Assessment of Land Use/Land Cover Detection and Its Impact on the Human Environment Using Geospatial Techniques in the University of Port Harcourt Host Communities, Nigeria

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Authors’ contributions

This work was carried out in collaboration between both authors. Author CHW designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author OSE managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

ABSTRACT

This study examines the use of GIS and Remote Sensing in Mapping Land Use/Land Cover changes in the University of Port Harcourt host communities, mainly Choba, Aluu and Alakahia, between 2005-2010 and 2010-2015, to recognise the changes that have taken place in these peri-urban areas within the period of study. The study aim is to detect and map the land use/land cover of the area over a period of 10 years (2005-2015). Three data set of Landsat Satellite images were layer-stacked, after which supervised classification in EARDAS imagine software was carried out and mapping in Arc GIS software were carried out. Five land use and land cover categories were distinguished: built-up areas, cultivation, vegetation, and water body. The results of the study show rapid growth in built-up land between 2010 and 2015, whereas the periods between 2005 and 2010 witnessed an increase in this class also. The rapid increase in built-up areas revealed by the

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study is due to the rapid urbanization and industrialization in the peri-urban area. It was further observed that the increasing population of students in the area brings about much more demand on housing, which resulted in a great detrimental effect on the land cover of the area in recent years. The study, therefore, recommends, amongst others, the regulation of land use in the peri-urban area, encouragement of afforestation by government and other critical stakeholders, and provision of a mitigating control measure to realistically address the contemporary issues of rapid urbanization in the peri-urban areas.

Keywords: Land use/land cover; peri-urban; geographic information system; remote sensing; Uman impact; environment.

1. INTRODUCTION

Land use/Land cover (LULC) change is one of the major challenges that impacts on the natural landscape. It is also the primary driving force of global environmental change and significant to sustainable development debate [1,2]. Causes and consequences of land-use change at the physical and social surroundings have been a research topic over a decade [3]. These consist of their effects on wetland/water quality, land and air resources, surroundings, ecosystem processes and function, weather change [1], biodiversity [4], soil degradation [5] and the potential of natural systems to support existence [6,2].

Over the years, further studies and research has shown that very few landforms or landscapes across the globe still exist in their natural or pristine state. However, increase in the human population, industrialization, urbanization and anthropogenic activities have intensified the pressure on natural resources and has become a major driving force to the shift that Land-use and Land-Cover have experienced [7]. Awoniran et al. [8] explained that Land-use and Land-Cover change is a key subject of study, according to the International Global Environmental Change Research Community, because it equips the intellectual community with large volume of data on changes in carbon storage and sequestration by plants and it also opens up a new frontier into understanding the human dimension of environmental change. The Land-use and Land-cover change detection research is a product of global determination to detect, predict, analyse and manage activities such as urbanization deforestation etc. that are ecologically damaging or altering Land-use [9].

Remote Sensing (RS) and Geographic Information Systems (GIS) are powerful tools to derive accurate and timely information on the spatial distribution of land cover/land use changes over large areas. GIS provides a flexible environment for collecting, storing, displaying and analysing digital data necessary for change detection [10]. Mmom et al. [11] examined the land use and land cover changes in Port Harcourt metropolis and its environs using GIS and RS techniques. The authors came up with the assertion that an analysis of land use/land cover changes are essentially the analysis of the relationship between man and land. Land use and land cover changes have become a central component in current strategies in managing natural resources and monitoring environmental changes.

The land use and land cover of a region is a reflection of the level of development in that region, hence LULC changes become essential in monitoring the development of a particular area. Achionye et al. [9] also studied land-use and land-cover transition of Warri vegetation zone of the Niger Delta region over the last four decades using Landsat imageries of 1975, 1987 and 2015 with the aid of RS and GIS techniques. The study area covered 187 km$^2$ and four LULC types where analysed, namely mangrove, non-mangrove, water body and urban area. The results showed that in 1975, on a total area of 187 km$^2$, mangrove covered 33.8%, non-mangrove 46.5%, water bodies 5.2% and urban settlements 14.4%. In 2015, mangrove covered 20.1%, non-mangrove 24.4%, water bodies 10% and urban settlements 45.3%. The results show a rapid and haphazard increase in urban areas and a reduction in mangrove and non-mangrove vegetation. This is a result of urbanization, oil and gas exploration and other anthropogenic activities.

