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Analysis of Land Use and Land Cover Changes in Owerri Municipal and Its Environs, Imo State, Nigeria (2005 – 2015)

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Authors' contributions

This work was carried out in collaboration among all authors. Author EE expanded the analytical framework, enhanced more review of relevant literature while supervising the production of current digital maps that are in keeping with the land use dynamics in the study area. Author FMDO supervised the field work and spatially identified the various land use/land cover changes in the area. Author OF implored current digital approaches to produce all the maps and their step-by-step methodologies. Author AS readjusted the topic and reviewed some literature while editing the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Land use/land cover changes in Owerri Municipal and its environs which included Orogwe, Ubomiri, Emii, Uratta, Ihiagwa and Egbu were studied as being driven by rapid population growth for urbanisation. The study applied the digital technology of Remote Sensing and Geographic Information System (ARC GIS 9.3 Version software). These tools were implored to generate land use/land cover maps for the period; 2005, 2010 and 2015 and to determine the area in km^2 of each of the six classes of land use/land cover types, the percentage change of the total area covered, accuracy of the overall classification including the Kappa coefficient, while a classification scheme was used to develop the classified land use/land cover maps. Also satellite imagery for the period (2005-2015) was imputed into the ENVI 4.5 software environment, composited, digitized and exported to the Arc. GIS where they were clipped with the study area. The extracted image of the study area was then exported back to the ENVI 4.5 environment for Arc.GIS environment in TIFF format. This was followed by a colour separation in the imagery repeated for all the raw satellite imagery. Image interpretation was done on ENVI 4.5 software based on a set of pixels of the Region Of Interest (ROI). Results are that Kappa coefficient values were high enough for the period of study with 0.9099, 0.9557 and 0.9685 for 2005, 2010 and 2015 respectively indicating a strong agreement between the classified maps and ground referenced information. Integrating GIS and satellite remote sensing with high spectral, spatial and temporal resolution at the local scale to develop urban environmental monitoring, effective land use planning and management of the current growth pattern were among others recommended.

Keywords: Land use; land cover; remote sensing; GIS; change; classification.

1. INTRODUCTION

“Globally, it has been observed that the impact of human activities on land has grown enormously, altering the entire landscape and impacting the earth’s nutrient and hydrological cycles as well as climate. Land use denotes how humans use the biophysical and ecological properties of land for agriculture, settlement, forestry and other uses including those that exclude humans as in the designation of natural reserves for conservation” [1]. “Land use is the function of land and the overall use to which it is put. In any case, the use to which the land is put globally varies from place to place” [2]. “The United Nations Food and Agricultural Organization (Water Development Division) explains that land use concerns the products and/or benefits obtained from the use of the land as well as the land management actions (activities) carried out by humans to produce those products and benefits. Land use describes the use of the land by the people usually with emphasis on the functional role of the land in economic activities and man’s activities which are directly related to the land” [3].

“Land cover on the other hand, refers to the physical material at the surface of the earth. This refers to the vegetation (natural and artificial), water, bare rock, sand and similar surface and man-made construction on the earth’s surface” [4]. “However, when man changes the activities on the land to another one, it becomes land use change. Land Use/Land Cover Change (LULCC) is a general term for the human modification of the earth’s terrestrial surface. The land use/land cover changes are caused by the mismanagement of agricultural, urban, range and forest lands which lead to severe environmental problems” [4]. “Land use/land cover has become increasingly important as Nigeria as a nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands and loss of fish and wildlife habitat. One of the prerequisites for better use of land is information on existing land use/land cover patterns and changes through time. Knowledge of the present distribution and area of such agricultural, recreational and urban lands as well as information on their changing proportions is needed by planners to determine better land use policies to project transportation and utility demand, to identify future development pressure points and areas and to implement effective plans for regional and national development” [5].

“Land use/land cover change is a strong indicator of ecosystems disturbances and global change processes especially in the tropics. It is probably the most significant anthropogenic and natural disturbance to the environment. Therefore, land use/land cover changes are products of prevailing interacting natural and anthropogenic processes and trade-offs among ecosystem services" [5]. They are central to environmental processes, environmental change and environmental management through their influence on biodiversity, water budget, trace gas emissions, carbon cycling, livelihoods and a wide range of socio-economic and ecological processes.

