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Department of Geography and Meteorology
Nnamdi Azikiwe University, Awka

Geospatial Analysis of Land Cover Change Impact on Flood Risk in Anambra East Local Government Area of Anambra State, Nigeria

*[1]Emmanuel I. Agulue, [1]Ifeanyi C. Enete, [1]Samuel O. Iheukwumere, [1]President O. Japhets.

[1]Department of Geography and Meteorology, Nnamdi Azikiwe University, Awka

*Corresponding Author Email: emmaagulue@gmail.com

Abstract

This study was driven by the need to determine the effect of vegetation loss, topography modification and structural development to persistent flooding in Anambra East Local Government Area of Anambra State. The research employed Geographic Information System and Remote Sensing methodology for its data gathering, visualization and spatial analysis. Multi-temporal Landsat TM, ETM+ and OLI of 2001, 2012 and 2023 imageries were obtained at 11years interval. The LULC analysis revealed the dominance of five (5) classes - Bare Land, Built Up, Dense Vegetation, Farmland/Sparse Vegetation, and Water Body. The Built-up and water Body classes were observed to consistently increase over time in the study area. Built-up increased by 22.1sq km from 2001 to 2023, and water bodies increased by 1.2 sq.km. Dense vegetation though appreciated to 26.6sq.km within the period but was confined mainly in southern part and along Oyi River valley. However, Farmland/sparse vegetation lost 17.6sqkm of its spatial extent within the same time, and Bare land lost its 32.4sqkm spatial extent too. It was observed that built-up class and paved surfaces increased both in spatial extent and density over the period, and extended heavily along Anambra River floodplains. It was further observed that continuous extension of built up into flood prone areas posed dangers of increasing overland flow, constricting the natural river flow, braiding river channels, aiding river depositional processes and increasing chances of severe flooding in the area during torrential rainfalls. The study therefore recommended among others that government should enforce extant city and building regulations and initiate intensive agro forestry and green belt developments along Anambra River and areas experiencing massive urbanization to regulate surface runoff and annual inundation of the river banks

***Keywords**: Land Cover, floods, extant city, green belts*

Introduction

Many environmental disasters threaten the world at varying scales, but flooding is considered today as the most devastating natural disaster worldwide (Komolafe, Adegboyega and Akinluyi, 2015). Flooding could be defined as an overflowing or eruption of a significant body

of water over land that is not usually submerged (Daniel and Udo, 2019). But besides inundation of land not usually submerged, flooding also overflows the floodplains and nearby settlements, causing severe harm to plants and animals, including man, buildings and infrastructure (Ujene and Oguike, 2020). Flooding is also considered a threat that affects the quality of the environment and seen as a factor that is used in defining the environmental quality of residential neighborhoods (Mfon, Oguike, Eteng and Etim, 2022).

However, the number of reported flood disasters has steadily increased globally, and the severity and impact on the economy and environment is also on the increase. But comparatively, the impacts are more significantly reduced in developed countries due to their comprehensive strategy for its management; incidentally the case is still a novelty in developing countries (Adjei-Darko, 2017). In Nigeria, flooding has become an annual occurrence (Kolawole *et al.*, 2011; Nkwunonwo, 2016; Bamidele and Badiora, 2019). Nigeria has also had a long history of destructive flood records and, in more recent times, faced its worst flooding in a decade (Sullivan, 2022). For instance, in 2012, Nigeria was faced with an unprecedented flood disaster for three weeks, resulting in loss of lives and properties running into billions of Naira. Several states were affected but Anambra state was the most acutely affected (NEMA, 2012). It is also on record that eight out of twenty-one local governments in the state were affected, with Anambra West and Ogbaru entirely underwater. Again, in 2018, flooding in River Niger, with a record of 12.84m high, was reported to have drowned 12 persons in Ogbaru while property and farmland worth millions of naira was destroyed (NEMA, 2018). In all more than five local government areas were mainly affected in Anambra, including Anambra East, Anambra West, Ayamelum, Ogbaru and Awka South (NEMA, 2018).

However, in most cases, Anambra East local Government happened to be one those areas in Anambra State experiencing the recurring flood hazard. For instance, the years 2012, 2017, 2018, 2019, and 2020, the area saw major flood events that submerged many communities and displaced thousands of residents (Ajayi, 2020). Anambra East Local Government Area is found vulnerable to flooding partly due to its proximity to Omamballa River, Niger River and their numerous tributaries, and because of its low-lying topography. In addition, human actions in the area of poor urban planning and development, have significantly contributed to their severity. Studies have consistently shown certain human activities like land use changes, river channel modification; deforestation and urbanization in flood-prone areas exacerbate flood risk (Ebuzoeme, 2015, Berbante, 2017). These human activities, especially the expansion of impermeable surfaces through urbanization processes result in more surface runoff and, hence,

more sudden torrential floods (Panahi *et al*., 2010). They are also capable of silting the rivers, and exposing lives and properties to severe dangers of flashflood (Lwenya and Yongo 2010; Acheampong and Anokye 2013).

However, several related studies on Land use/ land cover Change Impact on Flooding have been carried out in Nigeria and beyond. These studies include that of Wizor and Week (2014) on the implication of land use and land cover in Yenagoa, Bayelsa state of Nigeria. A combination of geospatial techniques and statistical analysis for mapping and modeling were employed in the research and findings showed that 7% of the total land area of Yenagoa LGA were affected, and that 50.6% of the flooded land was in built-up areas. Wahab and Ojolowo (2018) also used GPSs and a stratified sampling method which revealed that more than 60% of the 1,025 buildings sampled in Lagos metropolis violated the building codes in flood-prone zones. Similarly, in the work of Tabiri (2015), the four main causes of floods in Accra metropolis, Ghana were found to be negligence/ignorance or sheer megalomania, poor planning of the city, building on waterways and indiscriminate disposal of waste material. In a related work, and in support to the roles of vegetation cover within the drainage basin, Adewumi, Akomolafe, Ajibade and Fabeku (2016) also carried out a research by applying GIS and remote sensing techniques to identify flood-prone areas in Igbokoda town in Ondo state for the years 1986, 1999, and 2013, respectively. The imageries obtained showed a high percentage reduction in vegetation and change in land cover over time, making the town highly susceptible to flooding. Therefore, in line to these previous works, this study aims at determining the effect of vegetation loss, topography modification and structural development to persistent flooding in Anambra East Local Government Area of Anambra State. It further aims at employing the use of GIS and Remote Sensing techniques in gathering and analyzing data over time on land cover changes associated to the persistent inundation of the area.

Material and Method

Study Area

The area of study is Anambra East Local Government Area. The area lies within the coordinates of latitude 6º12’0” N and 6º28’0”N of the equator, and between longitudes 6º32’20”E and 7º0’0”E. (See Fig 1). It is bounded by Anambra West LGA by the west, Ayamelum LGA by the North, Oyi and Awka North LGA by the East and Onitsha North and Oyi LGA by the South.