RS imagery is the most important data resource for GIS. The satellite imagery can be used for recognition of synoptic data of earth’s surface. The change detection process aims to recognize land use on digital images that change features of interest between two or more dates. There are
many change detection techniques such as post-classification comparison, conventional image differentiation, using image ratio, image regression, manual on-screen digitization of change, principal components analysis and multi-date image classification.

But, the availability of free geographical data and open source GIS that can be accessed freely on the internet can address part of the problem of which technique to use. To detect the land-use change of Devak catchment, [12] produced a LULC map of the catchment by classifying a false colour composite (FCC) image of the study area. This was implemented using RS and GIS techniques. They discovered changes from one land use to another. For example, the results of their study showed that 76% of erstwhile open scrubland was replaced with forest and agriculture over the period of study.

The understanding of land-use/land cover changes has moved from simplicity to realism and complexity over the last decades. In the beginning, the studies were concerned mostly with the physical aspect of the change, but later, they have been put on the research agenda on global environmental change. Scientists realized that land surface processes influence climate because of the land use/cover change. In mid 1970s, it was recognized that land cover changes modifies surface albedo and thus surface-atmosphere energy exchanges, which have an impact on regional climate [13,14,15]. A much broader range of impacts of land-use/cover change on ecosystems, goods and services was further identified. Of primary concern are the impacts on biodiversity worldwide [16], soil degradation [5], and the ability of biological systems to support human needs [6].

Historically, humans have been modifying land to obtain the essentials for their survival, but the rate of exploitation was not the same as it is today. The recent rapid rate of exploitation has brought unprecedented changes in ecosystems and environmental processes at local, regional and global scales. Presently, LULC changes encompass the environmental concerns of the human population including climate change, biodiversity depletion and pollution of water, soil and air. Today, monitoring and mitigating the adverse consequences of LULC changes while sustaining the production of essential resources, has become a major priority of researchers and policymakers around the world [17]. Unsustainable human activities are becoming a key environmental concern as they deteriorate the quality of water in the environment. The relationship between land use and water quality helps in identifying threats to water quality and builds an understanding about ‘access’ to sanitation which is crucial for human survival [18].

The study is aimed at detecting and mapping the LULC of the University of Port Harcourt host communities, Rivers State, over a period of 10 years (2005-2015), to trace the transition of land use and land cover changes over the years and finding out the state of five land use and land cover categories, which are bare land, built-up areas, cultivation, vegetation, and water body. The University of Port Harcourt host communities include but not limited to Choba, Aluu and Alakahia, which are peri-urban areas.

2. MATERIALS AND METHODS

To carry out this study, the Land Viewer App was used to extract Landsat satellite images of three different years, 2005, 2010 and 2015. These Landsat images were obtained from USGS (U.S Geological Survey) and EOS (Earth Observing System) land viewer for real-time analysis. A high-resolution satellite image of the University of Port Harcourt host communities was also obtained from Google Earth and Google Earth Pro. Based on both the prior knowledge of the study area for over 10 years and a brief fieldwork and additional oral interviews in the study area, a classification scheme was developed and five classes were used for the classification.

Six main methods of data analysis were adopted in this study to identify changes in the land use types. Calculation of the area in hectares of the resulting LULC types for each study year and subsequently comparing results, Overlay operation, Image recoding, Maximum likelihood classification (supervised classification), Layer stacking/band combination and Signature creation/editing. Therefore, the various methods above and some others that are not listed were combined in this study.

The comparison of the LULC statistics assisted in identifying the percentage change, trend and rate of change between 2005 and 2010, 2010 and 2015. Trend Percentage Change = (Observed Change/ Sum of Change) x 100. Four applications were used for the study and they are as follows: ArcGIS 10.4, Erdas imagine, SPSS and Microsoft word.
To illustrate the whole methodology adopted in this study, a flow chart is presented in Fig. 1.

