categories of data, based on their data file values. Twenty (20) training samples were collected for each land cover classes. They were determined based on ground truthing, researcher's personal experience and physiographical knowledge of the study area. Training is the process of defining the criteria by which these patterns are recognized [33]. A supervised classification using the Maximum Likelihood Classifier was performed using ArcGIS 10.0 software. The supervised method was utilized because it allows for the selection of pixels that represent pattern or land use features that is recognizable or identifiable with the use of other source such as ground truth data [32]. Ground control points were determined from the field global positioning system readings. The classified images of different time periods were superimposed in GIS environment with the objective of filling out a matrix showing transitions between the classified land use/cover categories. Other procedures involved in the image classification had being discussed in a previous study [34]. The evolving land use/land cover types were quantified using cross tabulation statistics to carry out land use/land cover change. Accuracy assessments of the classified images were elaborated using the original mosaic and the Google Earth images.

2.6. Change detection analysis

Change detection analysis was carried out on Landsat images of different years (namely 1984, 2000 and 2014) to analyze the pattern and trend of change analysis in the study area using Land Change Modeller (LCM) for ecological sustainability developed by Idrisi Selva and Markov chain model embedded in Idrisi [33]. Land Change Modeller is an innovative land planning and decision support software, which allows for the rapid analysis of land cover change and simulate future land change scenarios [35], [36].

The LCM relies on separate multi-temporal image classification and subsequent image comparison. It is suited for analysis and prediction of land use/land cover (LULC) types and evaluation of implications of the changes on the entire ecosystem [37]. LCM can be used to know detail spatial increase and loss, net change, net change drivers, tendencies of change and landscape prediction [35], [39]. Furthermore, Change Analysis and Map Transition Option in LCM is a mapping tool to visualize the change that occurred from one land class to the other land classes and predicting the course of change into the future [39].

Since modelling using LCM requires mainly two time categorical maps, the classified maps of 1984 (time-1) and 2014 (time-2) were used as inputs for the Change Analysis Tab of IDRISI, which enabled us to understand the gains and losses and the transition of areas among the land use/land cover classes; and to quantify the changes occurred from time-1 to time-2 [40]. Pairs of LULC maps were overlaid to produce the LULC change map.

2.6.1. Markov Chain Modelling

Markov Chain determines the amount of using the earlier and later land cover maps along with the date specified. It helps to determine exactly how much land would be expected to transit from the later date to the predicted date based on a projection of the transition potentials into the future and creates a transition probabilities file [36], [42]. Markov Chain model is a randomised stochastic process that relies on probabilities rather than certainties [43], [44]. The Markov chain projection model was implemented on the three classified LULC maps of different times [45].

The model according to Iacono et al. (2012) is based on the assumption that a future state (t_2) can be determined by its current state (t_1) [45]. In LULC modelling, the process determines the t_1 to t_2 LULC distribution using a transition matrix. This can be expressed as:

$$Vt_2 = M \times Vt_1 \quad (1)$$

where:
Vt_1 is the LULC proportion vector input;
Vt_2 is the LULC proportional vector output;
M is the m×m transition matrix for the time difference $\Delta t = t_2 - t_1$.

The transition probabilities file is a matrix that records the probability that each land cover category will change to every other category.

2.7. Statistical analysis

For the purpose of this study, different statistical analyses were conducted, as follows:

a). The percentage change (trend) and annual rate of change (%) in land use between 1984, 2000, and 2014 using the land use/land cover statistics obtained from the change detection.

Percentage change (trend) = observed change / sum of change multiplied by 100 (2)

Annual rate of change = percentage change divided by 100 and multiplied by the number of study year e.g. 1984-2000, which equals 14 years (3)

b). To provide complementary information on the changes between 1984 and 2014, the land cover maps were employed to quantity land cover changes. The change statistics for the two years were computed in two different ways:

As absolute percentage increments of the whole study area calculated by subtracting percentage areas between 2014 and 1984 (4)

As relative percentage increments from 1984 (5)

The negative symbol in the statistics indicated a loss of surface [4].

3. RESULTS AND DISCUSSION

Land Use/Land Cover Distribution around Eleyele lake area. The study area spread over 14.86 sq km was classified into four different land use categories namely water body (Eleyele lake), wetland forest, built-up and agro-forestry land-use. The areas of each land use category were computed from the classified images of 1984, 2000 and 2014. Figure 4 shows changes within and around Eleyele Lake area, and also the pattern of change during the study periods. The rapid urbanization in the city has resulted into tremendous increase in built-up area and the resultant expansion within period of study.

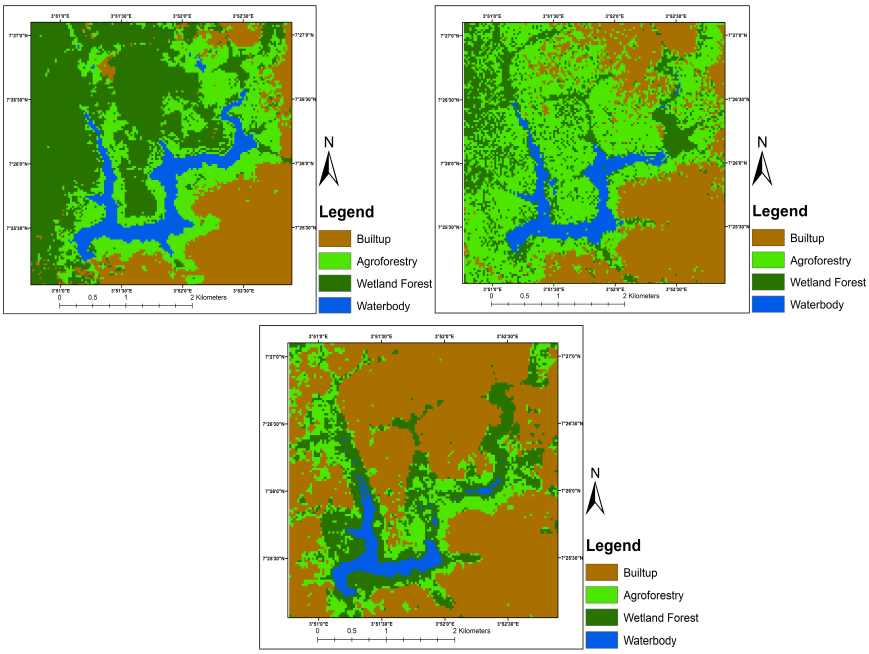

Fig. 4. Changes in and around Eleyele Lake and its environs during the study period.

