MANAGING AND MONITORING NATURAL RESOURCES: A STUDY OF OBEN AREA, NIGER DELTA, NIGERIA

TERSEER SARWUAN 1, FRANCIS T. BEKA 2, ALICE OGBOLE 3

1,3 DEPARTMENT OF GEOGRAPHY, UNIVERSITY OF PORT HARcourt, CHOBA NIGERIA
2 CENTRE OF PETROLEUM GEOSCIENCES, UNIVERSITY OF PORT HARcourt, CHOBA, NIGERIA

ABSTRACT

The main drivers that altered the character of land use/cover in the study 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 Oben Area show an increase trend in built up and woodland/rangeland areas at the expense of forests and water cover. Suggestions are made at the end of this research work on ways to use the information as contained herein optimally.

(I) INTRODUCTION

Land use and land cover change has become a central component in the current strategies for managing natural resources and also in monitoring the environmental changes. The advancement in the concept of vegetation mapping has greatly increased research on land use and land cover changes. In this way, it is providing an accurate evaluation of the widen and health of the world’s forest, grassland, and agricultural resources has become an important priority.

In situations of rapid and often unrecorded land cover change, observations of the earth from space provide objective information of human utilization of the landscape. Over the past years, data from the Earth sensing satellites has become very vital in mapping the Earth’s features and infrastructures, managing natural resources and studying environmental change.
In view of the advantages of repetitive data acquisition, digital format and synoptic view suitable for computer processing of remotely sensed data such as Thematic Mapper (TM), Enhanced Thematic Mapper (ETM) and Advanced Very High Resolution Radiometer (AVHRR), have become the major sources for different land use/cover change detection in the past decades.

(II) AIM AND OBJECTIVES

Aim
The aim of this study is to detect and delineate land use/cover change of Oben Area at different timelines using remote sensing

Objectives
The following specific objectives will be pursued in order to achieve the aim above.

- To delineate land use/cover spatially and quantitatively.
- To determine the trend, nature, rate, location and magnitude of land use/cover change.
- To identify the drivers of land use/cover change within Oben Area.
- To project the future pattern of land use/cover in the area.

The Study Area
Detailed information on the project area were extracted from previous studies conducted within the Oben Area. These reports include: Final Report of the Environmental Impact Assessment (EIA) of Oben Gas Development Project, 2008, Final Report of the Post Impact Assessment (PIA) for 10” Oben - Amukpe Trunkline, 2008 and Draft Environmental Evaluation Report (EER) for Oben Flowstation and Gas Plant, 2010. The study area is Oben field which is situated in OMLs 04 & 38, about 90km South of Benin City 60km North East (NE) of Warri. It is bounded by the coordinates top left Eastings 374758.00; Northing -233188.00; bottom right Eastings 390531, Northings 214778.00  Figure 1
Figure 1: Image Map Highlighting Oben Area

Land Use and Agriculture
The land use pattern in Oben Area are forestry reserve, industrial, agricultural and settlements. The Oben Area is part of the Urhonigbe Forest Reserve, although a sizable part of the forest has been destroyed by human activities. Exploitation of this forest for economic trees is on-going. The Oben flow station and gas plant, with associated well heads, pipeline and flowline routes constitute the industrial land take in the area.

Aside the oil production facilities (Flowstation, gas plant and wellheads) and few residential buildings, land in the entire area is basically used for subsistence farming. These are observed as designated farmlands, pilots scale model farms, and cultivated farmlands owned by individuals in the communities. The cultivation of both tree crops such rubber, Oil Palm (*Elaeis guineensis*), Plantain, Cassava and small plots of pepper are in manifested mosaic or sparse arrangements in the entire area. Importantly, there are visible presences of animal (cattle) grazing activities and are supervised by herdsmen in the entire area.
Geology/Hydrogeology and Hydrology
The study area is part of the Niger Delta Basin characterised by nearly flat topography and underlain by quaternary sands of the Somberiro plain. It is within the Deltaic Plain Belt (Sombriero-Warri) which is characterized by an extensive low-lying area dominated by fluvial systems, some with braided characteristics. The typical lithology ranges from very fine to very coarse grained sand with variable amount of quartz and feldspar minerals. The sand is unconsolidated, reddish to light coloured from top to bottom.