Urbanization which entails the conversion of a rural area or an area set aside for other land uses to efficient and improvement in modern facilities like good transport network, deforestation of areas for urban infrastructure including institutional and recreational uses presents many challenges for the farmers on the urban and rural fringes. Conflicts with non-farm neighbours and vandalism such as destruction of crops and damages to farm equipment are major concerns of farmers at the urban fringe [6]. Neighbouring farmers often cooperate in production activities- equipment sharing, land renting and irrigation system development. These benefits and synergy disappear whenever neighbouring farms are converted to development. Farmers may no longer be able to benefit from information sharing and formal and informal business relationships among neighbouring farms. Urbanization may also cause a lack of confidence in the stability and long-run profitability of farming, leading to a reduction in investment in new technology or machinery or idling of farmland [7].

Land use change- deforestation for example along with urban sprawl, agriculture and other forms of human activities has substantially altered and fragmented the earth's vegetation cover. Such disturbance can change the global atmospheric concentration of carbon dioxide- the principal heat trapping gas, as well as affect local, regional and global climate by changing the energy balance on the earth's surface [8]. For urban development and infrastructure, their linking environmental problems are air pollution, water pollution, and loss of wildlife habitat. Urban runoff often contains nutrients, sediment and toxic contaminants, and can cause not only water pollution but also large variation in stream flow and temperatures. Habitat destruction, fragmentation and alteration associated with urban development have been identified as the leading causes of biodiversity decline and species extinction [9,10]. Also in the coastal areas of the world, urbanization and intensive agriculture are major threats to the health, productivity and biodiversity of the marine environment.

"Land use/land cover changes have become the main cause of ecosystem service change at the global scale and Africa is experiencing substantial changes across the continent" [11-14]. "In recent decades, African grassland, woodland, bush land and other vegetation covers have been transformed into agriculture and settlement area" [15,16]. "In Africa, 5% of woodlands and grasslands and 16% of natural forest cover have disappeared during the period from 1975 to 2000; and more than 50,000km^2 of natural vegetation is lost per year" [17]. "LULC changes are the result of a multidimensional interaction among institutional, socioeconomic and environmental dynamics" [18-21]. "Limited technology and livelihood options have aggravated the competition between different land uses while government policy and tenure insecurity have also played a significant role [14,22,19] as LULC plays significant roles in spatio-temporal environmental stability with its linkage with local, regional and global climate conditions, carbon cycle, biodiversity stability, clean water, agriculture and food security" [23-25].

"Recently GIS and RS have been extensively used in LULC mapping and change detection across the world" [13, 18, 21, 26, 27]. "Moreover, advances in RS such as the use of digital image processing algorithms have increased the use of satellite imagery such as landsat data in studies concerned with LULC changes across multiple spatial and temporal scales" [27,28].

While some believe that land use planning protects farmland, forests, water quality, open space and wildlife habitat, and at the same time, increases property value and human health, others argue that uncontrolled development will destroy the natural environment and long-term economic growth.

The main rationale behind this study is that population growth for urbanisation has brought about changes in land use/land cover in Owerri and its environs which altogether are increasing development points in the south-eastern geo-political zone of Nigeria. This development has prompted reckless and indiscriminate deforestation while the lack of utility maps has contributed to failure of effective land use management in the face of increasing population.

This study set to analyse the spatio-temporal land use/land cover change patterns using multi-temporal land-sat imagery between 2005 and 2015 in Owerri municipality and its environs. This is in a bid to uphold on a spatiotemporal basis, life on land as part of the Sustainable Development Goals of protecting, restoring and promoting sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is Owerri municipality and its environs which the satellite data covered. These surrounding environs included; Orogwe, Ubomiri, Orji, Owelu, Uratta, Umunahu, Ihite Akalovo, Azaraegbelu, Awaka, Emekuku, Emii, Naze, Abala, Amaeze, Emekeobibi, Ulakwo, Umunam, Amorie, Obinze, Ihiagwa, Umuoma, Nekede, Irete and Egbu. The area is located between latitude; 5^0; 23^1 and 5^0; 25^1 N of the equator, and longitude; $7^0 2^1$ and $14^0 90^1$ E of the Greenwich Meridian (Fig. 1). The vegetation is typical of the tropical rainforest with luxuriant floral complexes [29]. Some of the vegetation have been transformed to guinea savannah due to increasing land use demands leading to poor environmental quality [30]. The climate is in the humid tropical zone as described by Koppen's classification having a mean annual rainfall of between 2,250 and 2500m with a mean monthly temperature of between 25^oC and 27^oC. Relative humidity is over 78% in the rainy season while rainfall is of the double maxima between the onset and cessation annually [29].

2.2 Methodology

Satellite imagery of 2005, 2010 and 2015 of the study area were obtained from landsat global land use/land cover facility and processed using the Arc.GIS 9.3 version software to yield their respective land use/land cover classified maps for the analysis. Remote sensing and GIS were used to generate land use/land cover maps for the period – 2005, 2010 and 2015. These were used to determine the area in square kilometres of each of six classes of land use/land cover type, percentage change of the total area covered of the six different land use/land cover types, accuracy of the overall classification including the Kappa co-efficient, while a classification scheme was used to develop the classified land use/land cover maps. Also generations were made to several categories to obtain consistent land use/land cover classes over the period (see Table 1).

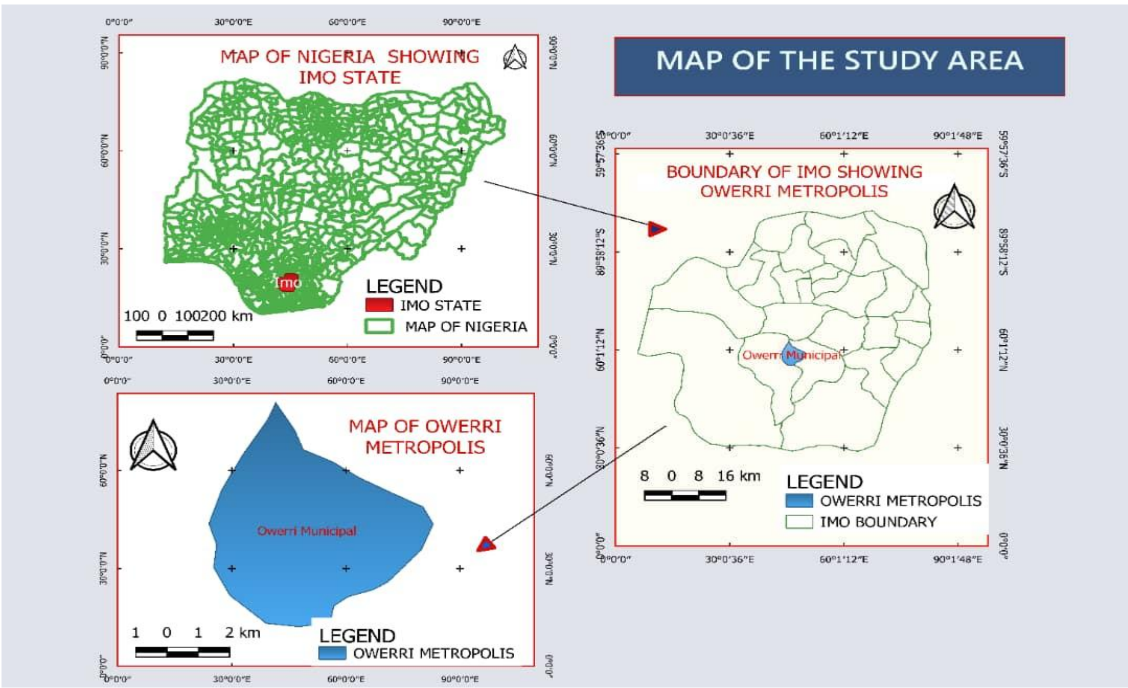

Fig. 1. Study area

Table 1. Land use/land cover classification scheme and their general description

Classes	Description
Built up area	Residential, Commercial, Industrial, facilities etc
Open space	Open land and non-vegetated land
Forest	Evergreen forest and mixed forests with higher density of trees
Farmland	All types of agriculture practice
Vegetation	Mangrove, sparse vegetation etc
Water bodies	Rivers, ponds, lagoons, dams and waterlogged areas

Satellite imagery for the years 2005, 2010 and 2015 were imported into the ENVI 4.5 software environment, composited, digitized and exported to the ARC GIS where they were clipped with the study area. The output of this operation became an extract of the study area fully geo-referenced in the coordinate systems in the three image bands. The extracted image of the study areas was then exported back to the ENVI 4.5 environment from the Arc. GIS environment in TIFF format. This was followed by colour separation operation in the imagery respectively repeated for all the raw satellite imagery. This was followed by building the colour composites of the imagery using compositions of different bands until the result is a close colour to the true colour is achieved (RGB; 4.3.2). As a result, the classified land use/land cover map of the study area for 2005, 2010 and 2015 is produced.

Image interpretation was done on ENVI 4.5 software based on a set of pixels of the Region Of Interest (RO1) as classified before. This was done to identify the pixels with similar spectral characteristics. With the maximum likelihood classification algorithm, the classification accuracy was detected by looking at each layer in each spectrum channel as the standard distribution. For the extent of land use/land cover change in the area these variables were developed and computed;

- Total area (Ta)
- Change area (Ca)
- Change extent (Ce)
- Annual rate of change (Cr)

These variables were described by the following formula;

$Ca = Ta\,(t2) - Ta\,(t1);$
$Ce = Ca/Ta(t1);$
$Cr = Ce/(t2-t1)$

Where; t1 and t2 are the beginning and ending time of the Land cover studies conducted.

Also, accuracy of the images and their Kappa coefficient were assessed through crossing the sample sets and the classified images. Confusion matrix operation was performed on the ENVI 4.5 application software which houses it.

3. RESULTS

Accuracy of the classified images was calculated from the confusion matrix in the ENVI 4.5 software environment. Within the period of study, 2005 had an accuracy of 97.22% with a Kappa coefficient of 0.9099, 2010 had an accuracy of 97.75% with Kappa coefficient of 0.9557 while 2015 had 98.41% and 0.9685 for accuracy and kappa coefficient respectively (see Table 2).

- Kappa value < 0.20 (poor agreement)
- Kappa value between 0.20 and 0.40 (fair agreement)
- Kappa value between 0.40 and 0.60 (moderate agreement)
- Kappa value between 0.60 and 0.80 (good agreement)
- Kappa value between 0.80 and 1.00 (very good agreement)

Since the entire Kappa coefficients of the years in consideration were greater than 0.80, then there is strong agreement between the classified maps and the ground referenced information.

Table 2. Summary of overall classification summary

Year	Overall Classification accuracy %	Overall Kappa coefficient
2005	97.22	0.9099
2010	97.75	0.9557
2015	98.41	0.9685

Table 3. Overall amount, extent and rate of land use/land cover change from 2005 – 2015

Land use/ Land Cover	Ta (Km^2) 2005	Ta(Km^2) 2010	Ta(Km^2) 2015	Ca(Km^2) 2005-2010	Ce 2005-2010	%Cr 2005-2010 (Ce/Ca)	%Ce 2005-2010	Diff. m Area (Km^2)	Ce 2010-2015	%Cr 2010-2015 (Ce/Ca)	%Ce 2010-2015
Built-up	55.4	71.9	140.1	16.5	0.2978	1.8	29.78	68.2	0.948	1.3	94.8
Farmland	165.3	113.9	126.1	-51.7	-0.4551	0.88	45.51	12.5	0.11	0.88	11
Vegetation	141.2	180.9	124.1	39.7	0.2812	0.7	28.21	-56.8	-0.457	0.81	45.7
Open space	25.8	12.9	7.2	-12.9	-1	7.75	100	-5.7	-0.791	13.89	79.1
Forest	128.3	136.1	118.8	7.8	0.0608	0.77	6.08	-17.3	-0.146	0.84	14.5
Water body	13.6	14.2	13.3	0.6	0.0441	2.64	4.41	-0.9	-0.068	7.44	6.77

Out of the total area in 2005 mass class, farmland had the highest percentage (31.21%); vegetation (26.66%); forest (24.23%); built-up (10.46%); open space (4.87%) and water body (2.57%). In the 2010 mass class, vegetation had 34.16%; forest (25.69%); farmland (21.45%); built-up (13.58%); water body (2.68%) and open space (2.44%). When compared with 2005 mass class, built up, forest, vegetation and water body increased while farmland and open space decreased. In 2015, the spatial analysis of land use/land cover showed that built up had the highest percentage of 26.45%; farmland (23.81%); vegetation (23.43%); forest (22.43%); water body (2.52%) and open space (1.36%). See Table 3.

3.1 Author's Calculation

The change values in the above table indicated that increase in built-up/urban areas mainly emanated from the conversion of other land cover in particular open spaces, farmlands and forest to urban land uses during the period of study following development pressure within and around the municipality. Besides the summary statistics, graphical representations of the classification and visual comparison offer a general insight into the relative amounts of the defined classes across the landscape and the changes observed. Temporal patterns of land use/land cover changes are shown in Figs. 2, 3 and 4. Further, spatial patterns of land cover show that the built-up surface expansion/growth followed certain directions depending on the new plan for land type for management and population growth. The response of built-up surfaces to expansion was consistent since the period in its areal extent with the continuous conversion of non-built-up surfaces to built-up environments.

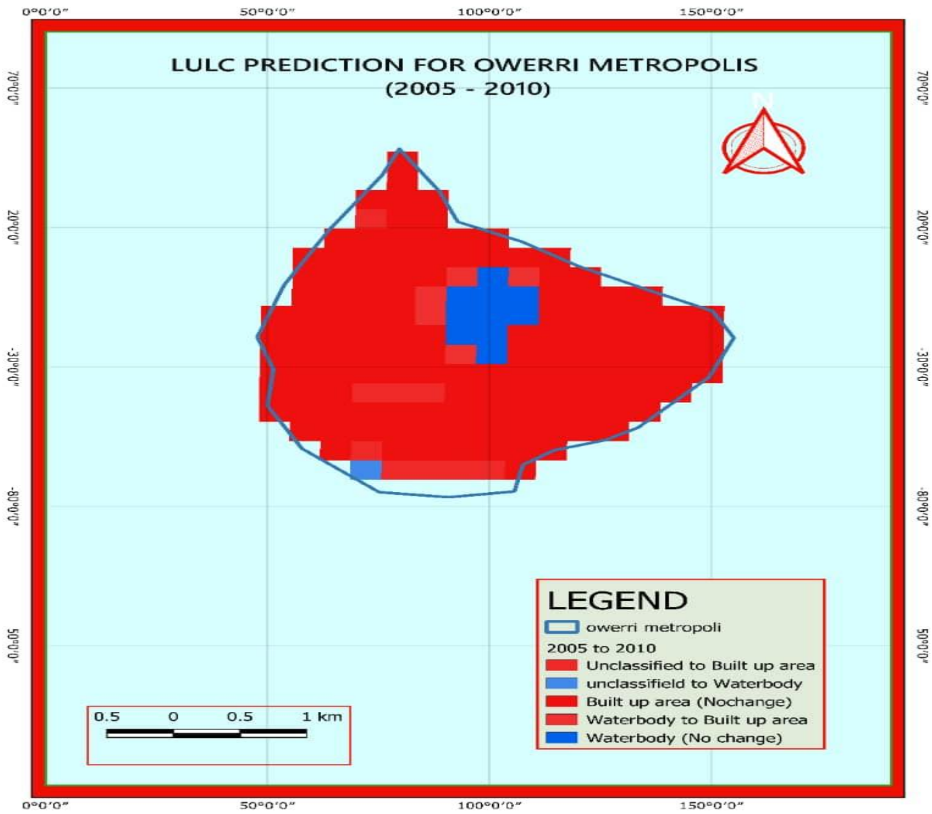

Fig. 2. LULC for 2005-2010

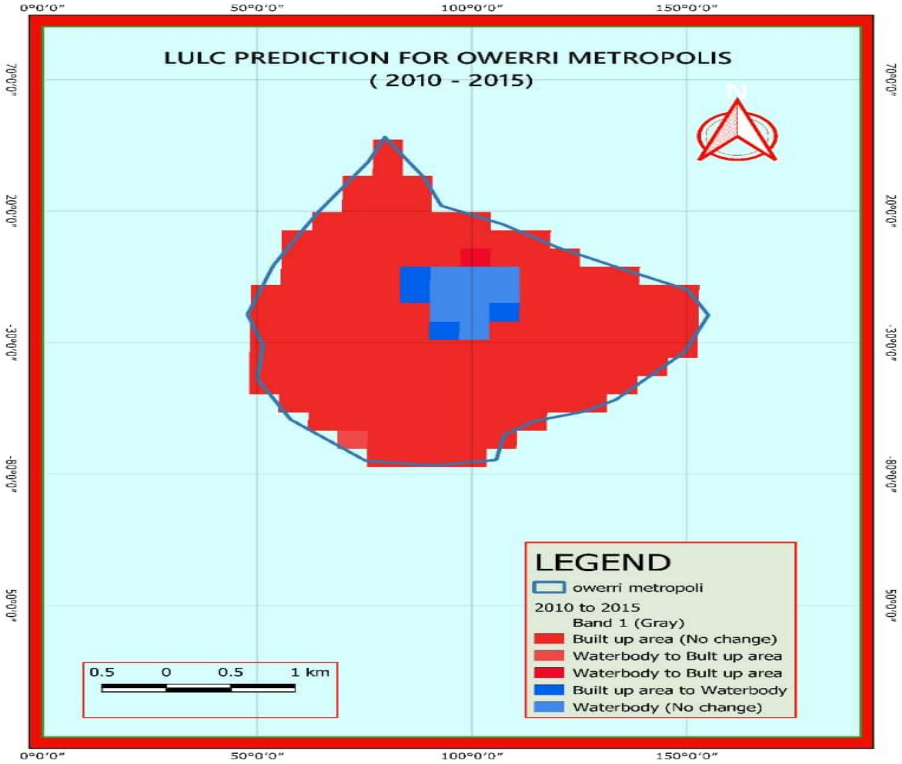

Fig. 3. LULC for 2010-2015

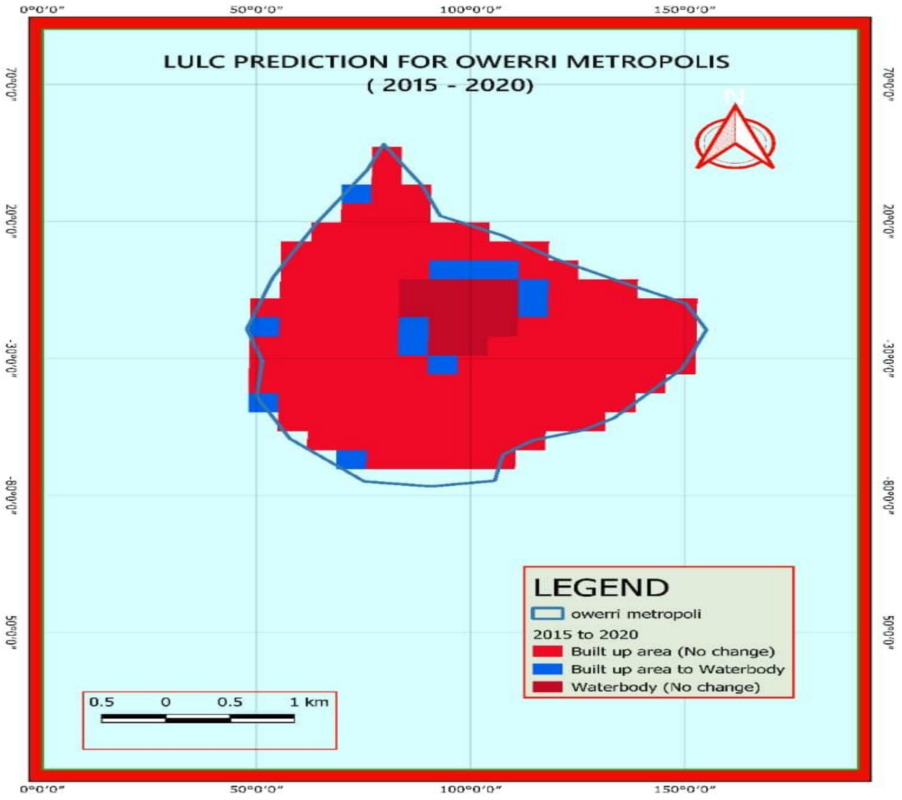

Fig. 4. LULC for 2015-2020

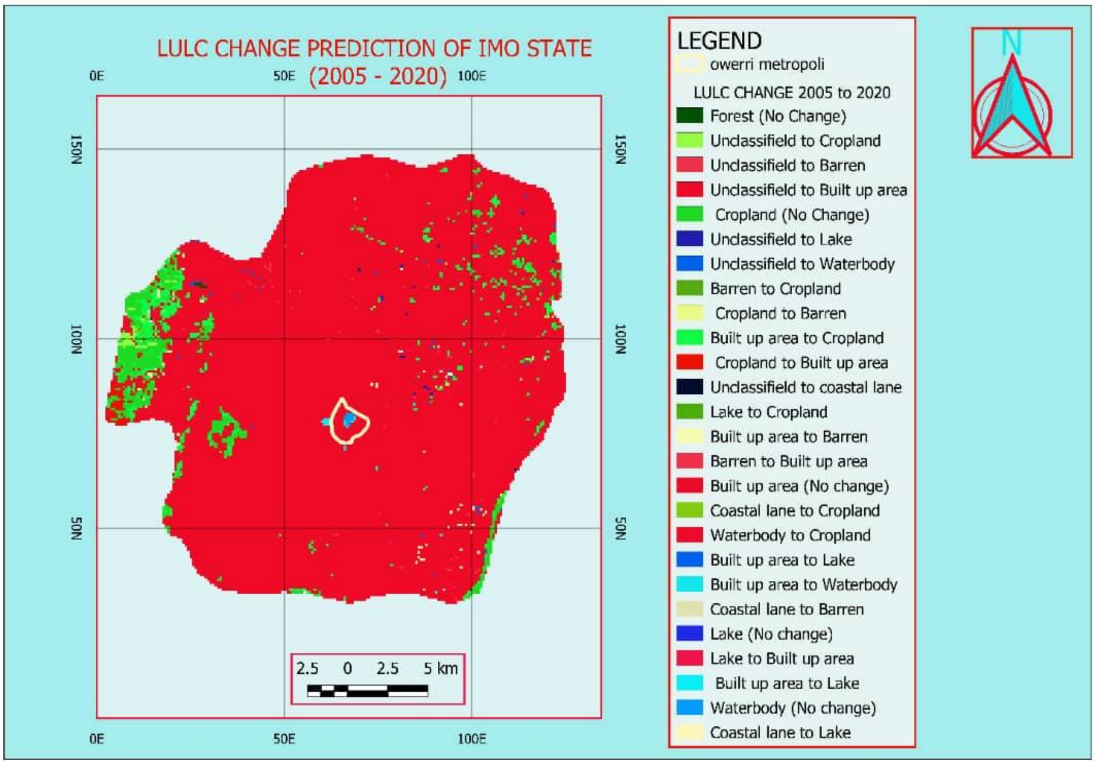

Fig. 5. Overall change for Imo state for 2005-2020

4. DISCUSSION

With the increasing built-up expansion, other land uses stand the risk of conversion as population drive is consciously and continuously adjusting land use in the area. A final projection of a cluster of land use/land cover change for 2020 (see Fig. 5) thus shows that the trend of change especially for built-up continues to spread to the outliers as population is on the increase and the concomitant demand for space continues to heighten. This finding is consistent with the works of [13,24,9] where in recent decades, African grassland, woodland, bush land and other vegetation covers are being rapidly transformed into agriculture and settlement areas. Also, the work supports the view that 50,000km^2 of natural vegetation is lost every year. All these dynamic scenarios are population-pressure determined while [3,28,26] assert that competition between land use due to limited technology and livelihood options are worsened by government policy and tenure insecurity. Worse still is that the environmental consequences associated with these increasing land use/land cover changes are not considered in the drive for all these expansion.

5. CONCLUSION AND RECOMMENDATIONS

Built-up from the result of analysis is obviously the fastest growing land use class in the study area in spatial and temporal terms. Therefore an integrated assessment of land use/land cover change mapping and spatial and temporal modelling should be done to monitor the rate of urbanisation. This task is expected to integrate remote sensing, spatial matrix tools and socio-economic data to manage urban growth and its spill-over challenges as erosion, flooding, congestion, excessive deforestation, and other forms of environmental problems.

In order to control the indiscriminate land use/land cover changes and adverse environmental impacts of urban expansion and increasing built-up surfaces, the current growth pattern requires to be managed through effective land use planning and management. Future research works should focus on integrating GIS and satellite remote sensing with high spectral, spatial and temporal resolutions at the local scale to develop urban environmental monitoring.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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