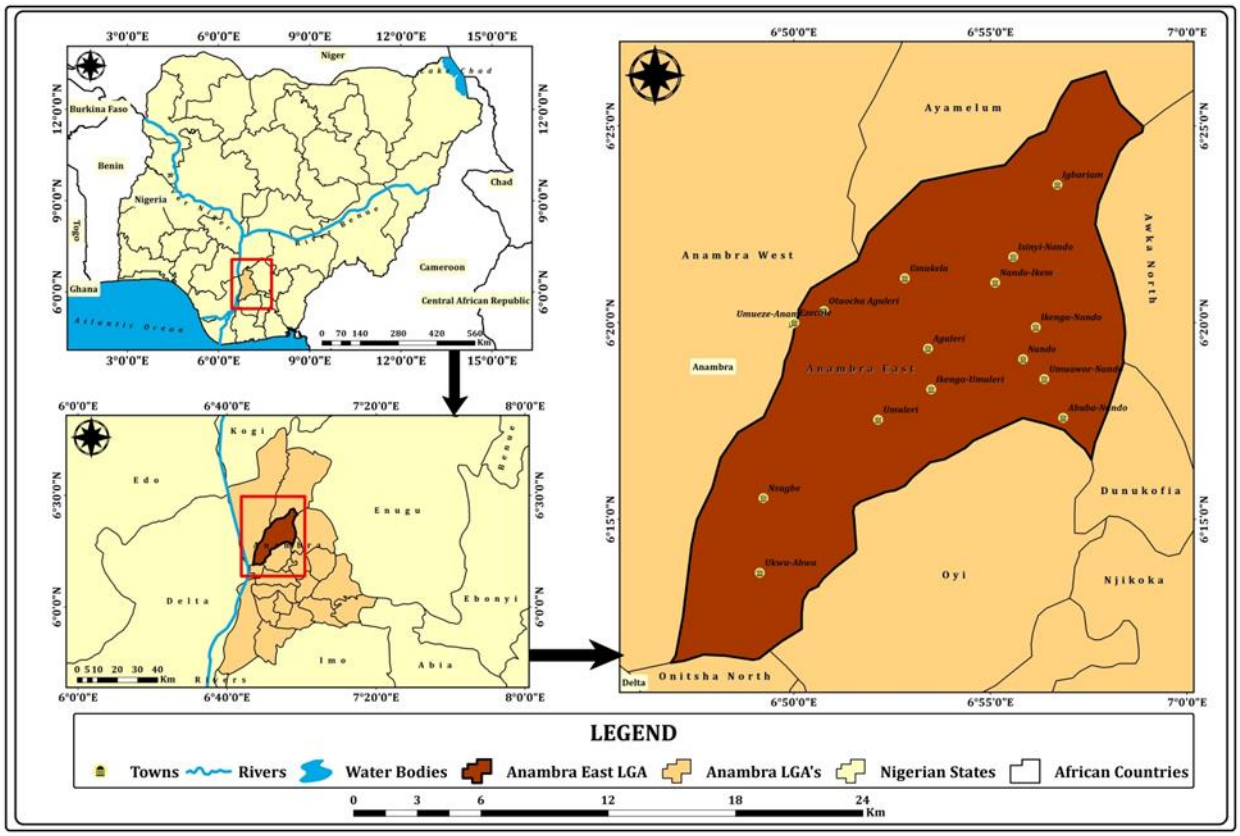


Figure 1: Location of Anambra East L.G.A, Anambra State, Nigeria.
Source: Cartography and GIS Lab, Department of Geography and Meteorology, NAU, Awka.

Climate of the area under Koppen's classification falls within the tropic wet and dry type (Aw), otherwise called tropical savanna. The rainfall usually occurs from April to October, while the dry season occurs from November to March. The Mean annual rainfall is about 1805mm, while the maximum and minimum temperatures are 32.1^{0}C and 23.5^{0}C, respectively. Geologically, the area lies in the recent deposit of the Holocene Epoch/Quaternary Period, occupying and extending to the active floodplain of River Anambra/Omambala and River Niger. Its soil type is majorly of alluvium formation from the Niger River sediment, and topographically, it is characterized by plains and gentle slopes (Ejikeme *et al.,* 2015). The area is also drained majorly by River Anambra/Omambala, Oyi river and their numerous tributaries, all flowing westerly direction and emptying into River Niger. The population of Anambra East is 223, 150 as projected to 2023 (NPC, 2006).

Data Sources

The central data sources were secondary. The secondary data obtained for carrying out the LULC were obtained from these sources enlisted below;

The Administrative shapefiles of the study area, which defined the boundaries of the region of study, are obtained from the Office of the Surveyor General of the Federation (OSGOF)

LANDSAT 30m medium-resolution satellite imagery for the LULC analysis acquired from the United States Geological Survey (USGS) website. Landsat TM, ETM+ and OLI of 2001, 2012 and 2023 all have a resolution of 30 meters, except for OLI, which has a resolution of 28m. Each of the bands is tailored for detecting different features depending on the combination of three different bands: band 2 (green), band 3 (red), band 4 (infrared), band 5 (mid-infrared), band 6 (thermal infrared), band 7 (mid-infrared) and band 8 (panchromatic).

Published/Unpublished records and other relevant materials were obtained from online journals, departmental archives and other organizations.

Accuracy Assessment

Geospatial data accuracy assessment is a vital component of any project employing spatial data, which helps ensure that the resulting information has enough quality for decision-making processes. Anderson et al. (1976) recommended that the minimum classification accuracy level in identifying land use and land cover categories from remotely sensed data should be at least 85%. This suggestion is particularly relevant in the identification of broad land cover classes. To ascertain the usefulness of the LULC maps derived from this study, the entire region was aggregated. The results from the Confusion matrix were analyzed for classification accuracy and displayed below in Table 1. The overall accuracy determines that the research results fall in line with the accuracy limit of 85% posited by Anderson et al. (1976) and modified by Eastman (2009), as the overall map accuracy stands at 93%, indicating that there is a high chance that what is displayed on the map has a 7% error margin but a higher probability that the class within the map will be reflected in real time. The accuracy assessment results revealed that the LULC maps developed by the methodology outlined in this study are highly suitable for implementation in any decision-making process.

Table 1: Accuracy Assessment for 2001 to 2023 LULC Maps

Years	Class	Bare Land	Built Up	Dense Vegetation	Farmland/Sparse Vegetation	Water Body	ACCURACY/KAPPA
2001		1.0	0.98	0.91	0.98	1.0	0.94 (94%)/0.92 (92%)
2012		1.0	0.95	0.89	0.96	1.0	0.91 (91%)/0.94 (94%)
2023		1.0	0.92	1.0	0.94	0.98	0.95 (95%)/ 0.98 (98%)
		OVERALL ACCURACY = 0.93 (93%)					

Source: Researcher's GIS Analysis, 2023

Results and Discussion

Determination of the Effects of Vegetation Loss, Topography Modification, and Structural Development to Flooding in the Study Area.

This analysis involved geospatial techniques used in capturing changes in vegetation and land use types commonly known as Land use land cover change (LULCC) analysis. The major classes detected and utilized for this analysis are – Bare Land, Built-Up, Dense Vegetation, Farmland/Sparse Vegetation, and Water Body. These classes are examined for their spatiotemporal changes within the LGAs in the study region.

LULC in Anambra East LGA from 2001 to 2023

The analysis of the observed LULC classes in Anambra East LGA shown in Table 2 indicates variations and consistent trends in the characteristics of the classes, percentages and spatial extents of each class per epoch. The region has a total spatial extent of 259sq.km.

Table 2: LULC Statistics of Anambra East LGA from 2001 to 2023

	2001		2012		2023	
	Area (sq.km.)	%	Area (sq.km.)	%	Area (sq.km.)	%
Bare Land	51.2	20	24.9	10	18.9	7
Built Up	4.4	2	24.3	9	26.5	10
Dense Vegetation	28.0	11	50.2	19	54.6	21
Farmland/Sparse Vegetation	169.3	65	152.8	59	151.7	59
Water Body	6.0	2	6.6	3	7.2	3
Total	259	100	259	100	259	100

Source: Researcher's GIS Analysis, 2024

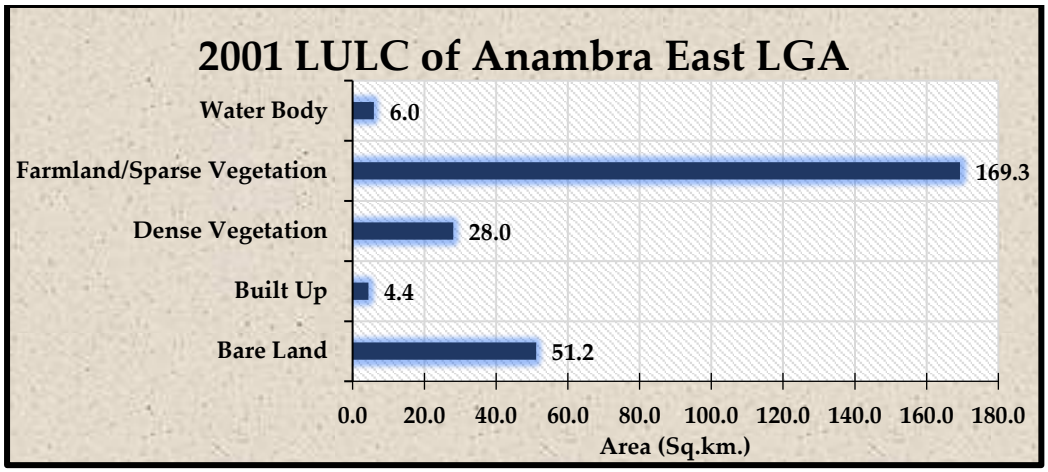


Figure 2: LULC chart for Anambra East LGA in 2001

In 2001, it was revealed that Bare Lands covered 51.2 sq. km. of the study area, while Built Up regions covered 4.4sq.km indicating low urban development in the region as it was the smallest class by all indices during this period. Dense Vegetation covered 28sq.km while Farmland/Sparse Vegetation covered 169.3sq.km, marking it as the dominant land use class in the region. Water bodies covered only 6 sq. km. (Fig.2).

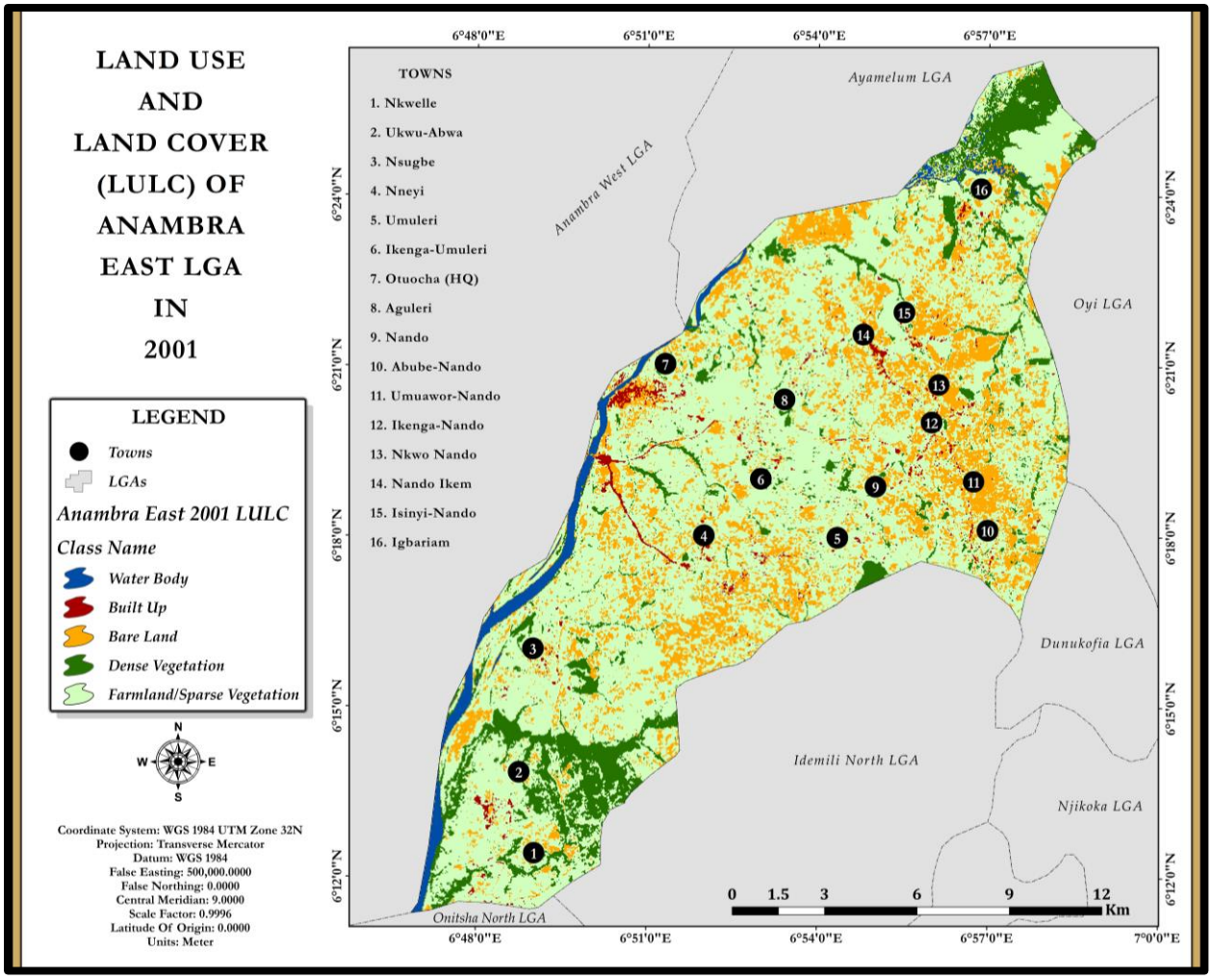


Figure 3: LULC Map of Anambra East LGA in 2001

The dominance of the farmland class is evident from the LULC chart and map in Fig. 3, as the class is predominant over other classes. The spatial distribution of the water body and built-up classes are illustrated further, displaying them as the smallest classes in spatial extents during this period. Water bodies were mostly found along the Anambra River in the parts wherein it enters the LGA towards the western part of the LGA. Towns such as Aguleri, Nando, Nando-ikem and Ikenga-Nando were observed to be small and linearly formed during this period. Dense vegetation mostly occurred towards the south and north of the region, likely in riparian distributions.

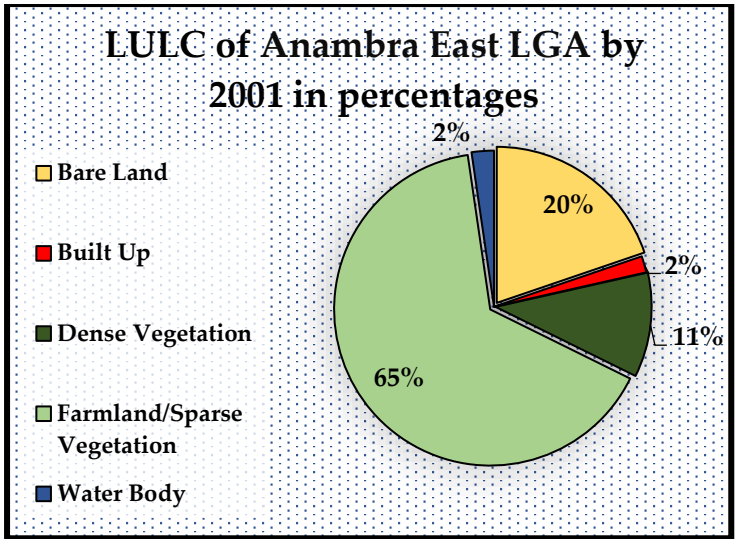


Figure 4: 2001 LULC of Anambra East LGA in percentages

Bare lands occupied 20% of the study area, as displayed in Fig.4, while Built-up part covered 2% of the area, indicating low urban development in the region during this period. Dense Vegetation covered 11% of the region, while Farmland/sparse vegetation covered 65% spatial extent percentage, marking it out as the dominant land use class in the region. Water bodies are calculated to cover 2% of the region as well.

By 2012, it is observed from Fig.5, that Bare land's spatial extent decreased to 4.9sq.km in the area, losing almost half of its previous size. Built-up areas increased to 24.3sq.km, which almost added 20sq.km to its previous size, and shows significant sign of increased urbanization occurring in the region. Farmlands/sparse vegetation area coverage reduced to 152.8sq.km yet remained the dominant class in the region. Dense vegetation area increased to 50.2sq.km.by 2012, while water bodies also increased to 6.6sq.km in the region.

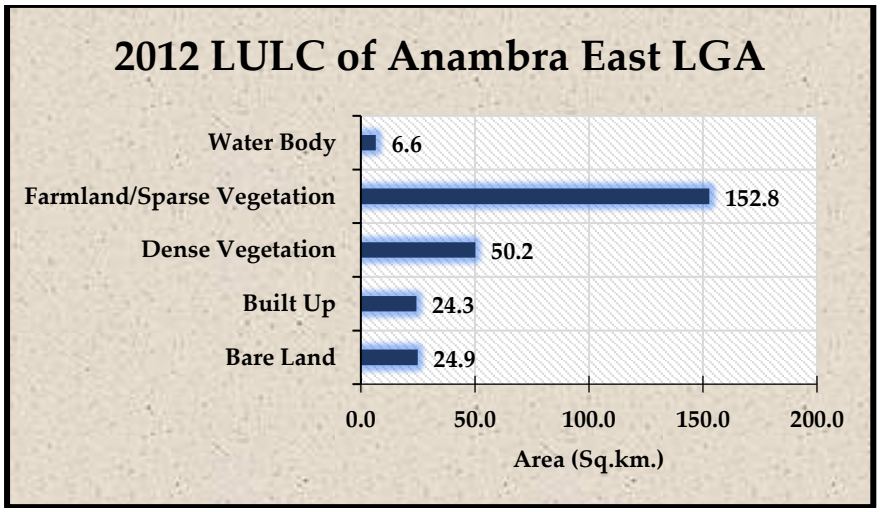


Figure 5: LULC chart for Anambra East LGA in 2012

The urban expansion estimated in Fig.5 is displayed further in Fig 6 as the spatial distribution of the built-up land use class is evident. The built-up spread is more visible in the southern area of the Local Government due to increased population and urban encroachment from Onitsha Metropolis. The water bodies also increased due to flood occurrence in the area during the period, and due to constriction of river flow by the increased Built-up along Anambra River thereby increasing its area coverage. The increased Built-up is seen visibly within Aguleri, Otuocha and Nsugbe areas as they extend west ward, and into the flood plains of Anambra/Omambala river. Farmland/sparse vegetation and Bare land class each experienced reductions in their spatial extents.

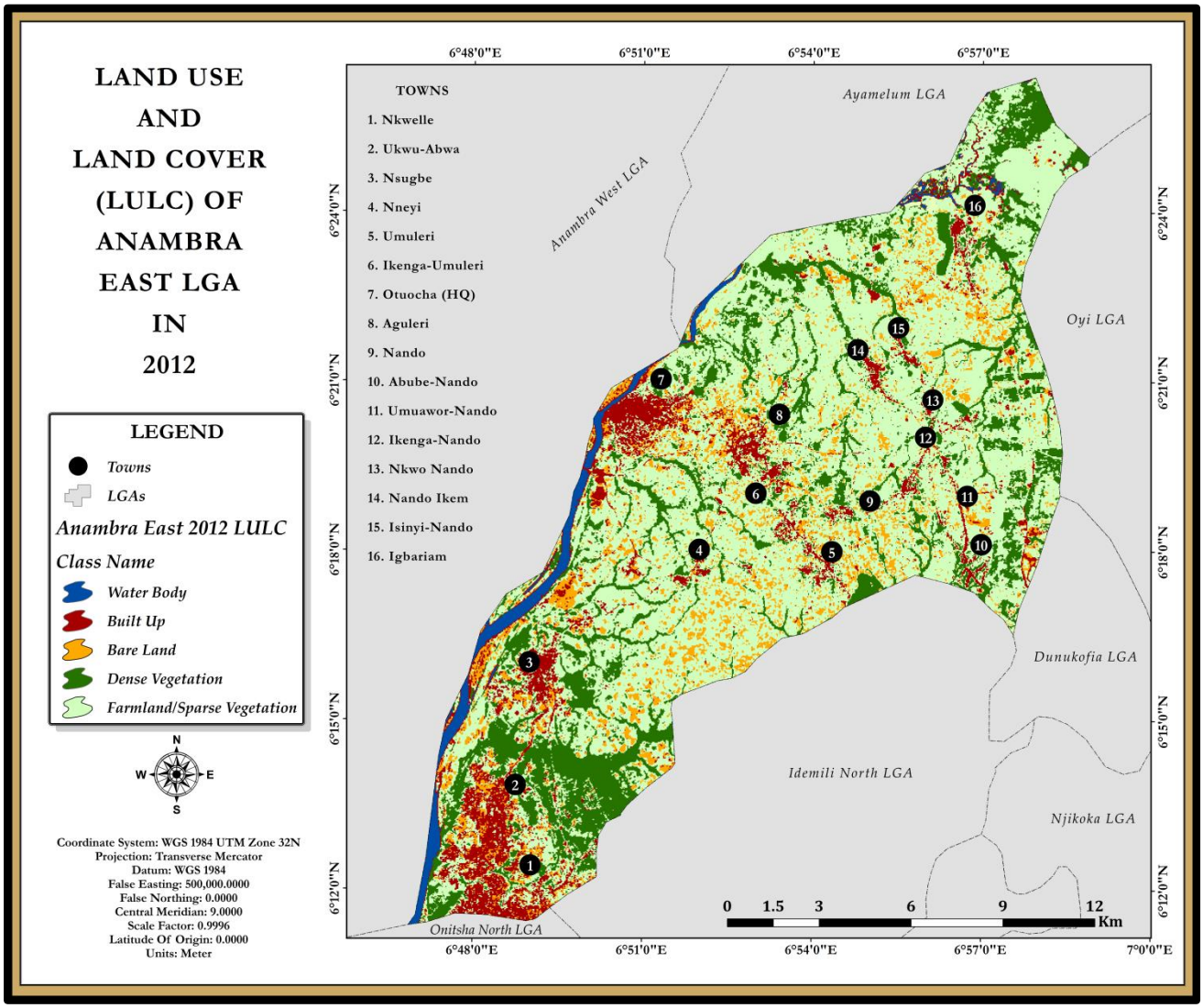


Figure 6: LULC Map of Anambra East LGA in 2012 (Source: Researcher's GIS Analysis, 2024)

Bare Lands covered 10% of the region (Fig.7), reducing from 20% in 2001, while built-up areas increased from 2% in 2001 to 9% in 2012. Dense vegetation in the area increased to 19%,

while farmlands/sparse vegetation decreased to 59%. Water bodies thus increased to cover 3% of the entire study area in 2012.

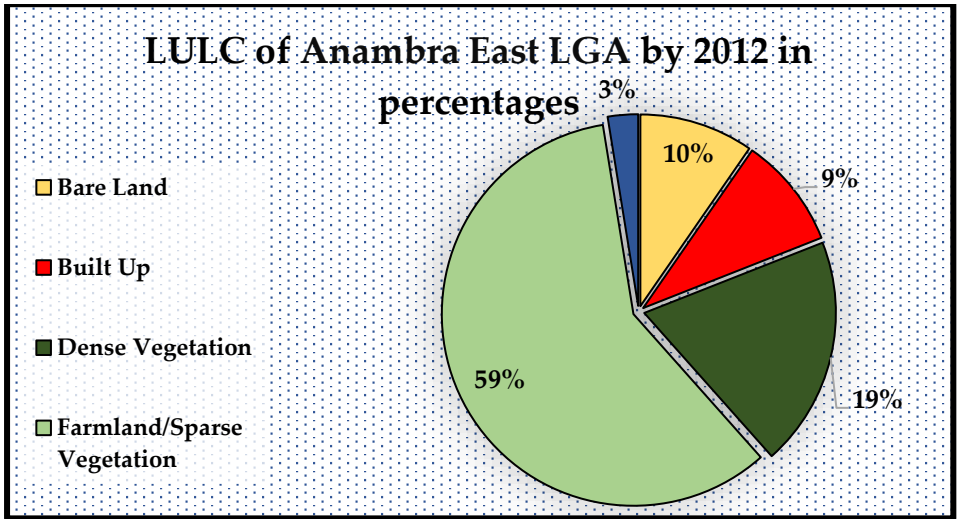


Figure 8: 2012 LULC of Anambra East LGA in percentages

Further transitions in LULC occurred 11 years later, by 2023, as bare lands also lost more spatial extent and reduced to 18.9sq.km, while the built-up class increased to 26.5 sq. km. (Fig. 9).

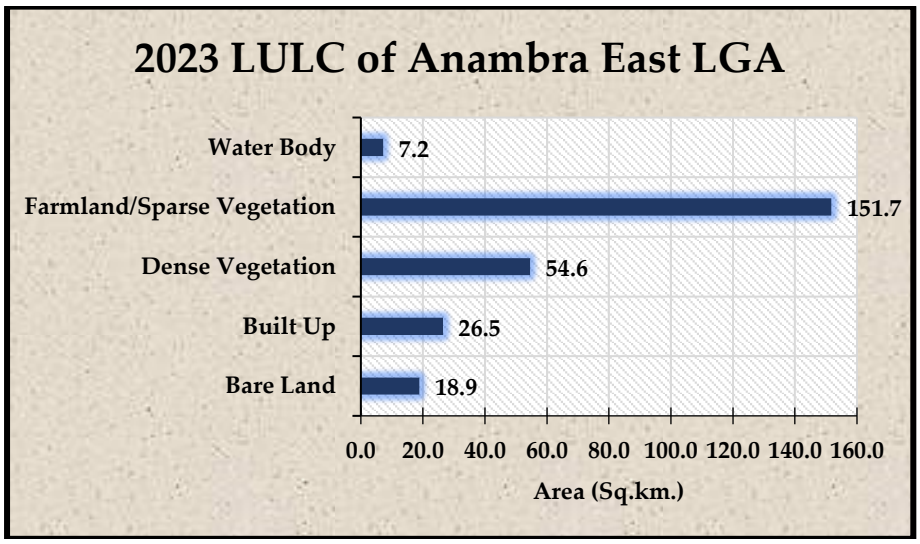


Figure 9: LULC chart for Anambra East LGA in 2023

Dense vegetation increased to 54.6sq.km as further reforestation attempts by successive governments including the recent by Soludo-led government began yielding results (Vanguard, 2023), while Farmlands/sparse vegetation observed minimal reduction to 151.7 sq.km. Water bodies significantly increased to 7.2sq.km, a likely consequence of increasing Built-Up and paved environment into areas susceptible to flooding. This also resulted to severe incidence of 2022 flooding of the Benue/Niger Rivers which devastated many states and regions along the

river banks (UNICEF, 2022). However increased Built-up also continued in spatial extent and in density along Anambra River thereby constricting the river flow continuously, and possibly aiding the river depositional processes, and resulting to more sand deposits along the river channels (see fig. 10). This development not only increased lateral size of water body but further braided the river channel and increased chances of more severe flooding in the area during heavy rainfall.

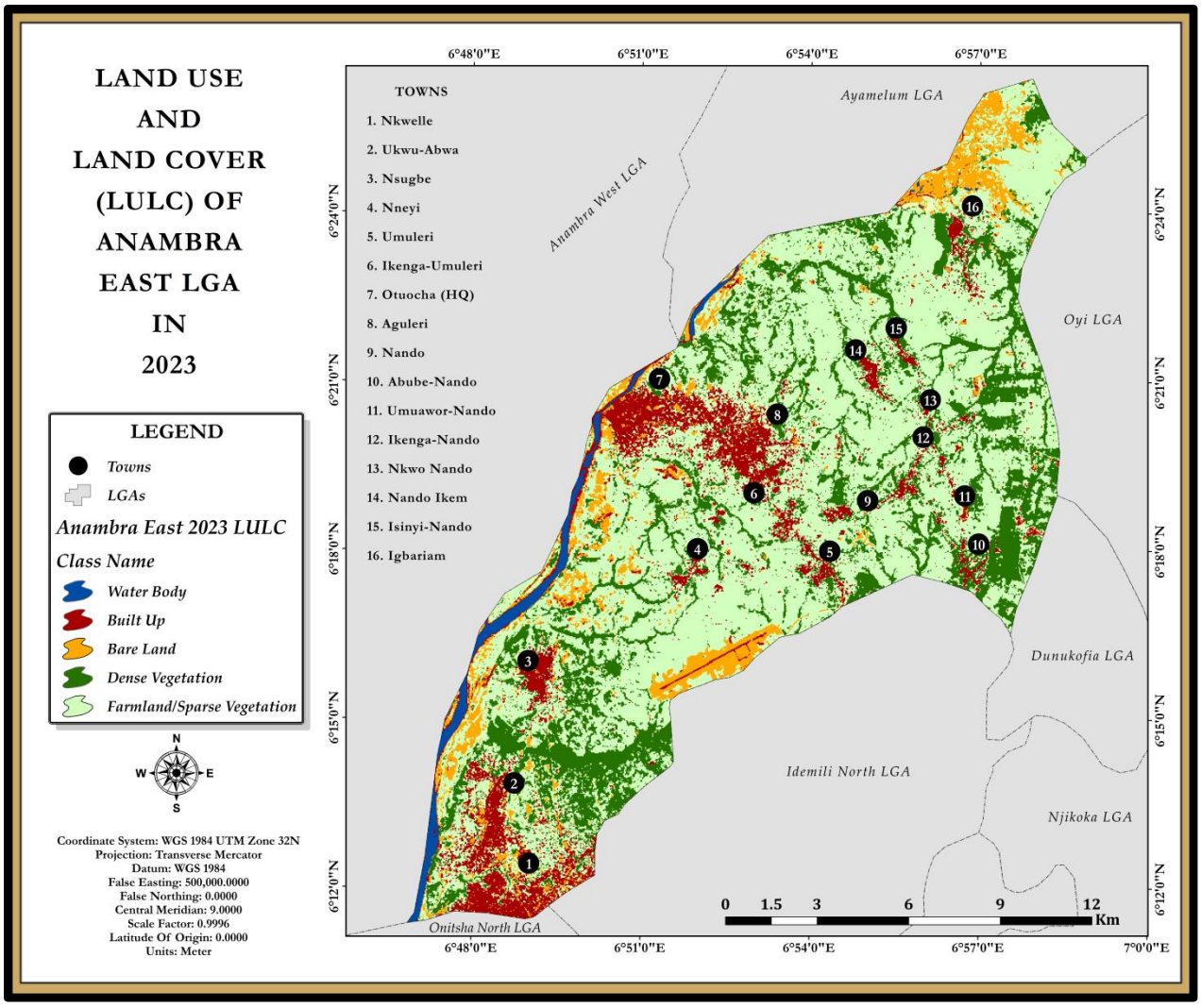


Figure 10: LULC Map of Anambra East LGA in 2023 (Source: Researcher's GIS Analysis, 2024)

Urban development in towns such as Otuocha (7) and Aguleri (8) (Fig. 10) drove the increase in spatial extent of the built-up areas class. Bare surfaces are observed predominantly around the cargo airport that borders with Oyi Local Government Area, and along the banks of the rivers as more sand are deposited and sand-mining activities occur regularly in the area.

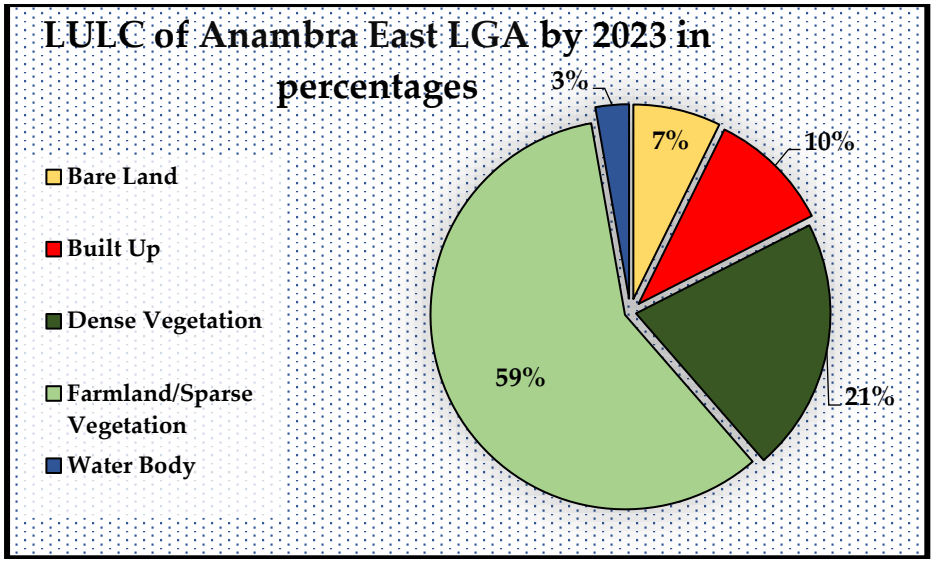
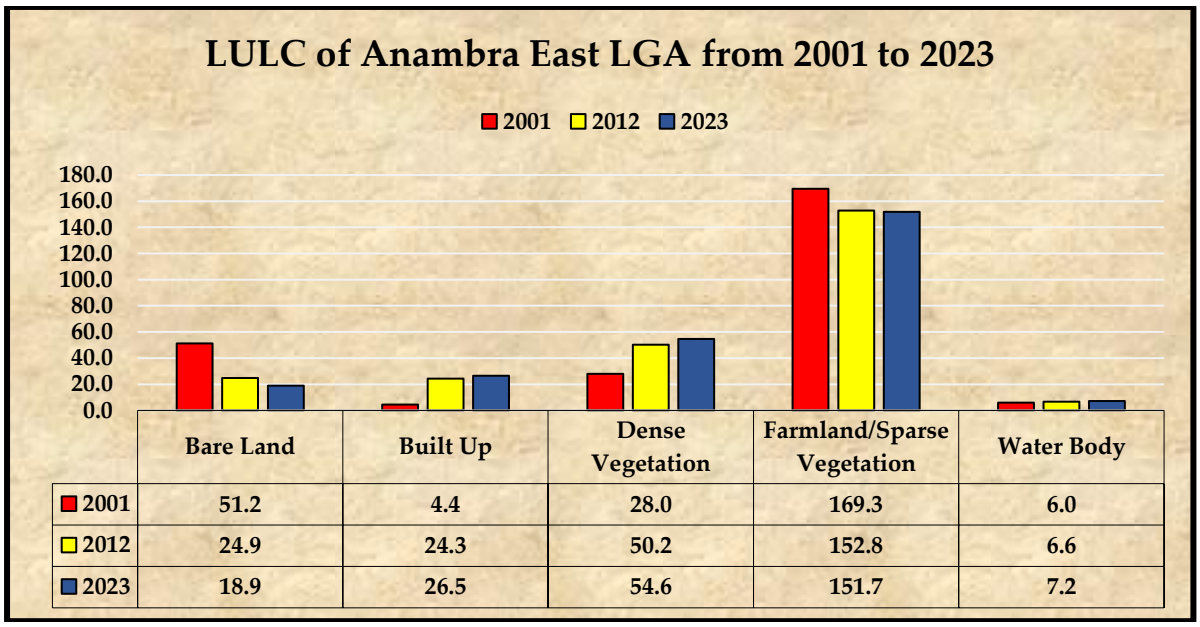


Figure 11: 2023 LULC of Anambra East LGA in percentages

In 2023, bare lands covered 7% of the study area, with Built-up areas covering 10% of the region. Dense vegetation spread over 21% of the area, while sparse vegetation covered 59%. Water bodies are estimated to cover 3% of the area (see Fig 11).

The total trend of LULC changes in Anambra East from 2001 to 2023 is observed in Fig. 12, as different rates of transition in spatial extents of these classes are estimated. The aforementioned dominance of the Farmland/sparse vegetation class is displayed in the chart, amongst the dynamics of the other LULC classes.



	Bare Land	Built Up	Dense Vegetation	Farmland/Sparse Vegetation	Water Body
2001	51.2	4.4	28.0	169.3	6.0
2012	24.9	24.3	50.2	152.8	6.6
2023	18.9	26.5	54.6	151.7	7.2

Figure 12: Comprehensive LULC chart of Anambra East LGA from 2001 to 2023

To further determine and display the level of changes that occurred in the region between classes and epochs, a change detection analysis is deployed and this reveals that from 2001 to 2012, bare lands lost 26.3sq.km and also lost 6.1sq.km between 2012 and 2023 (Fig. 13). The built-up areas increased by 19.9sq.km from 2001 to 2012, and further increased by 2.1sq.km between 2012 and 2023. Furthermore, Dense vegetation increased by 22.2sq.km between 2001 and 2012, and also grew by 4.4sq.km from 2012 to 2023. Farmlands/sparse vegetation lost 16.5sq.km of its spatial extents between 2001 and 2012, and further lost 1.1sq.km between 2012 and 2023. Water bodies consistently increased by 0.6sq km between both epochs.

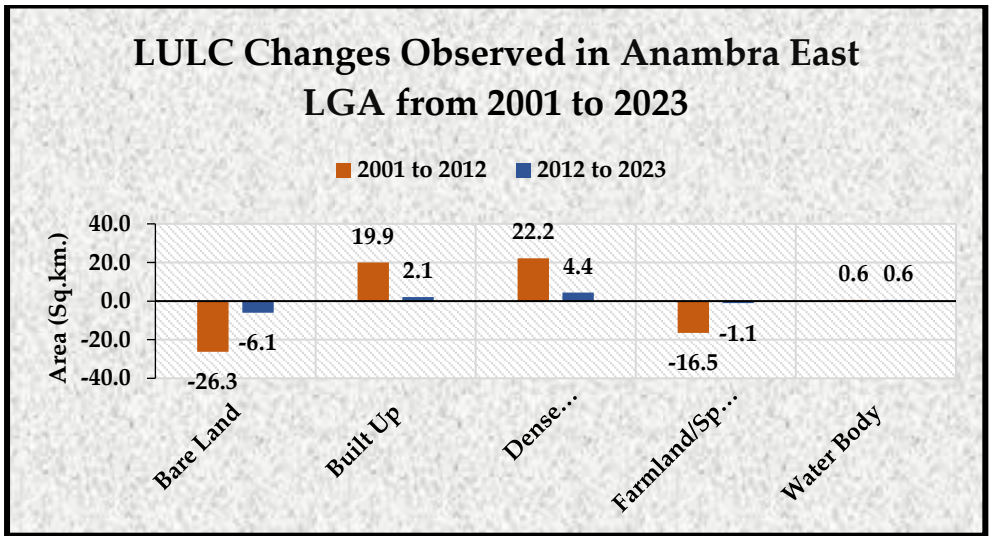


Figure 13: Anambra East LGA LULC Changes per epoch

Based on the results above, bare lands lost a total of 32.3sq.km from 2001 to 2023, while Built-up areas gained a total of 22.1sq.km in the same period (Fig.13). Dense vegetation gained 26.6sq.km marking it as the class with the most gains in spatial extent, while farmlands/sparse vegetation lost 17.6sq.km between 2001 and 2023. Water bodies increased by 1.2sq.km in the same period.

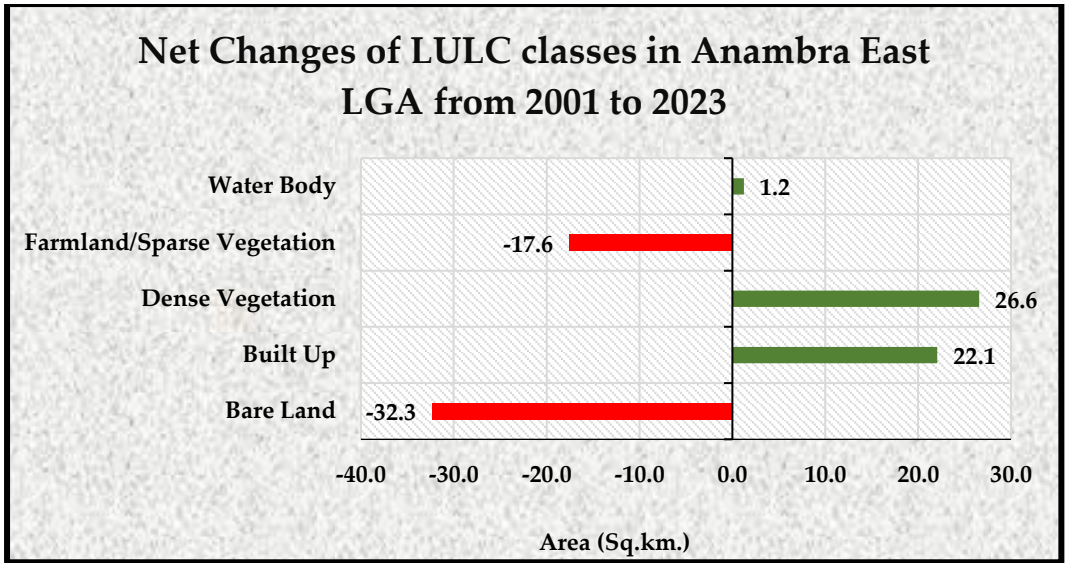


Figure 14: Total changes experienced per class in Anambra East LGA

The total increase in water bodies indicates a direct impact of flooding on the prevalence of water bodies in the area. It is ascertained from Fig. 15 that from 2001 to 2012, Water body gained 0.2sq.km from Built-up areas, 0.31 sq.km from Bare lands, 0.05sq.km from Dense vegetation and 0.06 sq.km from Farmlands/sparse vegetation. Based on this result, Bare lands contributed the most to the increase in Water body from 2001 to 2012 followed by Built-up areas, indicating that the 2012 flooding event impacted buildings and sand mines/open areas significantly more than the other land cover classes.

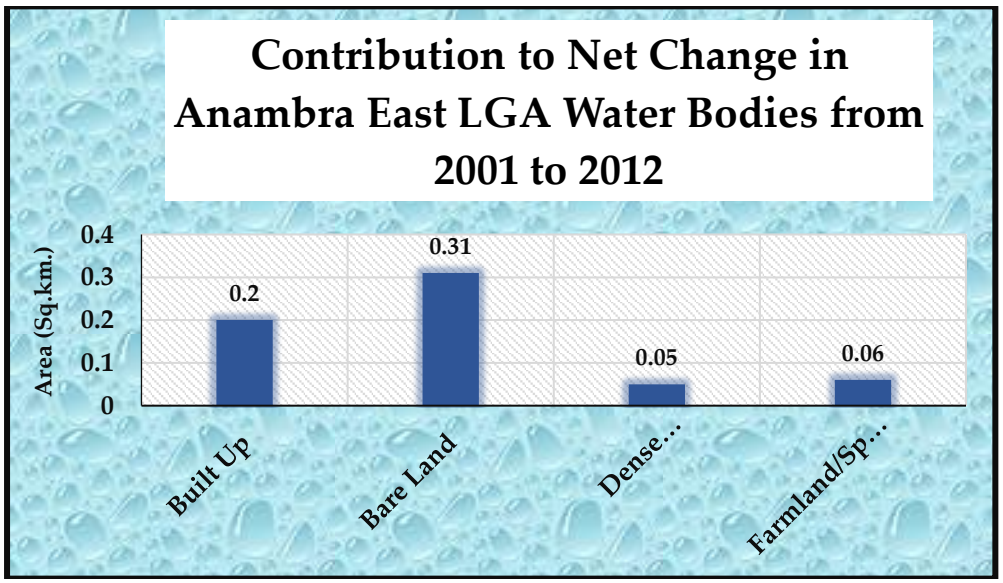


Figure 15: Contribution to Net change in Anambra East LGA water bodies from 2001 to 2012

As observed in Fig. 16, from 2012 to 2023, water bodies gained 0.1sq.km from built-up areas, gained 0.3 sq.km from bare lands, 0.03 sq.km from dense vegetation and gained 0.2 sq.km

from farmlands/sparse vegetation. This indicates that water bodies significantly impacted bare lands and farmlands during this period more than any other class.

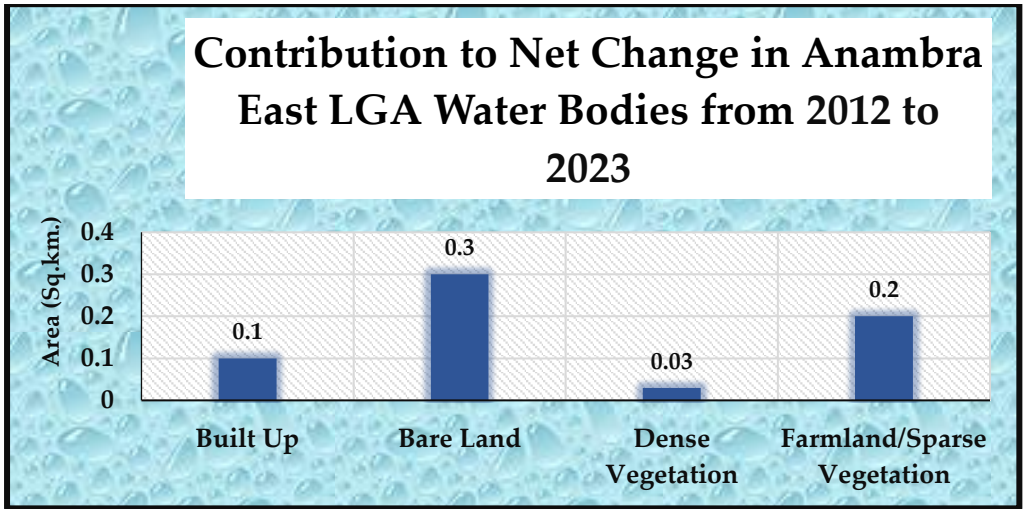


Figure 16: Contribution to Net change in Anambra East LGA water bodies from 2012 to 2023

The result shows that from 2001 to 2023, bare lands lost a total of 32.3 sq.km of its spatial extent. On the other side, built- up spatial extent was seen to have increased by 22.1sq.km. The observed increasing built-up is an indicator of heavy urbanization being experienced in the area. Dense vegetation also increased by 26.6sq.km but its increased spatial extent appears riparian as they were more confined within Oyi river valleys and southern part of the study area. On the contrary, Farmlands/sparse vegetation were seen to have lost as much as 17.6sq.km between the periods. The obvious loss in Farmland/sparse vegetation cover is believed to be due to pressure on land for other uses especially for built-up and other commercial activities that carter for the teeming population, following the observed urbanization being experienced in the area. Water body class was seen to have increased by 1.2sq.km within the period. The increased Water body spatial extent was gained from other land cover classes. For instance, from 2001 to 2012, Water body gained 0.2 sq.km from Built-up class; 0.31 sq.km from bare land class; 0.05 sq.km from dense vegetation class; and 0.06 sq.km from Farmlands/sparse vegetation class. Also, from 2012 to 2023, Water body gained 0.1sq.km from Built-up cover class; 0.3sq.km from bare land cover class; 0.03sq.km from Dense vegetation cover class; and 0.2sq.km from Farmlands/sparse vegetation (fig.15 and fig.16). The observed continued increased in spatial extent of water could also be as a result of increased sedimentation on the river thereby leading to sallower river depth but increased spatial coverage. The enlarged water coverage is also facilitated by man's alteration of the floodplain by extension of built-up and tarmacs within the floodplains (Fig 6. and Fig 10).

Conclusion

Summarily, this paper addressed the critical research problem of determining the effects of vegetation loss, topography modification, and structural development to flooding in Anambra East, Nigeria. Key findings indicate that loss of vegetation in the area particularly in Farmlands/sparse vegetation class is already significant and, on the increase, and has considerable negative implications in the area. Loss of vegetation was found to be particularly high within most towns experiencing heavy urbanization and along Omambala River where other economic activities have led to deforestation. Additionally, the analysis revealed continuous growth in land use especially on built ups and increased tarmac coverage. The research also underscores significant disruption of both river flows and overland flow due to increasing topographical modifications and structural developments. It was found that urbanization emanating from increasing built up is on the increase, growing laterally and extending into the floodplains of Omambala River and other places liable to flooding.

In conclusion, the implication of the findings is profound. They underline the urgent need for proactive and strategic physical planning by all environmental stakeholders to regulate the persistent flooding and enhance environmental sustainability. Again, since many places in the area are still undergoing urbanization which often initiates competitions for different land uses, further sensitization and constant real time monitoring of the area with GIS and RS should be encouraged. This is also hoped to aid in observing the direction of structural developments in the area and for sustainable urban growth. However, intensive agro-forestry and green belt development along Omambala River and places experiencing massive urbanization is seen to be necessary and recommendable in order to regulate river flood and reduce overland flow due to increasing paved surfaces.

This research therefore recommends enforcement of extant city and building regulations by the authorities responsible for town planning and ensuring also that proper penalties are emitted on defaulters. It suggests also the need for intensive agro-forestry and green belt development along Omambala River and places experiencing massive urbanization where vegetation is progressively diminishing. The intensive agro-forestry will also help to regulate annual inundation of the area and subsequent overland flow due to increasing paved surfaces. It also recommends sensitization on the dangers involved in erection of structures within areas liable to flooding.

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