3. STUDY AREA

3.1 Location/Extent

The University of Port Harcourt is located in Choba, Aluu and Alakahia, which are peri-urban areas of Rivers State, Nigeria (See Figs. 2 and 3). The University has three campuses. The three campuses are Choba campus, Abuja (Main) campus and Delta campus. These campuses have a boundary with the three main host communities of the University. The University of Port Harcourt host communities include Aluu with latitude 4°56'1.65"N and longitude 6°56'37.58"E with an elevation of 24 m and eye altitude 106 m. The second main host community of the University of Port Harcourt is Alakahia with latitude 4°53'6.51"N, longitude 6°55'30.01"E, elevation 14 m, and eye altitude 2.58 km. The third main host community is Choba with latitude 4°53'51.30"N, longitude 6°54'26.93"E, elevation 14 m and eye altitude 1.07 km.

The University of Port Harcourt host communities are drained by a river known as "New Calabar River". The study area enjoys a tropical hot monsoon climate as a result of its latitudinal position. The daily tropical monsoon climate is characterized by heavy rainfall and high temperature all year round [19]. The Community experiences lengthy and heavy rainfall season and very short dry season. Rainfall in the study area is heavy and persistent as a result of the strong influence of the southwest trade wind, and it follows an almost predictable sequence of increase towards July-September before decreasing in November – February [19,20]. Rainfall has its peak in July and September with a little dry season occurring in August, although the period of the break has been fluctuating in recent times. University of Port Harcourt host communities also experience
a double maximum rainfall between July and August. Although there might be some rain during the months of December, January and February, most of them are unreliable [21,20].
Rainfall in the study area occurs over a long duration of usually between 2-4 hours and it is high in intensity [21].

The temperature, on the other hand, is high and fairly constant throughout the year in the area. February is the warmest of all the months of the year with an average temperature of 32°C at noon. Like Port Harcourt, mean annual temperature in the study area is based on 28°C while the mean daily maximum temperature is about 30°C. The months of February, March and April record the highest mean maximum temperatures. The maximum temperature also exhibits the same sequence [21,20].

In addition to these, the University of Port Harcourt host Communities experience a seasonal variation in relative humidity. This is mainly due to the seasonal variation in the amount of isolation received. The relative humidity is high in the area with a mean annual value of about 80%. The rainy season months record the highest values. These months are very cloudy due to the strong presence of the south-westerly wind [21,20].

4. RESULTS AND DISCUSSION

4.1 Visual Presentation of the Detected Changes with Image Maps

This part of the study has to do with the visual presentation of the detected changes in the Landsat images used in the study for the three years sampled, 2005, 2010 and 2015 (Figs. 4-6, respectively).

In Fig. 4, light green colour represents the bare land, the red colour represents the built-up area, which was very minimal in the University host communities in 2005, the yellow colour represents farmland that is very noticeable and depicts the extent of farmland around the area, the green colour represents forest that is also minimal around the study area, and lastly, the blue colour represents swamps which are very noticeable in the western part of the study area and mostly dominate that part of the peri-urban area.

Fig. 5 shows that there is a reduction in the bare ground in 2010. Moreover, there is a conspicuous increase in the built-up area, due to the rapid inflow of people in the peri-urban area as a result of urbanization and needs to accommodate more students in the University host communities. In contrast, there is a reduction in farmland and the causes may be attributed to the increasing population of students, rapid urbanization and submersion of the swamp around the University host communities. There is also a great reduction in the forest, and lastly there is a remarkable increase in the swampy area. The noticeably increase in the swampy area was caused by the flood that occurred in 2010 leading to the submerging of substantial parts of the area by water, which was also the case in most parts of River State.

This result is consistent with the study of [22,23]. Prakasam [24] study of LULC changes in Kodaikanal taluk, Tamil Nadu tends to also support this result.

It is visible from Fig. 6 that in 2015 there is a remarkable increase in built-up areas and a reduction of farmland. In addition, there is a very minimal presence of bare land. This is due to an increased population in this area that ultimately led to a high demand for housing and other peri-urban infrastructural projects in the area. Interestingly, there is also a great decrease of swamp that has been displaced inside farmland and some dispersed built-up areas. The study of Fabiyi [25] on Ibadan metropolitan area of Nigeria corroborates the result of this study.