The altitude of the Oben Area rises slightly in excess of 50ft above mean sea level. Three (3) chrono-stratigraphic units - Agbada, Akata and Benin formation have been identified in the sedimentary building of the Niger Delta Basin. Sediment thickness in sequence in most basins was Quaternary deposits characterized with geomorphologic units.

The hydrogeological set-up is made of fine medium grain sand aquifers, which are more than 15m thick (Oben closest depth is between 46-60m). A clay layer ranging in thickness from 3.5-9.0m overlies the aquifers and the static water level at Oben is low.

Empirical Reviews
Land cover detection and delineations are data hungry, needing both historical and current land-cover maps coupled with data representing the driving forces of change. Availability of data, and temporally consistent data representing to those driving forces, is a primary challenge for Land use land cover (LULC) modeling (Parker et al., 2002; Tayyebi et al., 2008); Site-based observations may be used, but the remote sensing data have numerous characteristics. It is most notably repeated synoptic coverage with consistent observation at a relatively low cost, that make them ideal for modeling change. Direct observation and mapping of land cover with the help of remote-sensing analysis are generally critical for identifying and quantifying the major processes of change. This grid-cell-based (or raster) view of the earth’s surface offers completeness, efficient and simple processing for analysis (Crews and Walsh; 2009). Empirical diagnostic models of LULC change. It can then be developed from these observations (Mertens and Lambin; 1999). However, to understand the driving forces of such observed change, these data must be linked to socio-economic data.
(III) 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 follows the flow chart indicated in Figure 1. It integrated data from different sources and are visible presences of animal (cattle) grazing activities and are supervised by herdsmen in the entire area.

The study area is part of the Niger Delta Basin characterised by nearly flat topography and underlain by quaternary sands of the Sombriero plain. It is within the Deltaic Plain Belt (Sombriero-Warri) which is characterized by an extensive low-lying area dominated by fluvial systems, some with braided characteristics. The typical lithology ranges from very fine to very coarse grained sand with variable amount of quartz and feldspar minerals. The sand is unconsolidated, reddish to light coloured from top to bottom.

The altitude of the Oben Area rises slightly in excess of 50ft above mean sea level. Three (3) chrono-stratigraphic units - Agbada, Akata and Benin formation have been identified in the sedimentary building of the Niger Delta Basin. Sediment thickness in sequence in most basins was Quaternary deposits characterized with geomorphologic units.

The hydrogeological set-up is made of fine medium grain sand aquifers, which are more than 15m thick (Oben closest depth is between 46-60m). A clay layer ranging in thickness from 3.5-9.0m overlies the aquifers and the static water level at Oben is low.

Land cover detection and delineations are data hungry, needing both the historical and the current land-cover maps coupled with the data representing the driving forces of change. Availability of data, temporally consistent data, especially spatially and representing those driving forces, is a primary challenge for Land use land cover (LULC) modeling (Parker et al., 2002, Tayyebi et al., 2008). The site-based observations can also be used, but remote sensing data have several characteristics, most notably repeated synoptic coverage with consistent observation at a marginally low cost, that make them an ideal for modeling change. Mapping of land cover and direct observation through remote-sensing analysis are critical for identifying and quantifying the major processes of change. This raster (or grid-cell-based) view of the earth’s surface offers simplicity, completeness, and efficient processing for analysis (Crews and Walsh, 2009). An Empirical diagnostic models of LULC change may then be developed from these observations (Mertens and Lambin, 1999).
However, to understand the driving forces of such observed change, these data must be linked to socio-economic data.

Figure 1: Flow Diagram of the Study Methodology
The research design for this work formed the basis for obtaining data for land use land cover trend and subsequent. Overall, the findings used different approaches and methods to analyse the long term land use land cover changes and trends in Oben Area for a twenty eight (28) year period. The approach 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.

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.

Image Classification
Image classification procedure is used in automatically categorization of all pixels in an image into land use/cover classes or themes. Normally, the spectral pattern present within the data for each pixel and multispectral data are used to perform the classification is used as the numerical basis for categorization. That is, different feature types manifest different combinations of DNs based on their inherent spectral reflectance and remittance properties. Spectral pattern recognition refers to the family of classification procedures that utilizes this pixel-by-pixel spectral information as one of the major basis for automated land cover classification.

Spatial pattern recognition involves the categorization of image pixels on the basis of their spatial relationship with pixels surrounding them. Spatial classifiers might consider such aspects as image texture, pixel proximity, feature size, shape, directionality, repetition and context. These types of classifiers attempt to replicate the kind of spatial synthesis done by the human analyst during the visual interpretation process.
Temporal pattern recognition uses time as an aid in feature identification. In agricultural crop surveys, for example, distinct spectral and spatial changes during a growing season can permit discrimination on multi-date imagery that would be impossible given any single date.

As with the image restoration and enhancement techniques, image classifiers may be used in combination in a hybrid mode. Also, there is not a single “right” manner in which to approach of an image classification problem can be adopted. The particular approach one might take depends upon the nature of the data being analysed, the computation resources available, and the intended application of the classified data.

One means of classification smoothing involves the application of a statistical filter. In such operations a moving window is passed through the classified data set and the majority class within the window is determined. If the center pixel in the window is not the majority class, its identity has been changed to the majority class. If majority class is not available in the window, the identity of the center pixel is not changed. As the window progresses through the data set, the original class codes are continually used, not the labels as modified from the previous window positions. The classified map was prepared in this manner, applying a 3 x 3 pixel medium filter to the data.

**Table 1: land Use/Cover Classification Scheme (Anderson et al 1976)**

<table>
<thead>
<tr>
<th>S/N</th>
<th>LAND USE / COVER CATEGORIES</th>
<th>LAND USE LAND COVER DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water</td>
<td>Jamieson river, lake/ponds</td>
</tr>
<tr>
<td>2</td>
<td>Forest</td>
<td>Deciduous and evergreen and coniferous, including both protected and open forests – low land rainforest, protected areas, thicket forest areas.</td>
</tr>
<tr>
<td>3</td>
<td>Woodland / Rangeland</td>
<td>Open shrub-land, grassland and herbaceous rangelands, including sparse savanna-like vegetation cultivated with crops such cassava, yam, cocoyam, pepper, plantain , banana, citrus, rubber, palm and open animal grazing areas.</td>
</tr>
<tr>
<td>4</td>
<td>Built-up area</td>
<td>Urban, industrial, bare soil, residential, commercial, educational, settlements/Villages, infrastructures, road networks, oil and gas facilities – pipeline, flowlines, wellheads, gas plant, flowstation, open and cleared areas.</td>
</tr>
</tbody>
</table>

**Accuracy Assessment**

Assessment of the accuracy of the final images produced for the study was a vital step in the study. This involved identifying a set of sample locations and conducting field visit to the study site on Saturday 22\textsuperscript{nd} November 2014 to validate these locations. The land use land
cover found were compared to that which was mapped in the image for the same locations. Photographs were taken and coordinates of various land use/cover obtained with a GPS.

Cohen’s kappa statistic was used to measure the level in accuracies of land use/land cover classification categories.

Methods of Data Analysis

The main methods of data analysis adopted in this study include.

- Calculation of the area in kilometre square (km²) of the resulting land use/land cover types for each study year and subsequently comparing the results.
- Markov Model for predicting change
- Overlay Operations
- Maximum Likelihood Classification

The first three methods above were used for identifying change in the land use/cover types. Therefore, they have been combined in this study.

The comparison of the land cover statistics assisted in identifying the percentage change, trend and rate of change from 1987 to 2015. In achieving this, the first task was to develop a table showing the area in square kilometres and the percentage change for each year (1987, 2002 and 2015) measured against each land cover type. Percentage change to determine the trend of change is calculated by dividing observed change by the value of the preceding year and multiplied by 100.

\[
\text{(trend) percentage change} = \frac{\text{observed change}}{\text{Value of the preceding year}} \times 100
\]

In obtaining rate of change, the percentage change is divided by 100 and multiplied by the total number of years 1987 – 2015 (28 years) of the study.

Going by the second method Markov Model is a convenient tool for modelling land cover change when changes and processes in the landscape are very difficult to describe. A Markovian process is one of those in which the future state of a system can be modelled purely on the basis of the immediately preceding state. Markovian chain analysis will describe land use land cover change from one period to another and use this as the basis to project future changes. This is achieved by developing a transition probability matrix of land used to change from time one to the time two, which shows the nature of change while still serving as the basis for projecting to a later time period. The transition probability may be accurate on the basis of a per category, but there is no knowledge about
the spatial distribution of occurrences within each land use category. Hence, was used to add spatial character to the model.

RESULTS AND DISCUSSION
Presentation and Analysis of Data

The main objective of this study is to quantify the change in land cover within Oben Area using remote sensing techniques. The objective of this study constructs the foundation of all the analysis carried out. The results are presented in form of maps, charts and statistical tables. They include the static, change and projected land use/cover of each class.

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 3-5 below.

Table 2: Accuracy Total Report (2002) of Oben Area

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Reference Totals</th>
<th>Classified Totals</th>
<th>Number Correct</th>
<th>Producer’s Accuracy (%)</th>
<th>User’s Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodland / Rangeland</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>66.67</td>
<td>100.00</td>
</tr>
<tr>
<td>Forest</td>
<td>17</td>
<td>20</td>
<td>16</td>
<td>94.12</td>
<td>80.00</td>
</tr>
<tr>
<td>Water</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>100.00</td>
<td>50.00</td>
</tr>
<tr>
<td>Built up Area</td>
<td>9</td>
<td>6</td>
<td>6</td>
<td>66.67</td>
<td>100.00</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>30</td>
<td>25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Over all Classification Accuracy: = 83.3%

Kappa (k) Statistics

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodland / Rangeland</td>
<td>1.000</td>
</tr>
<tr>
<td>Forest</td>
<td>0.5385</td>
</tr>
<tr>
<td>Water</td>
<td>0.4828</td>
</tr>
<tr>
<td>Built up Area</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Overall Kappa Statistics: = 0.6988
Table 3: Accuracy Total Report (2015) of Oben Area

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Reference Totals</th>
<th>Classified Totals</th>
<th>Number Correct</th>
<th>Producer’s Accuracy (%)</th>
<th>User’s Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodland / Rangeland</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>80.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Forest</td>
<td>11</td>
<td>12</td>
<td>11</td>
<td>100.00</td>
<td>91.67</td>
</tr>
<tr>
<td>Water</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Built up Area</td>
<td>14</td>
<td>14</td>
<td>13</td>
<td>92.86</td>
<td>92.86</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>30</td>
<td>28</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Over all Classification Accuracy: \( = 93.3\%

Kappa (k) Statistics

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodland / Rangeland</td>
<td>1.000</td>
</tr>
<tr>
<td>Forest</td>
<td>0.8684</td>
</tr>
<tr>
<td>Water</td>
<td>0.000</td>
</tr>
<tr>
<td>Built up Area</td>
<td>1.8661</td>
</tr>
</tbody>
</table>

Overall Kappa Statistics: \( = 0.8913\)

Analysis of the overall accuracy assessment in Tables 2-3 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. These accuracy estimates met the minimum standards as stipulated under USGS classification scheme. According to Pontius (2000), a Kappa value higher than 0.5 can be considered as satisfactory for modeling of land use change. Landis and Koch (1977) characterized agreement for the Kappa coefficients as follows: values > 0.79 are excellent, values between 0.6 and 0.79 are substantial and values of 0.59 or less indicate moderate or poor agreement. Therefore the Kappa coefficients for the three classifications show excellent agreement with values ranging from 0.83 (1987) to 0.70 (2002) and 0.89 (2015).

**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 4. The total area under study is 237.893km².

The pattern of land cover distribution in 2015 indicated that forest occupied 45.09% of the total class, woodland/rangeland occupied 11.44% of the total class, built up area occupied 41.56% of the total class, water bodies maintain the least position in the classes with 1.91%.

Table 4: Percentage Change in Land Use Land Cover between 1987 - 2015 in Oben Area

<table>
<thead>
<tr>
<th>Land use / Cover Category</th>
<th>1987 (km²)</th>
<th>2002 (km²)</th>
<th>Change (km²)</th>
<th>(%) Change</th>
<th>2002 (km²)</th>
<th>2015 (km²)</th>
<th>Change (km²)</th>
<th>(%) Change</th>
<th>Total Change</th>
<th>Total % Change</th>
<th>Total Rate of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>411.139</td>
<td>719.4</td>
<td>-33.942</td>
<td>-82.51</td>
<td>719.4</td>
<td>4532</td>
<td>-2.662</td>
<td>-37.90</td>
<td>-4.81</td>
<td>-36.604</td>
<td>-119.51</td>
</tr>
<tr>
<td>Forest</td>
<td>161.103</td>
<td>165.63</td>
<td>4.560</td>
<td>2.75</td>
<td>165.63</td>
<td>107.2</td>
<td>58.388</td>
<td>54.43</td>
<td>-7.08</td>
<td>-53.828</td>
<td>-50.18</td>
</tr>
<tr>
<td>Woodland/Rangeland</td>
<td>24.244</td>
<td>25.026</td>
<td>0.882</td>
<td>3.52</td>
<td>25.026</td>
<td>21.89</td>
<td>3.139</td>
<td>1.04</td>
<td>2.966</td>
<td>41.14</td>
<td>1.57</td>
</tr>
<tr>
<td>Built up Area</td>
<td>11.407</td>
<td>40.100</td>
<td>28.693</td>
<td>71.55</td>
<td>40.100</td>
<td>59.44</td>
<td>19.34</td>
<td>32.98</td>
<td>8.469</td>
<td>88.46</td>
<td>18.46</td>
</tr>
</tbody>
</table>
Plate 1: Luxuriant forest vegetation

Plate 2: Forest regrowth showing an undifferentiated structure of herbs, shrubs and isolated trees.
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. Result of the analysis is presented in **Figures 2 and 3**.

**Figure 2: Land use/Cover Classification of Oben Area for 1987**
Looking at Figures 2 and 3 in terms of location of change, urban/industrial area (built up area) change between 1987, 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. Built up areas are predominantly located in open bare soil away from forested areas. Woodland/rangeland are predominately located in the northwest northeast and south in 1987, while in 2002 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 Jemison river straddling from north east to south west with part of the entire north west to south west under water in 1987, by 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.

Forested areas is observed spread across Oben Area as at 1987 and 2002, by 2015 forest areas are observed shrinking from the southern part of Oben, this part is taken over by built up/industrial, bare soil and rangeland/woodland areas. Hence, forest area is observed being restricted to the fringes in north east corner of Oben Area.

**Land Use/Cover Change: Magnitude of Change**

Table 5: Transitional Probability of Land Use/Cover of Oben Area between 1987-2015 (km²)

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Water</th>
<th>Forest</th>
<th>Woodland / Rangeland</th>
<th>Built up Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.76</td>
<td>19.83</td>
<td>7.36</td>
<td>11.75</td>
</tr>
<tr>
<td>Forest</td>
<td>0.02</td>
<td>73.70</td>
<td>16.84</td>
<td>68.83</td>
</tr>
<tr>
<td>Woodland / Rangeland</td>
<td>0.00</td>
<td>10.55</td>
<td>2.61</td>
<td>10.59</td>
</tr>
<tr>
<td>Built up Area</td>
<td>7.71</td>
<td>3.20</td>
<td>0.41</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The result indicated a transition/modification in land use land cover from one category to another in Oben between 1987 – 2015. The matrix indicated that the total water covered area change/converted to forest area was 19.83km², while total converted to woodland/range was 7.36km² and total coverage converted to built-up area was 11.75km². However, water retained its status over an area covering 1.76km² within the same period.

For forest the striking issue was that total forest area that remained forest area stood at 73.70km², forest areas converted to woodland/rangeland cover an area of 16.84km² while 68.83km² of forest area was converted to built-up areas.

Total woodland/rangeland converted to forest was 10.55km², it remained woodland/rangeland at 2.61km² and total converted to built-up areas within the same period stood at about 10.59km².
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$^2$.

**Land Use/Cover Projection**

The transition probability matrix records the probability that each of the land cover category will be changed to the other category. This matrix has been produced by the multiplication of each column in the transition probability matrix be the number of cells of corresponding land use land cover in the later image.

Table 6: Land Use/Cover Projection in Oben Area for 2035 (20yrs)

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Water</th>
<th>Forest</th>
<th>Woodland / Rangeland</th>
<th>Built up Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0.0152</td>
<td>0.5279</td>
<td>0.1670</td>
<td>0.2688</td>
</tr>
<tr>
<td>Forest</td>
<td>0.0091</td>
<td>0.4566</td>
<td>0.1099</td>
<td>0.4116</td>
</tr>
<tr>
<td>Woodland / Rangeland</td>
<td>0.0023</td>
<td>0.4536</td>
<td>0.1396</td>
<td>0.3816</td>
</tr>
<tr>
<td>Built up Area</td>
<td>0.0006</td>
<td>0.3540</td>
<td>0.0849</td>
<td>0.5560</td>
</tr>
</tbody>
</table>

As observed in Table 6, as we progressed through year 2035, water has a 0.0152 probability of remaining water and a 0.5279 of drying up within the forest areas in 2035. This is also an indication of an undesirable change (reduction), with a probability of change which is much higher than stability. Forest area during this period has 0.1099 probability of being converted to woodland/rangeland and a probability of 0.4116 of changing to built-up area in 2035. On the other hand, the woodland/rangeland has a probability of 0.3816 of changing to built-up area. Built-up land area has a probability as high as 0.5560 in 2035 which signifies stable growth in urban/industrial/bare soil area of Oben Area.

The findings of the research are:

Drivers of the land use land cover change in Oben Area include E&P development activities, demographic factors, infrastructural development, agricultural practices and economic factors.

The projections of future land use/cover changes on the basis of a Markov model showed a trend of increase in built up and woodland/rangeland and a continued decline in forests and water covers within Oben Area.

REFERENCES


C. Petit, T. Scudder and E. Lambin, 2000. Quantifying processes of land-cover change by remote sensing: resettlement and rapid land-cover changes in south-eastern Zambia, Department of Geography, Universite´ catholique de Louvain, place Louis Pasteur, 3, B-1348 Louvain-La-Neuve, Belgium 2 California Institute of Technology, Division of the Humanities and Social Sciences, 228-77, Pasadena, California 91125, USA.


SPDC, 2010: An Environmental Evaluation Report (Draft) for Oben Flowstation and Gas Plant Chptr 4 - Pg.11-34.


