International Journal of Mechanical Engineering & Computer Sciences, Vol.1, Issue 1, Jan-Jun, 2017, pp 36-54

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GEOSCIENCE APPLICATION OF REMOTE SENSING IN THE EVALUATION OF LONG -TERM LAND COVER ATTRIBUTES IN PART OF WESTERN NIGER DELTA, NIGERIA

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ABSTRACT

Detection of land use/cover change play a crucial role in land use planning and formulation of sustainable land use policies. In this study, remote sensing data were used to map and predict land use/cover change in Oben Area. The output maps were analyzed and cross-tabulated to quantify land use/cover change for the different timelines. The main drivers that altered the character of land use/cover in the area were oil and gas exploration and production (E&P) activities, demographic factors, infrastructural development, agricultural practices and economic factors. Markov model was used in projecting land use/cover change for 10, 20 and 30 year periods. Results of the land use/cover projection in Area field show an increase trend in built up and woodland/rangeland areas at the expense of forests and water cover.

Key Words: Oben, Landsat TM, ETM+ and OLI

Introduction

Periodic and precise change detections of the earth's surface features is extremely important for understanding relationships and interactions between human and natural phenomenon in order to promote better decision making. Remote Sensing data are primary sources extensively used for land use/cover change evaluation in recent decades.

Previous studies have indicated that only few landscapes on the Earth are still in their natural state. This is as a result of anthropogenic activities, the Earth surface is being significantly altered and man's presence on the Earth and his use of land has had a profound effect upon the natural environment thus resulting into an observable pattern in the land use/land cover over time.

Although the terms land cover and land use are often used interchangeably in change detection studies, their actual meanings are quite distinct. Land use refers to the purpose of land reserves, for example, recreation, wildlife habitat, or agriculture.

This study evaluated remote sensing techniques as tool and methodology for land use/cover change detection and delineation at Oben Area using high multispectral Landsat TM, ETM+ and OLI. Drivers of the land use/cover changes are also identified. Land use/cover change projection over a period of 10, 20 and 30 years is made using Markov model, the number of years considered for land cover change projection took into cognizance "*human population growth dynamic stability*".

(I) AIM AND OBJECTIVES

The aim of this study is to detect and delineate land use/cover change of Oben Area at different timelines using remote sensing techniques and project future change covering a period of 10, 20 and 30 years.

(a) The Study Area

The study area is Oben Area which is situated in OMLs 04 & 38, about 90km south of Benin City 60km North East (NE) of Warri, it lies within Orhionmwon Local Government Area of Edo State, West of the Niger Delta area, South-South region of Nigeria and occupies an area of over 237.893km^2. It is bounded by the coordinates top left Eastings 374758.00; Northings -233188.00; bottom right Eastings 390531, Northings 214778.00 (**Figures 1**). Oben Area was discovered in 1972 on two-dimensional (2D) seismic dataset and came on stream in 1974 with oil production peaking at 40 Mbopd in 1985. Thirty-three (33) wells have so far been drilled in the Oben Area of which 3 are gas wells.

(b) Climate and Meteorology

The study area is located in the Gulf of Guinea and lies in the semi-hot equatorial zone with distinct climatic seasons (wet and dry). The climate in the area is typical of the equatorial rain forest. Two main winds, southwest (SW) and the northeast (NE) generally influence the weather conditions in the study area.

Within the study area, rainfall is generally high with an average of about 2480mm per annum, based on historical records. Climatic conditions portray maximum wind speed of 55m/s in the north-eastern direction and a minimum of 0.9m/s in the north-eastern direction.

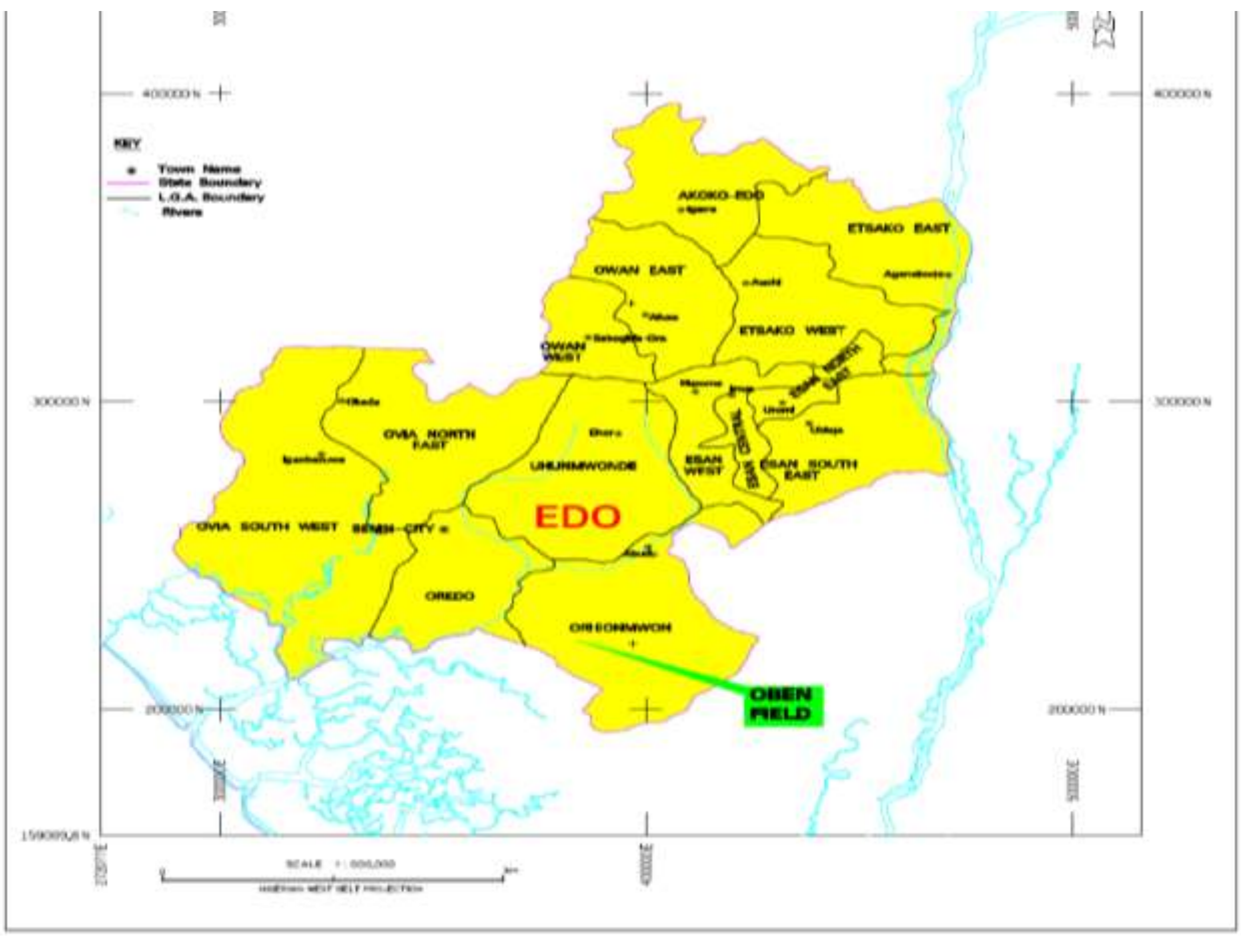

Figure 1: Map of Edo State Showing Oben Area

(c) Vegetation/Forestry

The study area is situated within the lowland rainforest belt of Nigeria. The natural vegetation has, however, been altered in most parts due to human activities.
Secondary lowland rainforests and bush fallows are the predominant types of vegetation cover. Various sizes of farmlands are located in the area.

The dominant plant species include *Chromolaena odorata*, *Alchorneacordifolia* (Christmas bush),*Icacina trichantha*, *Aspilia Africana* ,*Tremaoccidentalis*, *Musanga* cercropioides, *Solanumtorvum*, *Ficus esperata*, *Emilia coccinea*, *Tridax procumbens*, *Euphorbia heterophylla*, and *Panicum maximum* (Guinea grass).These species are good indicators of secondary succession.

(II) METHODOLOGY

The research design for this work formed the basis for obtaining data for land use land cover trend and subsequent overall, the findings.

The study integrated data from different sources and used different methods and approaches to analyse the long term land use land cover changes and trends in Oben Area for a twenty eight (28) year period. The include the use of epoch imageries from Landsat obtained at multi-temporal dates (TM 1987, ETM+ 2002 and OLI/TIRS 2015) and conducting ground-truthing. Object-based supervised classification is applied for image classification. Also additional secondary data is used to analyse the driving forces and effects of land cover change supported by classified maps derived from supervised classification of Landsat imageries.

(i) Data Acquired and Source

For the study, a time series of Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images were used to derive land use land cover maps of Oben Area. The data set include three Epochs for the years 1987, 2002 and 2015 (**Table 1**). The raw satellite data were obtained from the archive of the U.S. Geological Survey. These maps were brought to Universal Transverse Marcator (UTM) projection, datum WGS 84, Zone 32.

Table 1: Data Source

S/N	SATTELITE/ DATA TYPE	SENSOR	PATH / ROW	DATE	SCALE	BANDS	SOURCE
1.	Landsat 4	Thematic Mapper (TM)	189/056	21/12/1987	30m	1, 2, 3, 4, 5, 6 & 7	Courtesy of the U.S. Geological Survey
2.	Landsat 7	ETM+	189/056	30/12/2002	30m	1, 2, 3, 4, 5, 6 & 7	Courtesy of the U.S. Geological Survey
3.	Landsat 8	OLI/TIRS	189/056	08/01/2015	30m	1, 2, 3, 4, 5, 6, 7, 8, 9, 10 & 11	Courtesy of the U.S. Geological Survey

This datasets sensors has repeat cycles of 16 days, ground pixel dimension of 57m x 79m (TM), 16 bit pixel for values for OIL/TIRS and the spectral range includes seven spectral bands in the Visible/Near Infra-red (VNIR – Bands 1, 2, 3 & 4), Short Wave Infrared

(SWIR – Bands 5 & 7) and Thermal Infra-Red (TIR – Band 6) parts of the electromagnetic (EM) spectrum. The spectral resolution of Landsat TM, ETM+ and OLI/TIRS (30M) data makes it very useful for land use/cover classification and general mapping.

(i) Geo-referencing Properties of the Images

The geo-referencing properties of both 1987, 2002 & 2015 made use of Universal Transverse Marcator (UTM) projection, datum WGS 84, Zone 32.

(iii) Image Processing - Radiometric Correction

As with geometric correction, the type of radiometric correction applied to any given digital image data set varies widely among sensors. Some of these effects, such as viewing geometry variations, are greater in the case of airborne data collection than in satellite image acquisition. Also, the need to perform correction for any or all of these influences depends directly upon the particularly application at hand (Remote Sensing and Image Interpretation).

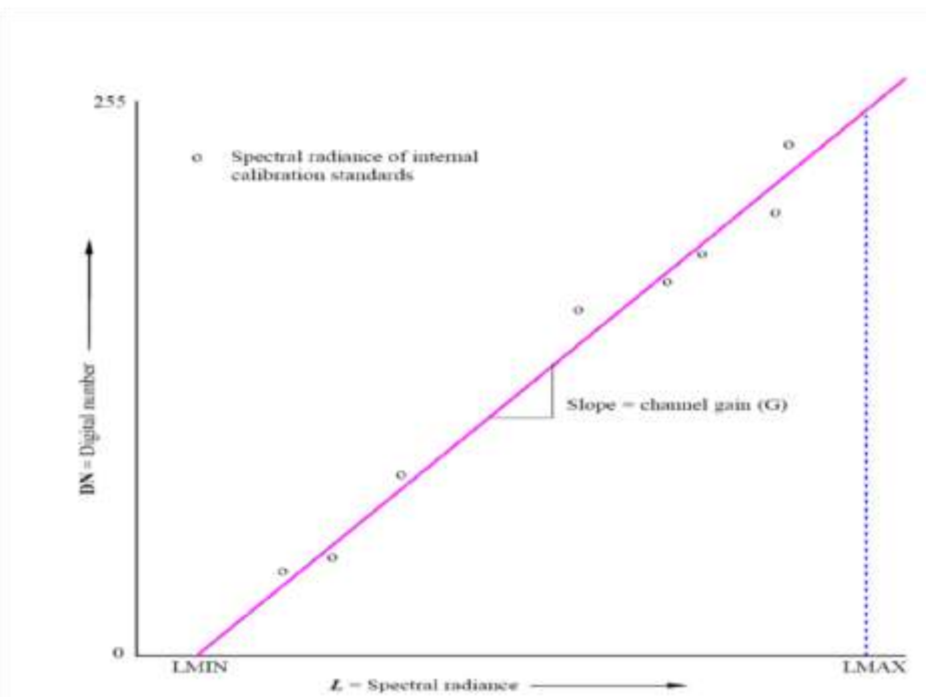

Figure 2 Radiometric response function for an individual TM channel

It can be seen that a linear fit to the calibration data results in the following relationship between radiance and DN values for any given channel:

$$DN = GL + B$$

Where

DN = digital number value recorded

G = slope of response function (channel gain)

L = spectral radiance measured

B = intercept of response function (channel offset)

Note that the slope and intercept of the above function are referred to as the *gain* and *offset* of the response function, respectively. In **Figure 2,** LMIN is the spectral radiance corresponding to a DN response of 0 and LMAX is the minimum radiance required to generate the maximum DN (here 255). That is, LMAX represents the radiance at which the channel saturates. The range from LMIN to LMAX is the dynamic range for the channel.

(iv) Image Enhancement

Three techniques for digital enhancement can be categorized as *contrast manipulation, spatial feature manipulation* or *multi-image manipulation*.

1. *Contrast manipulation*: Gray-level thresh holding, level slicing and contrast stretching.
2. *Spatial feature manipulation*: Spatial filtering, edge enhancement and Fourier analysis.
3. *Multi-image manipulation*: Multispectral band rationing and differencing, principal components, canonical components, vegetation components, intensity-hue saturation (IHS) color space transformations and de-correlation stretching.

(III) RESULTS AND DISCUSSION

PRESENTATION AND ANALYSIS OF DATA

(a) Land Use/Cover Classification

Three successive supervised and unsupervised land use/cover classifications were discriminated into four classes: water, forest, woodland/rangeland and built up area. Result of the accuracy assessment of the classification is as provided in **Tables 1** below.

Table 1: Accuracy Total Report (1987) of Oben Area

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy (%)	User's Accuracy (%)
Woodland / Rangeland	5	4	4	80	100.00
Forest	16	19	16	100	84.21
Water	7	5	5	71.43	100.00
Built up Area	2	2	2	100	100.00
Total	30	30	27		

Over all Classification Accuracy: = 90.00%

Kappa (k) Statistics

Class Name Kappa

Woodland / Rangeland 1.000

Forest 0.6617

Water 1.000

Built up Area 1.000

Overall Kappa Statistic: = 0.8324

Analysis of the overall accuracy assessment in **Tables 1** above indicated that the 1987 classification based on the assessed Landsat TM map was 90%, with a Kappa coefficient of

0.83, while the overall accuracies for the 2002 classifications based on Landsat ETM+ was 83.3% with a Kappa coefficient of 0.70, the 2015 classification accuracy based on OLI was 93.3% with a Kappa coefficient of 0.89.

(b) Land Use/Cover Distribution

In this section land use/ cover maps of different years were delineated and compared. The land use/cover of Oben Area had changed dramatically during the period of 28 years. The data interpretation, analysis/discussion is based on comparison of land use land cover for different timelines in a 28 year period. The spatial static land use land cover distribution for 1987, 2002 and 2015 as derived from the image maps are presented in **Table 2** below. The total area under study is 237.893km^2. The analysis and discussion on the result is presented in the section after the Table 2 below.

Table 2: Spatial Extent of Land Use/Cover Change for Oben Area (1987 - 2015)

Land Use/cover Categories	**1987**		**2002**		**2015**	
	Area (km ^{2})	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Water	41.139	17.29	7.194	3.02	4.532	1.91
Forest	161.103	67.72	165.663	69.63	107.275	45.09
Woodland / Rangeland	24.244	10.19	25.026	10.51	27.210	11.44
Built up Area	11.407	4.80	40.100	16.85	98.876	41.56
Total	237.893	100	237.893	100	237.893	100

A review of **Table 2** in 1987, built-up area occupied the least in class with just 4.80% (11.407km^2) of the total classes. This may not be unconnected to low demographic structure of the area, sparse settlements, inaccessibility due to thick forest cover as well as seasonal inundation of the area, woodland and rangeland occupied 10.19% (24.244km^2) of the total classes, this may be due to the fact that farming was practice moderately, E&P

activities were at exploratory level with drilling of appraisal wells. Water occupied 17.29% (41.139km^2) this is related to thick forest occupying over 161.103km^2 (67.72%), the thick forest area is a Government Reserve Forest called Urhonigbe Forest Reserve.

In 2002, built up area rose to 16.85% (40.10km^2) and maintained a double digit in growth to 41.56% (98.876km^2) in 2015. This period coincided with an increase in E&P activities in Oben Area with the opening up the hitherto un-accessed areas to the population to build houses, the population was also economically empowered through white collar jobs in the Forest area rose up marginally by 69.63% (165.663km^2) due to the reduction in water cover with such areas being reclassified as forest thus leading increase forest in 2002. Increase in woodland/rangeland is due to increase in farming activities within Oben Area. This may be due to siltation and runoffs/soil washed off from deforested areas into the Jamieson river and inability of the deforested areas to hold unto flooded water resulting to increased surface water runoffs and evaporation.

Plate 1: Savannah-like open rangeland with mainly overgrazed grassy weeds and widely spaced out trees and shrubs.

Plate 2: A Luxuriant forest vegetation showing *Anthocleista noblis* on the left

(c) Land Use/Cover Change: Trend, Rate and Drivers

Table 2 above highlights land use land cover change and trend and rate at Oben Area. A review of the data show a clear positive trend in built up areas of Oben Area to 28.693km^2 (over 71.55%) with annual rate of change totalling 10.73 from 1987 to 2002. This period was the peak in infrastructural development in the area such as roads, markets at each of the four existing communities, building of schools, building of oil and gas infrastructures such as flow station built on land area of about 92m x 75m, flare site located at about 250m northwest of the station, gas plant, located adjacent the flow station, has land area of 80m x 70m, other sub-surface facilities include: Wells (oil and gas), flow lines, delivery lines, trunk lines, NGC compressor station and their ancillary components, these facilities have taken up a sizeable amount of land area thus contributing to land use land cover change of Oben Area.

Forest captured in **Plates 1 & 2** experienced a positive change of 4.560km^2 with a percentage change of 2.75% at the annual rate of change totalling 0.41 from 1987 to 2002. This positive trend in forest within this period is attributed to cultivation of cash crops such as palms and rubber within the period.

Woodland/rangeland captured in **Plates 1 and 2** also experienced marginal positive change of 0.883km^2 with a percentage change of 3.52% with annual rate of change totalling 0.53 from 1987 to 2002. This change could be attributed to the activities of oil and gas operators contributing in the following ways:

- **Crude oil Generation using the flowstation:** The generation and supply of crude oil through the automated flow lines occasionally results in spillage of the crude oil due to technical maintenance defaults or sabotage thus leaving the area degraded.
- **Gas flaring:** Gas flaring accompanying crude oil production generally contributes to increased heat within adjoining environment thus leading to withering of land cover,
- **Pipeline destruction:** Importantly, petroleum hydrocarbon spills due to facility or damaged pipelines conveying crude petroleum and leakages are possible sources of discharges into the soil. Oil spillage on land may lead to retardation of vegetation growth.
- Various spillages of crude petroleum and associated products caused by wilful acts of vandalization, neglect of maintenance of oil pipelines or accidents occur within such facilities leading to the devastation of vegetation.

Land use land cover experience change in trend at Oben from 1987 to 2015, there was an exponential positive growth in built up area with a change of 58.778km^2 with a percentage change of 59.44% and annual change rate of 7.73. There are has been a sustained increase in oil and gas drilling and production activities of the areas hence increasing infrastructural development of the area, community members of the area are economically empowered by the oil and gas companies operating in the area through white collar jobs, sub-contracting, payment for land acquired hence leading to building of houses from the financial benefits by these community members thus increasing built-up areas. Schools, commercials centres like markets, hospitals have continued to be developed and expanded in the area leading to positive change in the built up area in Oben.

The Oben area has continued to experience urban/industrial growth. The oil boom has attracted a lot of people to the area leading to demographic change of the Oben Area with attendant physical expansion of the rural settlements such as Oben, Ikobi, Iguelaba and Obozogbe-Nugu. The Oil and Gas companies have continued to expand on their assets by drilling of multiple oil wells, installation of wellheads, pipelines, flowline, building of flowstations and gas plants which took up additional space within the area contributing to positive change in land use land cover of Oben. The household in the communities expanded up to six per household (EIA, 2008) modern open stalls markets are constructed at Oben and traditional makeshift sheds constructed at the other three communities took up spaces, each of the four (4) communities has a built primary school, two (2) secondary schools also exist in the area.

The decrease in forest within the period could be related to the positive increase in woodland/rangeland where forest areas were being converted to croplands. Opening up of the forest area for expansion in exploration and production (E&P) activities further gave additional access to the forest area for farming, logging/lumbering (timber harvest), extraction of fuelwood removals by the community members. The low to moderate nutrients (e.g. total organic carbon, total nitrogen, chloride, nitrate, sulphate and nitrite) status in soils of the area renders the soil infertile as reported in the SPDC EER, 2010. The infertile can no longer sustain lush forest trees (probably the reason grazing was ongoing within the area to add nutrient in the soils.

(d) Land Use/Cover Change: Nature and Location

An important aspect of change detection is to determine what is changing to what. This information is a vital tool in policy and management decision taking. This process involves a pixel to pixel and direct comparison of raster image maps of the study years.

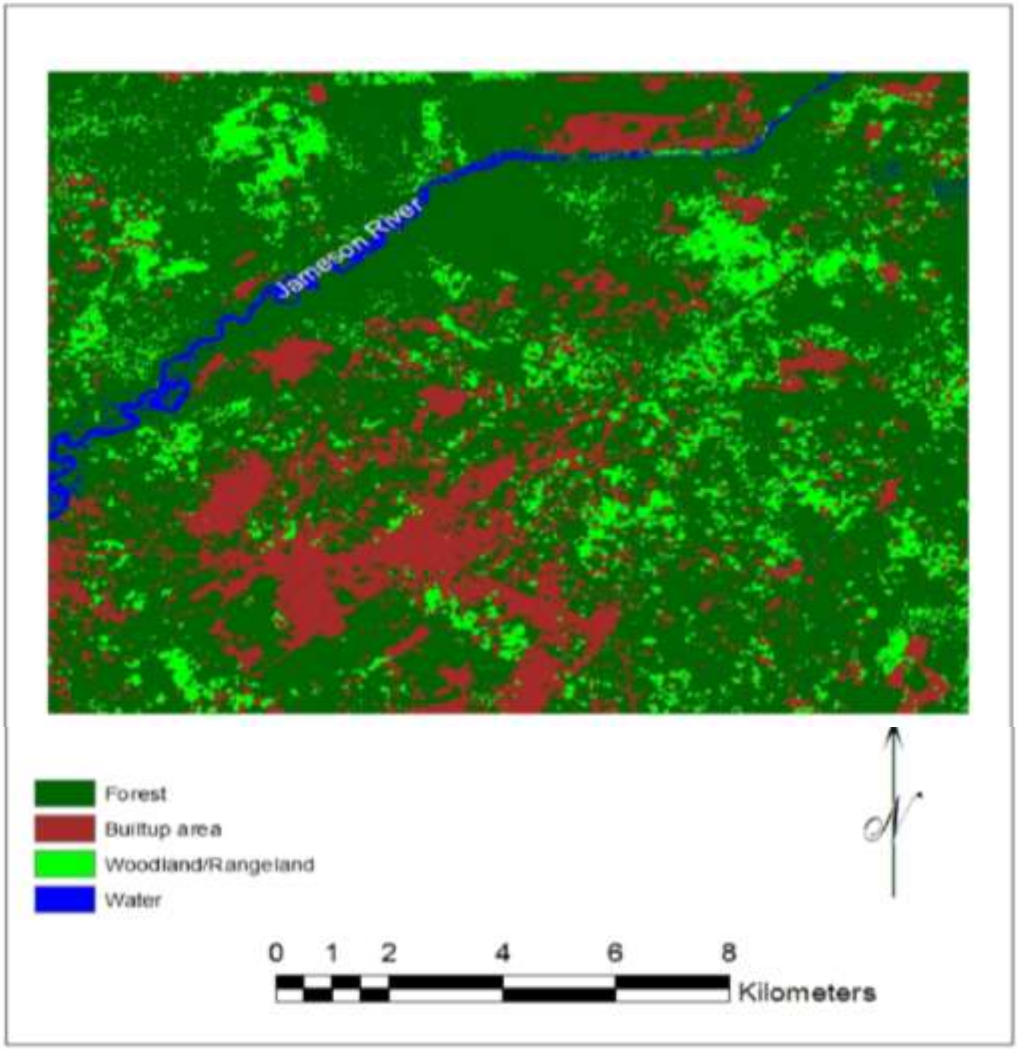

Figure 3: Land use/Cover Classification of Oben Area for 2002

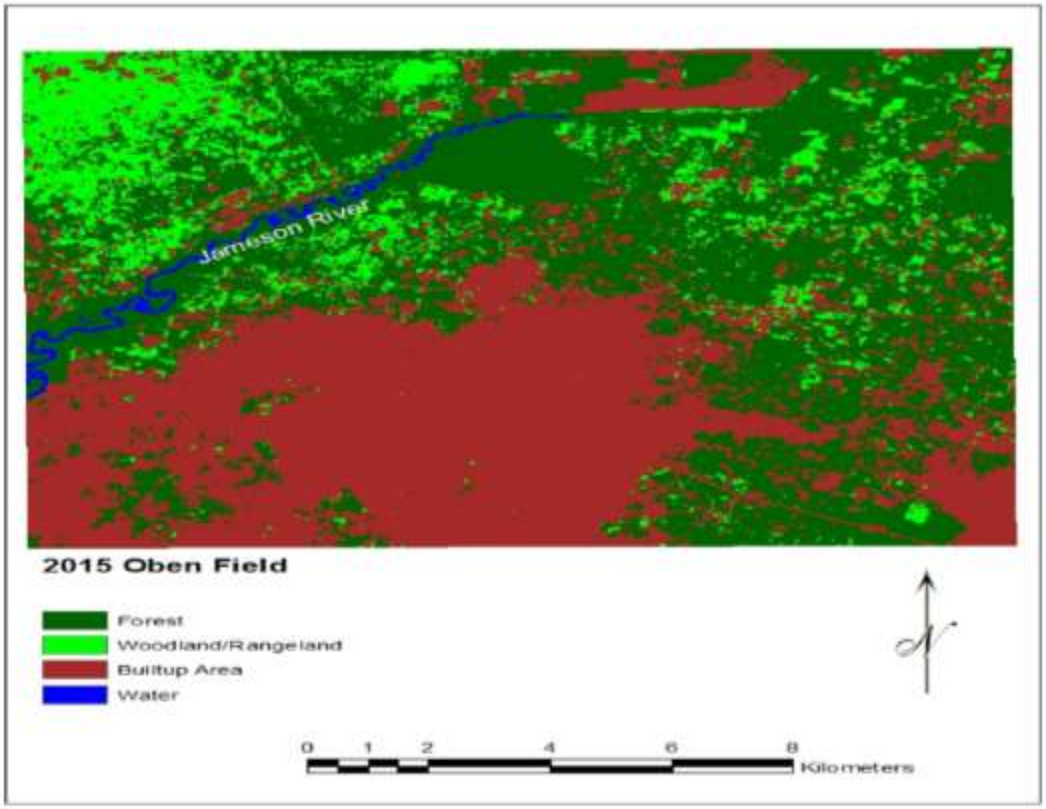

Figure 4: Land Use/Cover Classification of Oben Area for 2015

Looking at **Figures 3 and 4** in terms of location of change, urban/industrial area (built up area) change between 2002 and 2015 seemed to exists as the growth of the settlements is observed in the south around clusters of infrastructural development areas, road network away from the settlement centres following the concentric theory of urban growth postulated by Christaller (1933). Although the pattern seems to be uniform across the four communities in the study area.

Woodland/rangeland are predominately located in the northwest northeast and south in 2002 and then it was sparsely equally distributed around Oben Area but predominantly located in the northwest and northern part of Oben in 2015 away from population centres and thick forested areas.

Water is identifiable by the presence of Jemis on river straddling from north east to south west with part of the entire north west to south west under water in 2002, the water was reduced to a well-recognised stream flowing from North East to South West with visible pools also existing in the north eastern axis of Oben Area. By 2015, Jemies on river is observed stretching midway from Northeast to South West.

forest area is observed being restricted to the fringes in North East corner of Oben Area.

(e) Land Use/Cover Change: Magnitude of Change

Table 3 below is a matrix showing transition of land use/cover from one category to another from 1987-2015.

Table 3: Transitional Probability of Land Use/Cover of Oben Area between 1987-2015 (km^2)

Class Name	Water	Forest	Woodland / Rangeland	Built up Area
Water	1.76	19.83	7.36	11.75
Forest	0.02	73.70	16.84	68.83
Woodland / Rangeland	0.00	10.55	2.61	10.59
Built up Area	7.71	3.20	0.41	0.00

Review of **Table 3** above indicated a transition/modification in land use land cover from one category to another in Oben Area between 1987 – 2015 . The matrix indicated that the total water covered area change/converted to forest area was 19.83km^2, while total converted to woodland/range was 7.36km^2 and total coverage converted to built-up area was 11.75km^2. However, water retained its status over an area covering 1.76km^2 within the same period. For forest the striking issue was that total forest area that remained forest area stood at 73.70km^2, forest areas converted to woodland/rangeland cover an area of 16.84km^2 while 68.83km^2 of forest area was converted to built-up areas.

Total woodland/rangeland converted to forest was 10.55km^2, it remained woodland/rangeland at 2.61km^2 and total converted to built-up areas within the same period stood at about 10.59km^2.

Built up (urban/industrial/open/bare-soil) area converted to forest area stood at 3.20km^2. while total of industrial/built up area converted to water land cover was 7.71km^2. Built up areas converted to woodland/rangeland stood at 0.41km^2.

(f) Land Use/Cover Projection

Table 4: Land Use/Cover Projection in Oben Area for 2025 (10yrs)

Class Name	Water	Forest	Woodland / Rangeland	Built up Area
Water	0.0194	0.5663	0.1942	0.1949
Forest	0.0110	0.4708	0.1139	0.3396
Woodland / Rangeland	0.0014	0.4636	0.1563	0.3507
Built up Area	0.000	0.3305	0.0790	0.5881

As revealed in **Table 4 and 5** , the rows represent the older land use land cover categories and the column represents the newer categories. it was used in projecting land use land cover for 2025. a category represent land use land cover classes, column represents what is being change to progressively from left to right from 2025,. As revealed in **Table 4**, in the year 2025, water has a 0.194 probability of remaining water and a 0.5663 of drying up within the forest area in 2025. Forest area during this period will likely maintain its position as the highest class with a 0.4708 probability of remaining forest, with a 0.1139 probability of being converted to woodland/rangeland and 0.3396 probability of conversion to built up area in 2025. On the other hand, the woodland/rangeland has a probability of 0.3502 of changing to built-up. Built-up land area also has a positive probability as high as 0.5881 in 2025 which signifies stability and growth in urban/industrials/bare soil areas of Oben Area.

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