Comparing the extent of built-up areas from 2005 to 2010, 2010 to 2015 and 2005 to 2015, the results reveal remarkable change and visible pattern in built-up areas (Figs. 7-9).

In Fig. 7, the built-up areas in both 2005, in red and 2010, in yellow, are showed. It is evident an increase in built-up area from 2005 to 2010 and the map also visualizes the variation of built-up areas in the peri-urban neighbourhoods.

Fig. 8 shows the extent of built-up areas in both 2010, in yellow and 2015, in green. This map reveals and explains the extent and variation in built-up areas in the two years respectively.

The result of the study as shown in Fig. 9 helps to visualize the extent of built-up areas from the year 2005, in red colour, to 2010, in yellow and to 2015, in green colour. The map shows a remarkable change in built-up area within the period under review. The built-up areas in 2015 are very remarkable and can be attributed to the rapid suburbanization and the location of the University of Port Harcourt and other industrial
activities within the three major host communities. This result tends to agree with the survey of Mmom et al., 2013, Wizor and Wali, 2019 and Achionye et al., 2018.

Fig. 4. 2005 landsat image of the University of Port Harcourt host communities

Fig. 5. 2010 landsat image of the University of Port Harcourt host communities
Fig. 6. Landsat image of University of Port Harcourt host communities in 2015

Fig. 7. Map showing the extent and detection of the built-up area from 2005-2010
4.2 Land Use Land Cover Distribution Statistics

The static LULC distributions for each study year as derived from the maps are reported in Table 1. They represent the statistics of each LULC category for each study year. The results are further shown in Figs. 10-12 for visual clarity.
Table 1. LULC distribution Table for 2005, 2010 and 2015 respectively

<table>
<thead>
<tr>
<th>Class</th>
<th>2005 image area (Km²)</th>
<th>%</th>
<th>2010 image area (Km²)</th>
<th>%</th>
<th>2015 image area (Km²)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare land</td>
<td>537.34298</td>
<td>20.05</td>
<td>405.511</td>
<td>15.13</td>
<td>770.35298</td>
<td>28.74</td>
</tr>
<tr>
<td>Built-Up</td>
<td>170.2512</td>
<td>6.35</td>
<td>303.9419</td>
<td>11.34</td>
<td>507.36285</td>
<td>18.93</td>
</tr>
<tr>
<td>Farmland</td>
<td>750.24675</td>
<td>28.0</td>
<td>504.2448</td>
<td>18.81</td>
<td>612.5481</td>
<td>28.85</td>
</tr>
<tr>
<td>Swamp</td>
<td>562.9734</td>
<td>21.0</td>
<td>757.5525</td>
<td>28.26</td>
<td>250.22318</td>
<td>9.33</td>
</tr>
<tr>
<td>Vegetation</td>
<td>659.67233</td>
<td>24.6</td>
<td>709.2365</td>
<td>26.46</td>
<td>539.99955</td>
<td>20.15</td>
</tr>
<tr>
<td>Total</td>
<td>2680.4867</td>
<td>100</td>
<td>2680.4867</td>
<td>100</td>
<td>2680.4867</td>
<td>100</td>
</tr>
</tbody>
</table>

Fig. 10. LULC distribution of University of Port Harcourt host communities in 2005

Fig. 11. Land cover distribution of the University of Port Harcourt host communities in the year 2010
Fig. 12. Land cover distribution of the University of Port Harcourt host communities in the year 2015