Changes in land use/land cover. Awoniran et al (2012) observe that land use changes (land conversion) occur at the periphery of large urban concentration where urbanization and industrialization pressures frequently result in loss of prime agricultural lands and tree cover [46]. Eleyele lake area, which is located in the north-eastern periphery of Ibadan, has witnessed lot of changes in the land use during the study period. Table 3 presents the trend and magnitude of changes in land use in the area between 1984 and 2014. Between 1984 and 2000, agroforestry land use increased by 0.44 km², while wetland forest and water body decreased by 1.76 km² and 0.66 km² respectively. In the same period, the extent of the built-up areas increased by 1.99 sq km constituting about 41.03% (Table 3). Built-up area comprises all the developed part of the land covered by structures i.e. residential, scattered settlement, commercial, industrial, and transport units, construction sites and artificial non-agricultural areas land use categories.

About 36% of the wetland forests were lost to other land uses between 1984 and 2000. This finding is in line with Oyinloye et al (2004) and corroborates the United Nations Millennium Development Goal (MDG) progress report [47], [48]. The agricultural land use comprises both cultivated and irrigated farmlands in some particular location around the lake. Increase in the built-up area can be attributed to increasing demand of land from growing population and the development made in secondary and tertiary sectors such as schools, hospitals, market emerging near the area. Further changes in land use and land cover were noted between 2000 and 2014 with continued reduction in the extent of the wetland forest, agro-forestry and decline in the extent of the lake. There was a decrease in the surface area of lake by 0.19 km², while the forest decreased by 1.67 km² and the built-up area further increased by 3.80 km² indicating urban encroachment on the other land uses (Table 3). From the results of the study it can be observed that there was 29.62% decrease in the wetland forest between 1984 and 2014, which translates into a loss of 8.89 km² annually (Table 3). Much of the loss was gained by built-up areas that had 50% increase translating into 15 km² rate of growth.

Table 3. Land use/land cover change: Trend and Magnitude 1984 and 2014.

Land Use/Land Cover	1984 (km^2)	2000 (km^2)	Change (km^2)	% Change	Annual rate of change (km^2)
Built-up area	3.46	5.45	1.99	41.03	5.74
Agro-forestry	3.87	4.31	0.44	9.07	1.27
Water body	1.45	0.79	-0.66	13.61	1.91
Wetland Forest	6.07	4.31	-1.76	36.29	5.08
Total			4.85		
	2000	**2014**			
Built-up area	5.45	9.25	3.80	49.93	6.99
Agro-forestry	4.31	2.36	-1.95	25.62	3.59
Water body	0.79	0.6	-0.19	2.50	0.35
Wetland Forest	4.31	2.64	-1.67	21.94	3.07
Total			7.61		
	1984	**2014**			
Built-up area	3.46	9.25	5.79	50.00	15.0
Agro-forestry	3.87	2.36	-1.51	13.04	3.91
Water body	1.45	0.6	-0.85	7.34	2.20
Wetland Forest	6.07	2.64	-3.43	29.62	8.89
Total			11.58		

The period between 1984 and 2014 has shown drastic conversion of forested areas, agricultural land and the wetland into built-up areas with further shrinking of the lake area (Fig. 4).

Table 4 provides information on the overall land cover changes between 1984 and 2014 based on the land cover maps. Both the absolute percentage increments between the two years and relative percentage increments from 1984 were calculated. From table 4 we can note that the built-up area increased tremendously in both absolute and relative terms while other land use categories decreased.

The relative increment of the built-up area was of 167.40%, which shows that the number of built-up by 2014 increased three times the number available in 1984.

Table 4. Land cover surface change from 1984 to 2014.

Land cover classes	1984		2014		1984-2014 changes	
	(km^2)	(%)	(km^2)	(%)	Absolute increment (%)	Relative increment since 1984 (%)
Built-up	3.46	23.28	9.25	62.25	38.97	167.40
Agro-forestry	3.87	26.04	2.36	15.88	-10.16	-39.02
Forest	6.07	40.85	2.64	17.84	-23.01	-56.33
Water body (lake)	1.45	9.76	0.6	4.04	-5.72	-58.61
Total			14.98	100.00	Not applicable	Not applicable

3.1. Change detection analysis using LCM

Gains and losses between 1984 and 2014. The land use changes were assessed through the evaluation of gains and losses by classes. Most of the land use classes have both gains and losses except the water body, which does not have gains. The increment in infrastructure development of Ibadan, especially around Eleyele and environs overtime played a major role in the expansion of built-up areas. During the period between 1984 and 2000, there was a steady decline in the extent of agricultural areas and forest cover. The built-up areas increased with a gain of 1.47 km² with a loss of 0.44 km². Built-up further gained 3.85 km² with just 0.05 sq km loss by 2014 (Fig. 5).

Agro-forestry areas experienced significant gains and losses during the study period especially between 1984 and 2000 with 4.12 km² gain and 1.52 km² loss. The lost area of water-body was about 0.38 km² between 1984 and 2000 and 0.27 km² for 2000 and 2014 (Fig. 5).

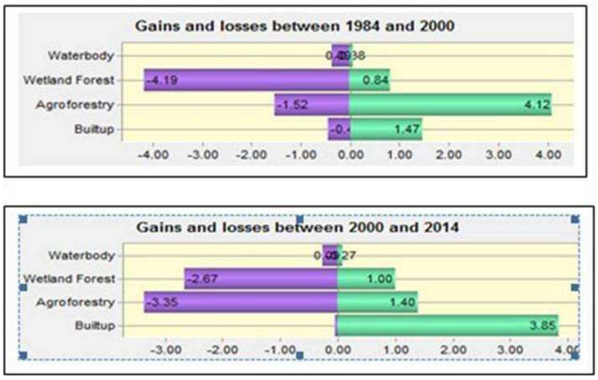

Fig. 5. Gains and losses of land use/cover categories between 1984 and 2014.

3.2. Net change

Figure 6 shows the net changes in area covered by different land use and land cover in the study area. Between 1984 and 2000 the net change in built-up area was of 1.03 km² as compared to the net change of 3.81 km² between 1984 and 2014. This shows significant conversion of other land uses to built-up in the study area mostly due to rapid influx of people and increasing demand for lands.

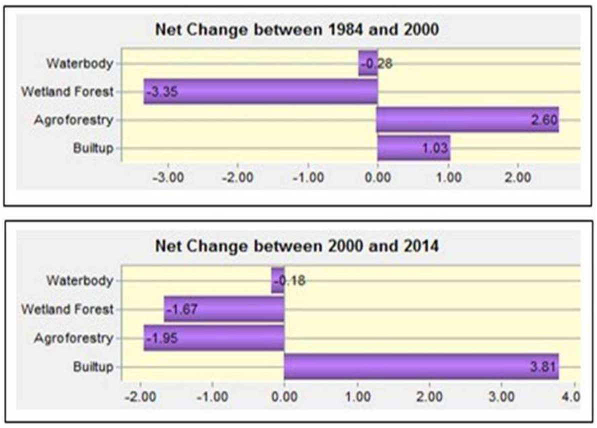

Fig. 6. Net change in area covered of different land use/ land cover between 1984 and 2014.

Forest in the area was also dramatically converted to other uses especially built-up. The forest cover had a net change of 1.67 km² between 1984 and 2014 compared to 3.35 km² net changes between 1984 and 2000. The trend observed was the continuous increase in the extent of the built-up with corresponding decline in the extent of other land uses.

3.3. Contribution of different land cover to net change

The major contributors to changes in the different land uses in the study period were determined using the Land Change Modeller in the IDRISI GIS software. The use of models such as LCM gives a better understanding of the functions of the land use systems and the support needed for planning and policymaking [35]. It can also predict the possible future change and use of the land cover under different scenario [49]. In this study, the major contributors to the increase in the extent of the built-up area was the loss of forest and agro-forestry, while some part of the lake were taken over by vegetation. In addition, some parts of the original forest were cleared for agricultural purposes. Figure 7 shows the major contributors to different land use change between 1984 and 2000. About 0.22 km² of wetland forest contributed to the change in spatial extent of the water body with the growth of water hyacinth on the silted part of the lake, especially in the north east.

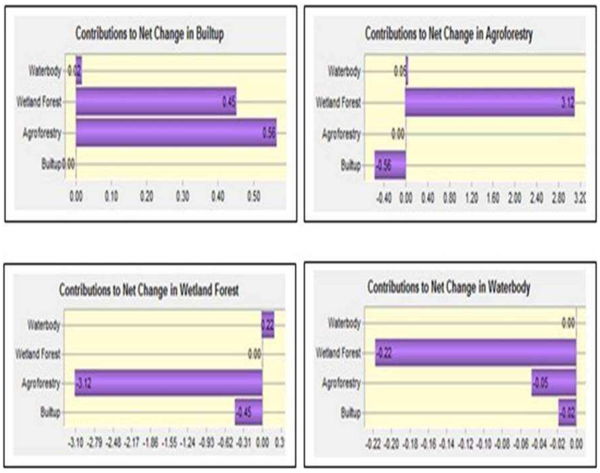

Fig. 7. Contributors to net change in area covered of different land use/land cover between 1984 and 2000.

It is clear that vegetal cover clearance contributed more to the increase in the spatial extent of the built-up area as the demand for more land increase forest areas are opened up likewise more agricultural land were lost. Moreover, vegetal covers were also lost to agricultural land use to provide land for the cultivation of crops. In the period between 2000 and 2014, a lot of agricultural land and forested land were lost to built-up areas (Fig. 8).

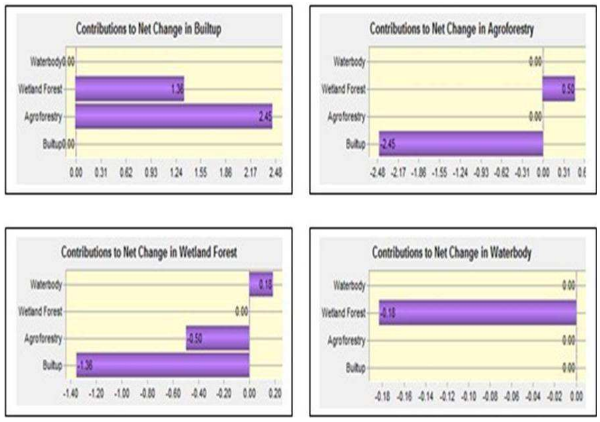

Fig. 8. Contributors to net change in area covered of different land use / land cover between 2000 and 2014.

3.4. Transition of land cover classes between 2000 and 2014

Transitions of the various land use/cover classes during the period 2000-2014 from one class to another were examined using the LCM. LCM allows us to produce and evaluate transitions from one land cover state to another, both in map and graphical form. The study revealed that there are significant changes and transitions among various classes. A transition map was generated from all land cover classes to water body (Eleyele Lake) in order to visualize and interpret the changes that happened to the extent of the lake between 2000 and 2014. The main changes and transitions are among agro-forestry, wetland forest and built-up area (Fig. 9).

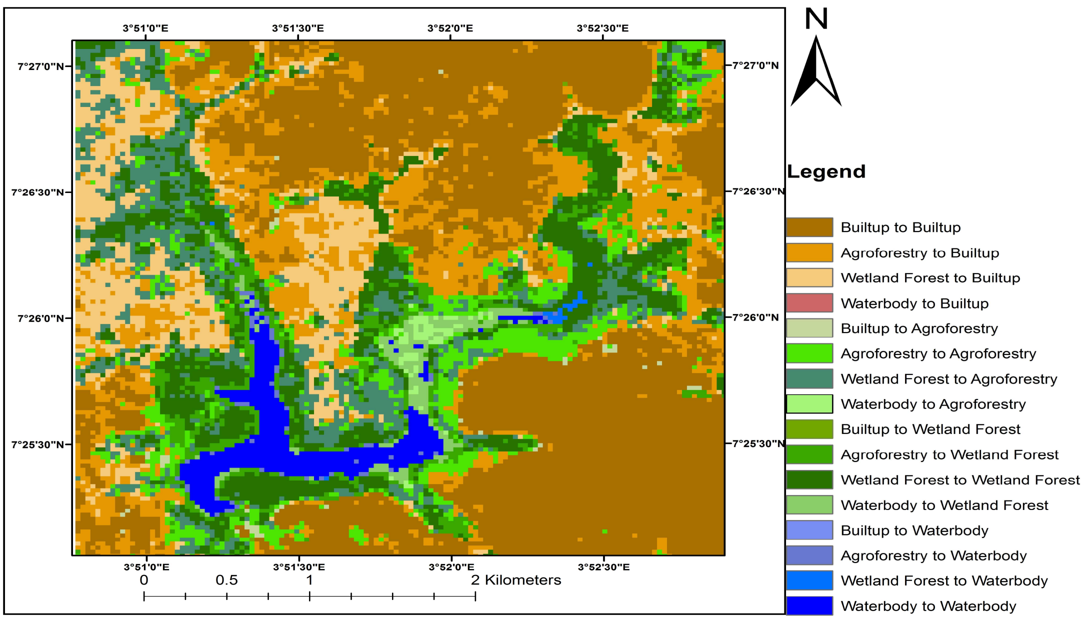

Fig. 9. Change detection in Eleyele Lake area and its environ from 2000 to 2014.

Agro-forestry to built-up showed considerable transitions between 2000 and 2014. The transitions could be viewed as possible development and caused by socio-ecological feedbacks that arise from socio-economic changes. Land use changes in many countries are progressively degrading wetlands with the expansion of agriculture and the development of water resource infrastructure being amongst the major drivers of adverse change globally [50]. In Europe for instance, the amount of space consumed per person in cities has more than doubled over the last fifty years while the share of agriculture areas has notably declined [51].

Increase in built-up close to the Eleyele lake are the major drivers of transformation of the wetland with potential environmental consequences including gradual reduction of biodiversity and landscape complexity and a higher vulnerability to natural hazards [52]. The area of water-body (Eleyele Lake) that remained unchanged for fourteen years (2000-2014) was of 0.52 km² and the wetland forest that remained unchanged was of 1.65 km² (Table 4).

Agro-forestry that remained unchanged was of 0.95 km² and built-up was of 5.39 km². In the course of fourteen years, there were some other transformations from one land use to another (Fig. 10). The 2000 and 2014 maps are compared to produce a cross-tabulation matrix that shows the surface of the landscapes for each transition (Table 4).

Table 5. Transition matrix (km²).

Land uses		2014					
		Built-up (km^2)	Agriculture (km^2)	Vegetation (km^2)	Water body (km^2)	Total 2014 (km^2)	Losses (km^2)
1984	Built-up	**2.69**	0.15	0.09	0.00	2.93	0.24
	Agriculture	1.54	**0.77**	0.65	0.16	3.12	2.35
	Vegetation	2.50	1.89	**3.36**	0.07	7.82	4.46
	Water body	0.002	0.13	0.33	**0.66**	1.12	0.46
	Total 1984	**6.73**	**2.94**	**4.43**	**0.89**	**14.99**	**7.51**
	Gain	4.04	2.17	1.07	0.23		
	Net Change	3.78	-0.18	-3.39	-0.23		
	Total change	**4.28**	**4.52**	**5.53**	**0.66**		

3.5. Spatial trend of change

The spatial trend analysis tool in LCM was used to compute maps of transition trends from different land cover categories to one another between 2000 and 2014. This was done using a default 3rd order of polynomial, which is best fit to the pattern of change, in LCM [42]. The most intense transition is the conversion of the wetland vegetation to built-up (Fig. 10).

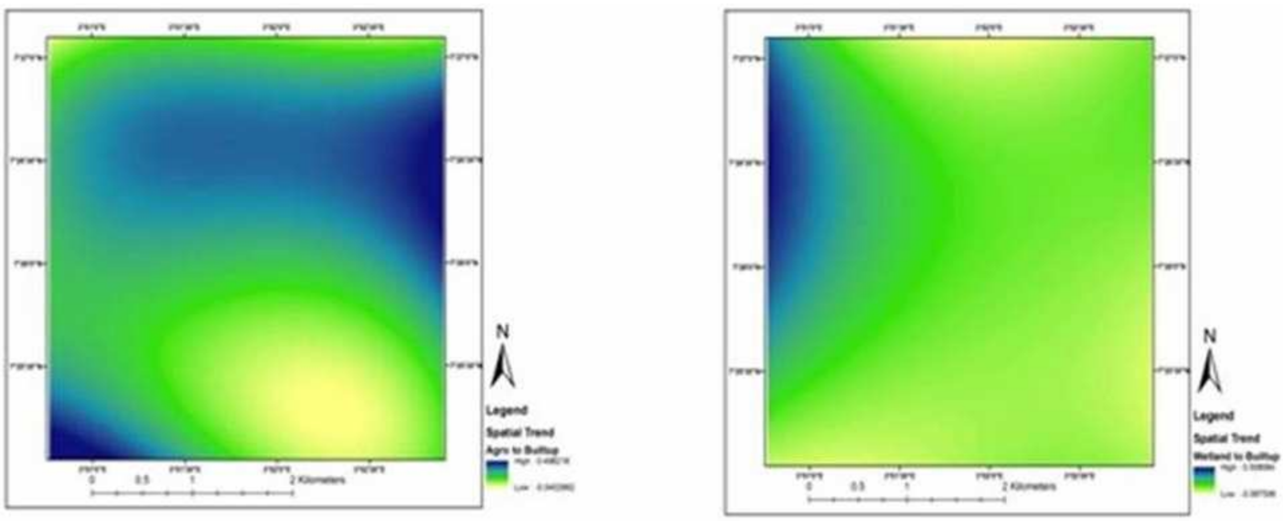

Fig. 10. Spatial trend of change.

3.5.1. Markov Chain Modelling

The analysis of past changes or LULC distributions with regard to spatial explanatory variables enables to assess the degree to which locations might likely change in the future [53]. The integration of Markov approach with cellular automata within GIS and remote sensing makes it more powerful in the utilization of land use dynamics in a spatial perspective [54], [55] because it can assess such parameters as probability related to Transitional Probability Matrix, Transitional Area Matrix, and Markov factors. A Markov Chain is a random process where the following step depends on the current state.

Table 6. Markovian prediction to 2044 based on LULC cover maps of 1984 and 2014.

LULC classes	Agro-forestry	Water body	Wetland forest	Built-up
Agro-forestry	**0.09**	0.01	0.10	0.79
Water Body	0.17	**0.40**	0.29	0.14
Wetland Forest	0.16	0.01	**0.17**	**0.66**
Built-Up	0.01	0.00	0.00	0.99

Markov produces transition matrix (Table 5) and a set of conditional probability image by analyzing two land use and land cover images from two different dates [56]. The rows represent the newer land use/ cover classes and the columns represent the older land use/cover categories. Markov analysis was performed for the multi-temporal land cover images of 1984-2014 including a prediction for 2044 as shown in Table 5. The probability of the water-body i.e. the Eleyele Lake having the same spatial extent in year 2044 is of 0.40, while the probability of water-body changing to built-up, wetland forest and agro-forestry were of 0.14, 0.29 and 0.17 respectively. The probability of the wetland forest remaining unchanged is of 0.17, while that of the built-up is of 0.99. Projected land use and land cover of the study area for year 2044 is given in Figure 11.

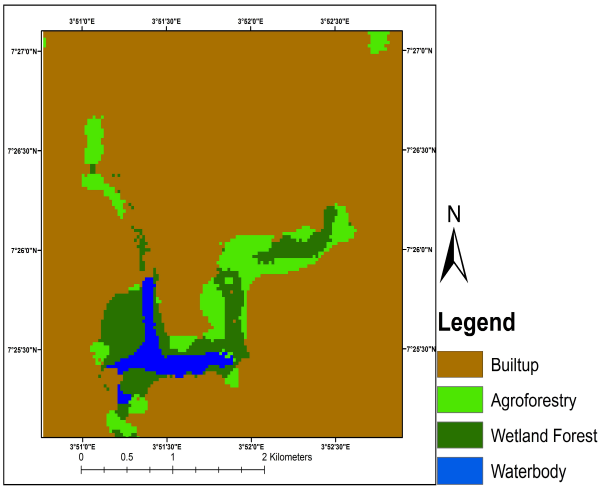

Fig. 11. Projected land use and land cover of the study area for the year 2044.

Table 7 below shows the predicted extent of the different land use /land cover classes for 2044. Built-up was predicted to have the largest spatial extent with continuous decrease in the extent of the wetland forest, and agro-forestry and also steady decline in the extent of the water body.

Table 7. Predicted extent of different land use by 2044.

Land uses	2044 Land Use/Land Cover Area (km^2)
Agro-forestry	0.83
Water body	0.30
Wetland forest	0.89
Built-up	12.82

In this study, between 1984 and 2000, wetland forest declined from 6.07 km^2 to 4.31 km^2 and further to 2.64 km^2 by 2014 largely through conversion to agro-forestry and built-up. Deforestation was more pronounced between 2000 and 2014. It must be noted that reduction of forest size and quality are important threats to environmental sustainability and the welfare of the communities living in or near forests [57]. In a similar study on the Eleyele lake area, Tijani et al. (2011) observed that the dense forest within the Eleyele catchment area reduced in extent from 3.38km^2 in 1984 to 3.01 km^2 by 2004 [5]. From these results, he projected a further decrease to 2.64 km^2 by 2014, while we projected that the wetland forest cover will be of 0.89 km^2 by 2044 (Table 6) mostly because further siltation may encourage the growth of herbaceous plants in the area. In 1984, the lake area was of 1.45 km^2, which was reduced to 0.79 km^2 by 2000 and further reduced to 0.60 km^2 in 2014. Illegal occupations on the lands surrounding the lake have resulted in the shrinking of the lake area. This poses problem to the capability of the wetland ecosystem to function well. Worldwide, the impacts of land-use/cover change on ecosystem goods and services have been identified [58]. The wetland area is the primary the land use/land cover class that is the major casualty of urban expansion in the study area. Inappropriate planning and management coupled with accelerated urban growth have resulted in tremendous loss in land, especially cropland thus posing great challenge for sustainable urban development [59].

Significant portion of lands surrounding Eleyele Lake were converted into residential areas due to the growing population. On the global level, it had been reported that a large percentage of wetlands have been lost in the last century, due to drainage and land clearance as consequence of agricultural, urban and industrial development activities [60]. Based on the past trend (from 1984-2014) of land use changes, the future land use map of the Eleyele Lake area for the year 2044 was generated, and the result showed that urban built-up areas will increase significantly with major contributions for this transformation coming from water bodies, agro-forestry and wetland forest. It is well-established that changes in land cover and land use (LCLU) are relevant to current local and global changes that are directly linked with food security, human health, urbanization, biodiversity, trans-border migration, environmental refuges, water and soil quality, runoff and sedimentation rates, and other processes [21].

4. CONCLUSION

The land cover dynamics in the case of Eleyele wetland area in Ibadan, Nigeria is closely related to the demographic and economic changes resulted from the urban sprawl of Ibadan metropolis. As a result of urban expansion and other anthropogenic activities around Eleyele Lake, there was a change in land use /land cover types in and around the area which led to the loss of vegetal cover of the wetland of Eleyele and profound effect on the size of the lake. With gradual increase in built-up area, there is loss in vegetal cover and loss of the wetlands around the lake, which is a threat to biodiversity conservation in the study area. This present study shows a probability of a particular land use changing to another land use around the Eleyele Lake area over a period of 30 years and a land use change prediction for 30 years (2014-2044) was performed. Furthermore, we generated a transition matrix that shows the transition from one category to another during all time intervals. The results revealed that wetland forest in 1984 was more extensive than in 2000 and 2014. A large amount of wetland forest and agro-forestry were converted to built-up which poses threats to the wetland area. Urban sprawl or urban encroachments have remained a by-product of our development practices and policies and planners require solutions that foster the ability to effectively predict and respond to chronic urban problems and future market fluctuation.

The study demonstrates that GIS and Remote Sensing coupled with statistical analysis can help immensely in assessing the extent of change of a particular region so that the necessary measures to prevent the adverse effect can be introduced. GIS modelling would assist planners in identifying and monitoring land use trends and also provides decision support to promote proper socio-economic planning and environmental land management.

REFERENCES

[1] **Araya, Y. H., Cabral, P.** (2010), *Analysis and Modelling of Urban Land Cover Change*. Setúbal and Sesimbra, Portugal. Remote Sensing, 2(6), pp. 1549-1560. DOI: 10.3390/rs2061549.

[2] **Sahalu, A. G.** (2014), *Analysis of urban land use and land cover changes: A case study in Bahir Dar, Ethiopia*. Dissertation, Instituto Superior de Estatística e Gestão de Informação (ISEGI), Universidade Nova de Lisboa, Lisbon, Portugal.

[3] **EEA** (2007), *Land-use scenarios for Europe: Qualitative and quantitative analysis on a European scale*. Luxembourg: European Environmental Agency (EEA). EEA Technical report. 9/2007.

[4] **Melendez-Pastor, I., Hernández, E. I., Navarro-Pedreño, J., Gómez, I.** (2014), *Socio-economic factors influencing land cover changes in rural areas: The case of the Sierra de Albarracín (Spain)*. Applied Geography 52, pp. 34-45.

[5] **Tijani, M. N., Olaleye, A. O., Olubanjo, O. O.** (2011), *Impact of Urbanization on Wetland Degradation: A Case Study of Eleyele Wetland, Ibadan, South West, Nigeria*. Proceedings of the Environmental Management Conference, September 12-15, 2011, Federal University of Agriculture, Abeokuta, Nigeria. Vol. 2:308-324. O. Martins, E. A. Meshida, T. A. Arowolo, O. A. Idowu and G. O. Oluwasanya (Eds.), Available at: http://www.unaab.edu.ng. [Accessed 12 September 2014].

[6] **Akingbogun, A. A., Kosoko, O. S. O. A., Aborisade, D. K.** (2012), *Remote sensing and GIS application for forest reserve degradation prediction and monitoring*. First FIG Young Surveyors Conference: Knowing to create the Future Rome, Italy, 4-5 May 2012, 1/27.

[7] **Satterthwaite, D.** (2005), *Meeting the MDGs in urban areas; the forgotten role of local organizations*. Journal of International Affairs, 58(2), pp. 87–112.

[8] **Odindi, J., Mhangara, P., Kakembo, V.** (2012), *Remote sensing land-cover change in Port Elizabeth during South Africa's democratic transition*. South African Journal of Science, 108 (5/6), pp. 1-7.

[9] **UNFPA** (2013), http://www.unfpa.org/pds/urbanization.htm [Accessed 12 September, 2014].

[10] **Sattherwaite, D., Cecilia, T.** (2002), *Seeking an understanding of poverty that recognizes rural-urban linkages*. In Rakoli, C., Lloyd-Jones, T (Eds) Urban livelihoods: a people centered approach, Earthscan, London, pp. 52–70.

[11] **Munich Re Group 2005** (2006), *Megacities—Megarisks: Trends and Challenges for Insurance and Risk Management*. Munich Re Group Knowledge Series, 25. Available at: http:www.munichre.com [Accessed 20 August 2014].

[12] **Hansen, A. J., Knight, R. L., Marzluff, J. M., Powell, S., Brown, K., Gude, P. H., Jones, K.** (2005), *Effects of Exurban Development on Biodiversity: Patterns, Mechanisms, and Research Needs*. Ecological Applications 15, pp. 1893-1905.

[13] **Amin, A., Amin A., Singh, S. K.** (2012), *Study of urban land use dynamics using geospatial approach*. Bulletin of Environment and Scientific Research, pp. 18-24.

[14] **Tejuoso, O. J.** (2006), *Wetland uses/dynamics for agricultural purposes and its health implications in lower Ogun River basin, Lagos, Nigeria*. Technical

Report submitted to International Development Research Centre (IDRC) Ecosystem Approach to Human Health Team, August, 2006.

[15] **Haines-Young, R.** (2009), *Land use and biodiversity relationships*. Land Use Policy 26 (Supplement 1): pp. 178-186.

[16] **Adeniyi, O. P., Omojola, A. S.** (1999), *Landuse/ Landcover Change Evaluation in Sokoto-Rima Basin of N.W. Nigeria Based on Archival Remote Sensing and GIS Techniques*. Geoinformation Technology Applications for Resource and Environmental Management in Africa (Edited by Adeniyi, O.P.) African Association of Remote Sensing of the Environment (AARSE).

[17] **Mayaux, P., Eva, H., Brink, A., Achard, F., Belward, A.** (2008), *Remote sensing of land-cover and land use dynamics*. In E. Chuvieco (Ed.), Earth observation of global change. The role of satellite remote sensing in monitoring the global environment (pp. 85-108). New York, USA: Springer.

[18] **Mejebi, D. J. J.** (2008), *An assessment of the various types of land degradation within the river Kubanni Basin of Zaria – Nigeria*. In: Bisong, F.E. (Ed.), Geography and the millennium development goals: translating vision into reality (64-70). Calabar: Ultimate Index Books Publishers.

[19] **Ezeomedo, I., Igbokwe, J.** (2013), *Mapping and Analysis of Land Use and Land Cover for a Sustainable Development Using High Resolution Satellite Images and GIS.* TS03B - Remote Sensing for Landuse and Planning, 6421. FIG Working Week 2013 Environment for Sustainability Abuja, Nigeria, 6–10 May 2013.

[20] **Oñate-Valdivieso, F., Sendra, J. B.** (2010), *Application of GIS and remote sensing techniques in generation of land use scenarios for hydrological modeling,* Journal of Hydrology, 395(3–4), pp. 256–263.

[21] **López-Granados, E., Mendoza, M. E. González, D. I.** (2013), *Linking geomorphologic knowledge, RS and GIS techniques for analyzing land cover and land use change: a multitemporal study in the Cointzio watershed, Mexico.* Revista Ambiente & Água - An Interdisciplinary Journal of Applied Science. 8(1), pp. 18-37, http://dx.doi.org/10.4136/ambi-agua.956 [Accessed 12 September 2014].

[22] **Coquery-Vidrovitch, C.** (1993), *Histoire des villes d'Afrique noire. Des origines à la colonisation*, Albin Michel, Paris.

[23] **Olaniran, O.** (1998), *The Geographical setting of Ibadan,* in G O Ogunremi (eds.) Ibadan. A Historical, Cultural and Socio-Economic Study of an African City. Oluyole Club, Ibadan.

[24] **Fourchard, L.** (2003), *Urban Slums Reports: The case of Ibadan, Nigeria,* in Understanding Slums: Case Studies for the Global Report on Human Settlements. Institut Francais de Recherche en Afrique. (IFRA), University of Ibadan.

[25] **Areola, O.** (1994), *The Spatial Growth of Ibadan City and its impact on the rural Hinterland.* In M.O Filani, F. O Akintola and C.O Ikporukpo (eds) Ibadan Region, Rex Charles Publication, Ibadan.

[26] **Onibokun, P.** (1998), *Urban Poverty in Nigeria*. Paper presented a the Workshop on Mainstream Urban Poverty in City/Municipal Level Planning and Management, organized by UNCHS, Nairobi, Kenya, September 21-25, 1998.

[27] **Ayeni, B.** (1994), *The Ibadan Metropolitan Area of Ibadan: its Growth and Structure.* In M.O Filani, F.O. Akintola and C.O Ikporukpo (eds) *Ibadan Region*, Rex Charles Publication, Ibadan.

[28] **National Population Commission (NPC)** (2006), *Final Results of the 2006 Census.* Abuja: National Population Commission.

[29] **El Hajj, M., Bégué, A., Lafrance, B., Hagolle, O., Dedieu, G., Rumeau, M.** (2008), *Relative radiometric normalization and atmospheric correction of a SPOT 5 time series*. Sensors, 8(4), pp. 2774-2791.

[30] **Bekalo, M. T.** (2009), *Spatial metrics and Landsat data for urban landuse change detection: case of Addis Ababa, Ethiopia.* Brockerhoff, M. (2000). An urbanizing world. Population Reference Bureau.

[31] **Kleeschulte, S., Büttner, G.** (2006), *European land cover mapping–the CORINE experience*. North American Land Cover Summit, *AAG* Special Issue, Chapt, 4, pp. 31-44.

[32] **Weng, Q.** (2002), *Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modelling*. Journal of Environmental Management, vol. 64, no. 3, pp. 273-284.

[33] **Lambin, E. F., Geist, H. J., Lepers, E.** (2003), *Dynamics of land-use and land-cover change in tropical regions.* Annu. Rev. Environ. Resour. 28:205–41. DOI:10.1146/annurev.energy.28.050302.105459

[34] **Adedeji, O.H., Tope-Ajayi, O. O. and Abegunde, O. L.** (2015), *Assessing and Predicting Changes in the Status of Gambari Forest Reserve, Nigeria Using Remote Sensing and GIS Techniques.* Journal of Geographic Information System, 7, pp. 301-318.

[35] **Eastman, J. R.** (2006), *IDRISI Andes Guide to GIS and Image Processing,* Worcester, USA, Clark Labs.

[36] **IDRISI** (2006), *Idrisi Andes Guide to GIS and Image Processing*. Clark labs, Clark University, USA (http://www.cartografia.cl/download/manuales/idrisiandes.pdf). [Accessed 27 September 2014].

[37] **Mishra, M., Mishra, K., Subudhi, A., Phil, M.** (2011), *Urban sprawl mapping and land use change analysis using remote sensing and GIS: Case study of Bhubaneswar city, Orissa.* Proceedings of the Geo-Spatial World Forum, January 18-21, Hyderabad, India.

[38] **Bangamwabo, V. M.** (2010), *Spatial and temporal extent of land degradation in a communal landscape of KwaZulu-Natal, South Africa'* MSc Thesis, University of KwaZulu Natal, South Africa.

[39] **Mhangara, P.** (2011), *Land Use/Cover Change Modelling and Land Degradation Assessment in the Keiskamma Catchment using Remote Sensing and GIS*. PhD Thesis, Nelson Mandela Metropolitan University, Port Elizabeth.
[40] **Fabio, P.** (2007), *Change Detection Algorithms*. State of the Art, Earth Observation Laboratory, Tor Vergata University, Rome, Italy.
[41] **Clark Labs** (2013), *IDRISI Spotlight: Earth Trends Modeller*. Clark labs. Clark University 950 Main Street Worcester, MA 01610-1477, USA.
[42] **Eastman, J. R.** (2012), *Idrisi Selva Tutorial*. Idrisi Production, Clark Labs-Clark University, 45. Eastman, J. R. 2006, *IDRISI Andes tutorial*, Clark Labs, Worcester, Massachusetts.
[43] **Lambin, E. F.** (1994), *Modelling deforestation processes: a review*. Office for Official Publications of the European Community.
[44] **Veldkamp, A., Lambin, E. F.** (2001), *Predicting land-use change*. Agriculture, Ecosystems & Environment, 85(1), pp. 1–6.
[45] **Iacono, M., Levinson, D., El-Geneidy, A., Wasfi, R.** (2012), *A Markov Chain Model of Land Use Change in the Twin Cities, 1958-2005,* Available at http://nexus.umn.edu/Papers/MarkovLU [Accessed 23 July 2014].
[46] **Awoniran, D. R., Adewole, M. B., Salami, A. T.** (2011), *Wetland Conversion and Fragmentation Pattern with its Impacts on Soil in the Lower Ogun River Basin*. Ife Research Publication in Geography, 10(1), pp. 125-133.
[47] **Oyinloye, R. O., Agbo, B. F., Aliyu, Z. O.** (2004), *Land Use/Land Cover Mapping in Osun State using NigeriaSAT-1 Data*. Available at: http://www.nasrda.gov.ng/docs/gueye.pdf [Accessed 16 June 2014].
[48] **United Nations (UN)** (2004), *Implementation of the United Nations millennium declaration*. Report of the Secretary-General. UN General Assembly A/59/282.
[49] **Ahmed, B., Ahmed, R.** (2012), *Modeling Urban Land Cover Growth Dynamics Using Multi-Temporal Satellite Images: A Case Study of Dhaka, Bangladesh*. ISPRS International Journal of Geoinformation, 1, pp. 3-31. DOI:10.3390/ijgi1010003.
[50] **Rebelo, L., Finlayson, C. M., Nagabhatla, N.** (2009), *Multiple scale wetland inventory, mapping and change analysis. Journal of Environmental Management, 90*(7), pp. 2144-2153. DOI: http://dx.doi.org/ 10.1016/j.jenvman.2007.06.027.
[51] **European Environmental Agency (EEA)** (2007), *Land-use scenarios for Europe: Qualitative and quantitative analysis on a European scale. Luxembourg:* European Environmental Agency (EEA). EEA Technical report, 9/2007.
[52] **Bielsa, I., Pons, X., & Bunce, B.** (2005), *Agricultural abandonment in the North Eastern Iberian Peninsula: the use of basic landscape metrics to support planning*. Journal of Environmental Planning and Management, 48, pp. 85-102.
[53] **Lillesland, M. T., Kiefer, W.R., Dupman, W. J.** (2004), *Remote sensing and image interpretation 5th Edition,* John Wiley and sons, Inc. New York.
[54] **Xin, Y., Xin-Qi, Z., Li-Na, L.** (2012), *A spatiotemporal model of land use change based on ant colony optimization, Markov chain and cellular automata*. Ecological Modelling, Elsevier, 233, pp. 11-19.
[55] **Arsanjani, J. J., Helbich, M., Kainz, W., Darvishi, A.** (2013), *Integration of logistic regression, Markov chain and cellular automata models to simulate urban expansion - the case of Tehran*. International Journal of Applied Earth Observation and. Geoinformation, 21, pp. 265-275.
[56] **Islam, M. S., Ahmed, R.** (2011), *Land use change prediction in Dhaka city using GIS aided Markov chain modelling*. J. Life Earth Sci., 6: 81-89. Available at: http://banglajol.info.index.php/JLES [Accessed 23 July 2014].
[57] **Joorabian Shooshtari, S. H., Hosseini, S. M, Esmaili-Sari, A., Gholamalifard, M.** (2012), *Monitoring land cover change, degradation, and restoration of the Hyrcanian forests in northern Iran (1977-2010)*. International Journal of Environmental Sciences 3(3).
[58] **Trimble, S. W., Crosson, P.** (2000), *Land use—US soil erosion rates: myth and reality*. Science 289, pp. 248-250.
[59] **Reveshty, M. A.** (2011), *The Assessment and Predicting of Land Use Changes to Urban Area Using Multi-Temporal Satellite Imagery and GIS: A Case Study on Zanjan, IRAN (1984-2011),* Journal of Geographic Information System, 3, pp. 298-305.
[60] **Williams, A. L., Wills, K. E. Janes, J. K. Schoor, J. K. V. Newton, P. C. D., Hovenden. M. J.** (2009), *Warming and free air CO2 enrichment alter demographics in four co-occurring grassland species*. New Phytol, 176, pp. 365–374.

Web Sources

Global Land Cover Facility (GLCF) – (http://www:glcf.umiacs.umd.edu).