Fig. 13. Different LULC distribution in 2005, 2010 and 2015

<table>
<thead>
<tr>
<th>Class</th>
<th>2005-2010 (Km$^2$)</th>
<th>2010-2015 (Km$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare land</td>
<td>-131.832</td>
<td>364.842</td>
</tr>
<tr>
<td>Built-Up</td>
<td>133.6907</td>
<td>203.4209</td>
</tr>
<tr>
<td>Farmland</td>
<td>-246.002</td>
<td>108.3033</td>
</tr>
<tr>
<td>Swamp</td>
<td>194.5791</td>
<td>-507.329</td>
</tr>
<tr>
<td>Vegetation</td>
<td>49.56413</td>
<td>-169.237</td>
</tr>
</tbody>
</table>
In the year 2005, as shown in Fig. 10, the bare ground was 20.05% of the total area. This is due to the low population density around the University host communities in that period, which gave room to spacious land. Indeed, the built-up area occupied 6.35% of the total area due to low population density in the area as at that period. The results also show a remarkable farmland area occupying 28% of the total area, which is likely because the main source of livelihood of the University host communities’ dwellers in the year 2005 was mainly agriculture. The swamp area also occupied 21% the of the total area. It is also noticeable that vegetation cover in 2005 is about 24.6% of the total land area of about 2680.4867 km².

Fig. 11 shows the situation in 2010. The bare ground reduced to 15.13% due to an increase in population density and demand for residential buildings and other housing infrastructures. The built-up areas expectedly increased to 11.34% whereas the farmland reduced drastically to 18.81%. Due to a flooding occurrence in 2010, the swamp area increased drastically to 28.26%, submerging some of the surrounding areas during the period. Vegetation also increased to 26.46%.

This successfully explains the variation in the change detection of LULC dynamics in these peri-urban areas.

In the year 2015, however, there was a renewed increase in bare land due to deforestation aimed at further building and industrial activities that occur in the study area. The results also revealed a conspicuous increase in built-up areas, and a very remarkable decrease in swamp areas. Surprisingly, farmland areas increased as well in 2015 (Fig. 12).

4.3 Land Use Land Cover Change Detection

Table 2 shows that there is a great reduction in the bare ground from the year 2005 to the year 2010 with a decrease of -131.82 km² and there is an increase in the bare ground from 2010 to 2015 with an increase of 364 km². The built-up area increased from 2005 to 2010 to about 133 km² and further increased from 2010 to 2015 to 203.42 km². The farmland decreased of -246 km² in the years 2005 to 2010 and later increased to 108 km² in the years 2010 to 2015. Moreover, there is a remarkable increase in the swampy area with 194 km² in the years 2005 to 2010, which is at the peak and later decreases drastically with about -507 km² from 2010 to 2015. Also, the vegetative cover increases to 49 km² within the years 2005 to 2010 and reduces drastically with -169 km² in the years 2010 to 2015.
Figs. 13 and 14 show the different LULC distribution and the relative changes in land/use land cover, in the study period.

5. CONCLUSION AND RECOMMENDATIONS

The study demonstrates the ability of GIS and RS in capturing spatio-temporal data. An attempt was made to capture as accurate as possible five LULC classes as they change over time in the University of Port Harcourt host communities. The five classes were distinctly produced for each study year but with more emphasis on built-up land as it is a combination of anthropogenic activities that make up this class; and indeed, it is one class that affects the other classes. In achieving this, LULC distribution and change detection as well as percentages of change were introduced into the research work to show the extent of land degradation arising from rapid urbanization and increase in the population of student around the University of Port Harcourt host communities. Interestingly, the results of the work show rapid growth in built-up land between 2005 and 2010 and also in 2010 and 2015. From the change detected in the study and current observations, it is obvious that the built-up areas will continually increase. It was also observed that areas covered by vegetation have been continually reducing due to cultivation arising from the rapid increase in population. Consequently, it is pertinent that the leaders in the two Local Government Areas (Obio/Akpor and Ikwerre) and the University authority must take into cognizance the LULC changes that are occurring in the study area. This will enable the authorities to plan effectively for the people living in the University host communities and to further reduce environmental degradation around the area.

Consequently, the following recommendations are made:

1. There should be a development control measure on urban sprawl by relevant government agencies to stop further destruction of agricultural land, as this will have serious repercussions on food production and food security.
2. An integrated assessment of LULC change mapping and spatial and temporal modelling works should be done. The task has to integrate remote sensing, spatial metric tools and socio-economic data to manage urban and peri-urban.
3. There should be constant monitoring of LULC in the University of Port Harcourt host communities using geographic information system and Remote Sensing to know the extent, rate and direction of change for effective land management and planning.
4. The local town planning authorities in these peri-urban areas should ensure development control by strictly ensuring plan approvals for all real development projects.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES