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Analysis Of Land Use And Land Cover Changes In Port Harcourt Metropolis Using Geospatial Techniques.

Regina Oluchi Amaefuna, Dollah Osademe Chukwudi
Institute Of Geosciences And Environmental Management, Rivers State University, Nkpolu-Oroworukwo, Pmb 5080, Port Harcourt, Rivers State, Nigeria.
Institute Of Geosciences And Environmental Management, Rivers State University, Nkpolu-Oroworukwo, Pmb 5080, Port Harcourt, Rivers State, Nigeria.

Abstract
The study examined Land Use and Land Cover Changes in Port Harcourt Metropolis Using Geospatial Techniques from 1990 to 2020. The study made use of geospatial and longitudinal data sourced from the United States Geological Survey (USGS), employing Google Earth Engine to analyse Landsat and Google Earth Imagery of the area. Utilizing satellite imagery with a spatial resolution of 30 meters by 30 meters, supplemented with high-resolution Google Earth imagery, the study offers an extensive concept of the dynamic changes in land use in the four epochs of 1990, 2000, 2010 and 2020. The methodology entails processing and analysing satellite images to identify and classify different land use and land cover types as well as tracking their changes over time. This technique allows for precise mapping and assessment of the trend, extent, rate, and spatial patterns of land use changes. The study employed supervised classification, change detection, and temporal analysis, to ensure robust and accurate results. ANOVA statistics was deployed to test the stated hypothesis for the study. The findings revealed a drastic reduction in land use coverage for the various land use classes in the epochs studied. Open spaces showed a reduction from 62,262.2ha (58.92%) in 1990 to 41,832ha (39.32%) in 2020; farmland reduced from 21,172.5ha (20.04%) in 1990 to 1,474.65ha (1.4%) in 2020; built-up area increased from 9,006.03ha (8.52%) in 1990 to 41,502.8 (39.28%) in 2022; water bodies increased from 1,529.73ha (1.45%) in 1990 to 3,424.32ha (3.24%) in 2020. These changes have profound implications for environmental sustainability, urban planning, and resource management in the area. The study concludes that there has been substantial land use and land cover changes in Port Harcourt metropolis, driven primarily by urbanization. Thus, it is recommended that the government implement stricter urban planning and sustainable land management practices to mitigate the impact of rapid land use and land cover changes in Port Harcourt.

Keywords*: Land use, Land cover, Geospatial analysis, Google Earth, Port Harcourt, satellite imagery*

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I. Introduction

There is a nexus between urbanization and land use/land cover dynamics (Akue *et al*., 2022). This is because the various land use classes, including swamps, wetlands, and water bodies, have been depleted over time to meet man's increasing demand for land space. Like other fast-urbanizing countries, Nigeria has its fair share of this loss due to rapid urbanization. The need for land for physical development, such as building homes, roads, factories, and waste management infrastructure, is increased by the rapid urbanisation of the world (Akue *et al*., 2022).

However, this surge in development comes at a significant environmental cost, with Gobo *et al*. (2022) highlighting that the level of environmental noise pollution has become alarming in recent years due to this rapid increase in human activities, and Ideriah et al (2022) reiterating that crowded cities as well as the creation of mechanized means of transport and modern devices for entertainment, which occur as a result of urbanization are polluting the atmosphere with their continuous noise. Environmental noise pollution often occurs as a result of urbanization and land use change, as they give rise to increased traffic, industrial activities and construction which elevate sound levels in urban areas and is increasingly becoming a source of concern. Many components that are in the urban system and its operation are impacted by changes in land use and land cover (LULC) at various spatiotemporal scales (Ding *et al.,* 2016; Vander-Hoven *et al.,* 2017).

Land use dynamics (change) is broadly understood to refer to the kinds of human activities carried out on land with the goal of achieving socioeconomic progress (Henderson et al., 2014; Wilson, 2015). According to Henderson et al. (2014), land use in urban environments refers to how the land and its ingrained resources are used spatially, socioeconomically, and institutionally for the construction of infrastructure. Therefore, land use

dynamics is a complicated process that may be brought about by a variety of interacting events, such as socioeconomic problems or other causes (Ding *et al.*, 2016).

Urban land has been affected and impacted by urban population, urban sprawl, and urban expansion, which has contributed to the issue of urban land use dynamics, an indicator of the degree of urbanization (Sapena & Ruiz, 2019). This is reflected in the changes in other attributes of the urban ecosystem and the urban system's functioning and sustainability. Due to population pressure, technological advancements, shifting governmental regulations, and economic factors, land use change has become a recognised phenomenon and the most important human activity influencing urban layout. This has resulted in ecological imbalance and urban stress (Okwakpane & Mark, 2021). The alarming and depressing extent to which land use change is taking place in most cities, like Port Harcourt, without corresponding public policy, urban land management techniques, and planning principles to deal with the extremely fast rate of urbanisation and change in land use and land cover, is leading to a multitude of urban problems (Pei *et al*., 2022).

The changes in land use in some neighbourhoods in Port Harcourt have brought significant changes in environmental quality. The city of Port Harcourt has faced several difficulties that have affected the town's spatial layout as a consequence of varying changes in land use conversion (Ayotamuno & Gobo, 2016 The city's drainage network system is believed to have become narrower due to significant changes in land use and land cover, which has resulted in ongoing floods (Okoye, 2019). Similar to other Nigerian metropolitan centres, Port Harcourt has competition for land from housing, industry, commerce, and desire for open areas for recreation (Ayotamuno et al., 2010). Potential for commercial and industrial enterprises to expand in residential neighbourhoods with minimal infrastructure is one element causing poor quality of life in cities to no oversight if there is inadequate land use planning and management. Since regular town administration is the extent of urban management in Port Harcourt, an urban land use management system is thus required.

Adopting a methodological pattern that makes use of remote sensing and a Geographic Information System will help us better comprehend the dimensions of urban land use changes in Port Harcourt. This approach offers a precise and affordable substitute for studying landscape dynamics (Ayotamuno & Ekaka, 2017). The key to navigating the current trends in urban growth and their impact on infrastructure and the environment lies in reliable geospatial data (Lopez-Sanchez *et al.,* 2014). The analysis of 'land-use/land-cover dynamics' (LULC) across different scales requires the acquisition of spatiotemporal data on land-use patterns and trends (Verburg *et al.,* 2015). This data serves as the foundation for practical and sustainable environmental and physical planning.

The process of monitoring, analyzing, and evaluating urban land-use changes involves change detection analysis. This method is instrumental in determining the nature, extent, and rate of land-cover changes over space and time (spatiotemporal) (Li *et al.,* 2017). Satellite imagery is a key component, with a variety of techniques used to detect urban expansion and other land-use dynamics (Yuan *et al.,* 2019). Using GIS software like Arc GIS, supervised classification techniques can be employed to determine land-use/land-cover classifications and changes within a specific area (Okocha *et al*., 2021).

Chaminé *et al*. (2021) in their work elucidated that remote sensing and Geographic Information Systems (GIS) are not just tools, but transformative technologies that empower urban planners with detailed spatial data. Applications of GIS and remote sensing may be utilised to get a better understanding of the urban environment, land use, and changes in land cover. This increased knowledge will be beneficial to applied urban planning and management. It is on this premise that this study is focused on the analysis of land use changes in Nkpolu-Oroworukwo, Borokiri, Fimie-Ama, Choba, Rumuomasi, Bori Camp, Rumuogba, Woji, Ogbogoro, Mgbuoba, Rumuokpareli and Mbori areas of Port Harcourt metropolis from 1990 to 2020 using geospatial techniques.

II. Materials And Methods

Study Area

Port Harcourt, which is made up of Obio/Akpor Local Government Area and Port Harcourt City Local Government Area (PHALGA), is the capital of Rivers State, and it lies on the banks of the Bonny River about 66 kilometres upstream from the Gulf of Guinea in south-western Nigeria. Port Harcourt is located geographically on latitude 4^0 45᾽ 00᾽᾽N and 4^0 55᾽ 00᾽᾽N and longitude 6^0 52᾽ 30᾽᾽E and 7^0 10᾽ 00᾽᾽E (Figure 1). Port Harcourt is a major industrial centre, with several multi-national firms located there, and the most important oil refining city in Nigeria. In 2007, over 1.6 million people lived in Port Harcourt, and almost 3.7 million lived in the Greater Port Harcourt region.

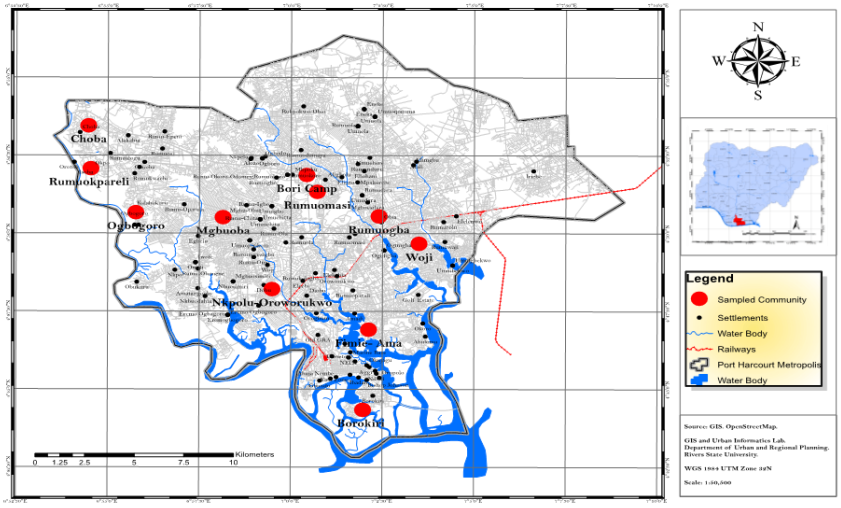
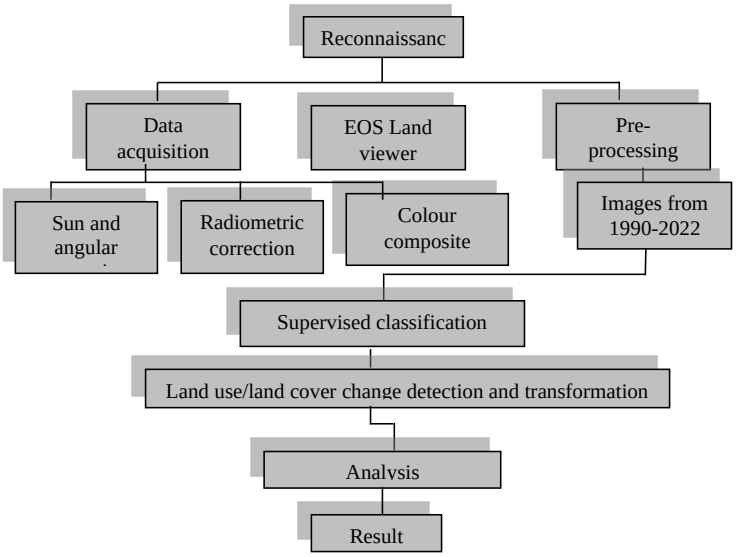


Figure 1: Map of Port Harcourt Metropolis
Source: GIS and Urban Informatics Laboratory, Department of Urban and Regional Planning, Rivers State University

Sample Collection

Geospatial and longitudinal data on land use changes from 1990 to 2020 were sourced from United State Geologic Survey (USGS), applying the Google Explorer, and taking the Landsat and Google Earth Imageries of Port Harcourt metropolis. The satellite imagery of the study area at 30M-by-30M spatial resolution was supplemented with the Google Earth Imagery of the area.

Land Sat bands obtained or acquired were imported into the Arc Map environment using the composite bands on the Image Analysis Panel (IAP), and the different bands were merged into a single raster data. The composite raster image was clipped using the Port Harcourt Metropolis boundary, where maximum likelihood-supervised classification was performed on the clipped images and a hand-use map classified into built-up areas, farmland, light forest, thick forest, bare land, wetland/swamp, and water bodies was produced. The data was classified as a raster image, reclassified, and then converted to polygon. Simple arithmetic was done to determine the percentage and sizes of LULC changes from 1990 to 2020. In doing this, the land viewer application was used to extract land Sat Satellite Imagery of Port Harcourt in four epochs of 1990, 2000, 2010 and 2020 from the USGS and the Earth Observing System (EOS) land viewer for real-time data analysis as shown in the flow chart of GIS processes in Fig. 2.



Flow chart of the research process
Source: Adapted from Wizor & Eludoyini (2018) and modified by the Researcher (2024)

Method of Data Analysis

The land use and land cover change in Port Harcourt metropolis in 1990, 2000, 2010 and 2020 were investigated. The satellite imagery of the study area for the four epochs, 1990, 2000, 2010 and 2020, were acquired from the USGS (2024) and analyzed using Geographic Information System (GIS) Software analytical techniques, Arc GIS 10.4.1. The data was used to run a time series analysis of Land Use and Land Cover (LULC) change in the Port Harcourt metropolis to ascertain the extent of land use and land cover change, as shown in Table 1.

The data collected on land use dynamics in Port Harcourt metropolis were presented in tables and maps for clarity purposes. The descriptive statistics was used to explain the information obtained from the data collected from the United State Geologic Survey (USGS), while the inferential statistics was used to explain the results of the stated hypotheses for the study. The stated hypothesis was tested using the ANOVA statistics.

III. Results And Discussion

The analysis of land use and land cover changes in Port Harcourt Metropolis from the Satellite Imagery acquired from the USGS (2024), as shown in Table 1 and 2 as well as Figures 3, 4, 5 and 6 revealed that there are significant changes in land use and land cover due to rapid urbanization. The findings of the study revealed that the highest land use and land cover among other land use in 1990 was open spaces, with 58.92% coverage of the entire study area, followed by farmland with an area coverage of 20.08% and built-up area with an area coverage of 9,00.67 amounting to 8.52% of the entire study area. However, a drastic reduction in land use coverage for the various land use classes was noticed as the years passed. Open spaces reduced from 62,262.2ha in 1990 to 41,832ha in 2020, showing a percentage change of 39.32% in 2020 from 58.92% in 1990. Farmland reduced from 21,172.5 ha, amounting to 20.04% in 1990, to 1,474.65ha, corresponding to a 1.4% decrease in 2020. In 1990, the built-up area increased from 9.006.03 ha (8.52%) to 41,502.8 (39.28%) in 2022. The nature of changes in land use for the various land use classes, as shown in Table 1 and 2, revealed that Port Harcourt, a coastal zone, has many economic activities that people want to take advantage of. Port Harcourt's rapid urbanization has come at the cost of its natural environment, as evident in the significant decline of open spaces and farmland. This has a significant impact on the environment, land use, land cover, and consequently, the morphology of the river catchment. This is in consonance with Fashae *et al.* (2022) and Nsiegbe *et al.* (2022), who confirmed that the coastal zones which represent the interface of land and sea are noted for profound economic advantage, significant ecological productivity, and settlement of human population.

Therefore, it is evident from the analysis that green forests, farmland, bare land, open spaces, wetlands/swamps, and water bodies are all being reduced due to urbanization, human development, and anthropogenic activities. The changes, either increasing or decreasing (Table 1), show that generally, the water bodies increased from 1,529.73 ha (1.45%) in 1990 to 3,424.32 ha (3.24%) in 2020, while the built-up area increased by 39.28%. Thus, the findings of the study show that the built-up area has been on a steady increase from the first year, 1990, to the last year, 2020, and the main factor for the increase witnessed is due to population growth. The effects of population on land use and land cover change detection in Port Harcourt Metropolis are essential to analyze the impact of urbanization and the pressure of population on land use development. The increasing urbanization and urban growth rate have influenced land use change by placing a high demand on land purchases for residential and economic purposes. The increase in land use demand relates to the growing population and, consequently, the increase in economic activities.

The reduction in swamp forests indicates that wetlands are quickly depleting and are lost at a more significant percentage in Port Harcourt Metropolis, which can rarely be reversed. This situation has increased the spate and rate of occurrences of urban ecological disasters, thus making the area very vulnerable to these disasters. The decrease in wetland and swamp forests has denied the metropolis the functions they perform, such as supporting flood control and providing livelihoods to the residents and the basic need for food, water, carbon sequestration and others.

The rapid and speedy rate of urbanization, which leads to land use changes, industrialization, and urban population growth in the city of Port Harcourt, as well as the changes in human economic activities and the modern lifestyle, has brought about high demand on land use (Ayotamuno and Ekaka, 2017). Thus, the analysis has shown that the demand for infrastructure and the different social amenities have brought about a lot of problems and poor conditions in the urban ambient climate.

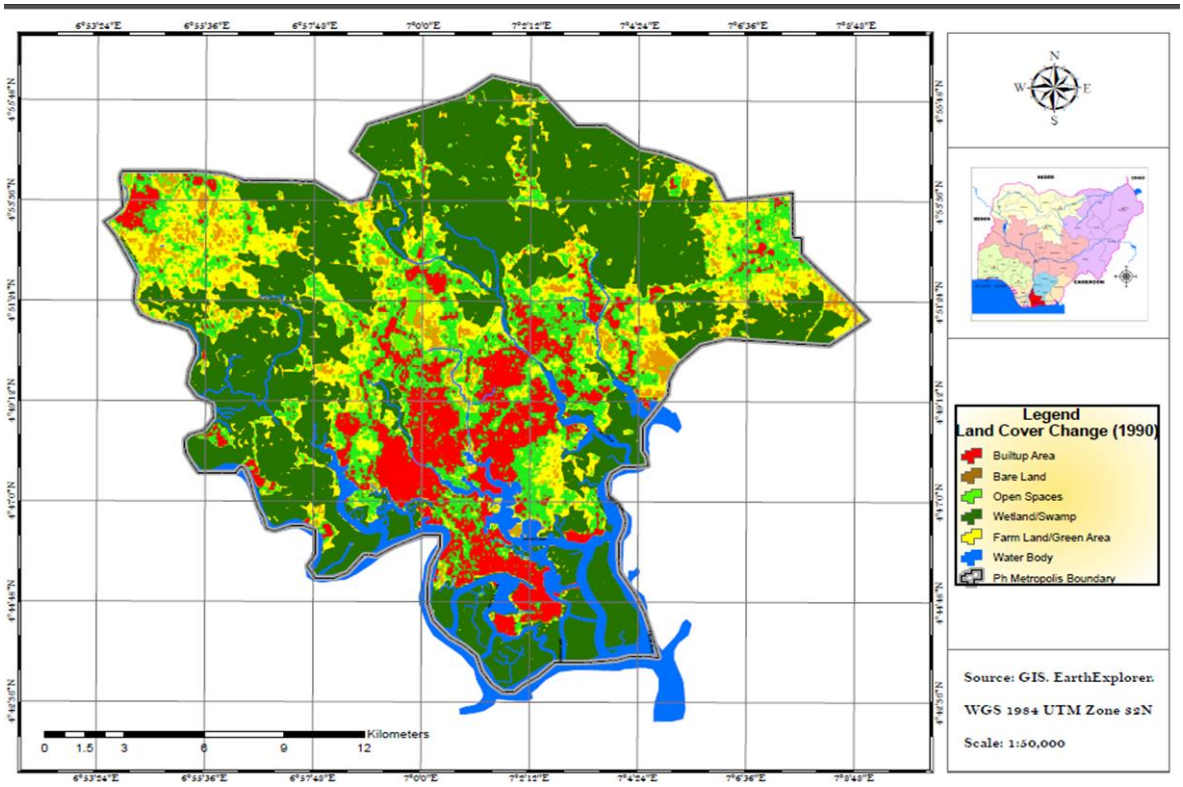


Fig. 3: Land use/ land cover of Port Harcourt Metropolis for 1990
Source: Researcher's GIS Earth Explorer, 2024

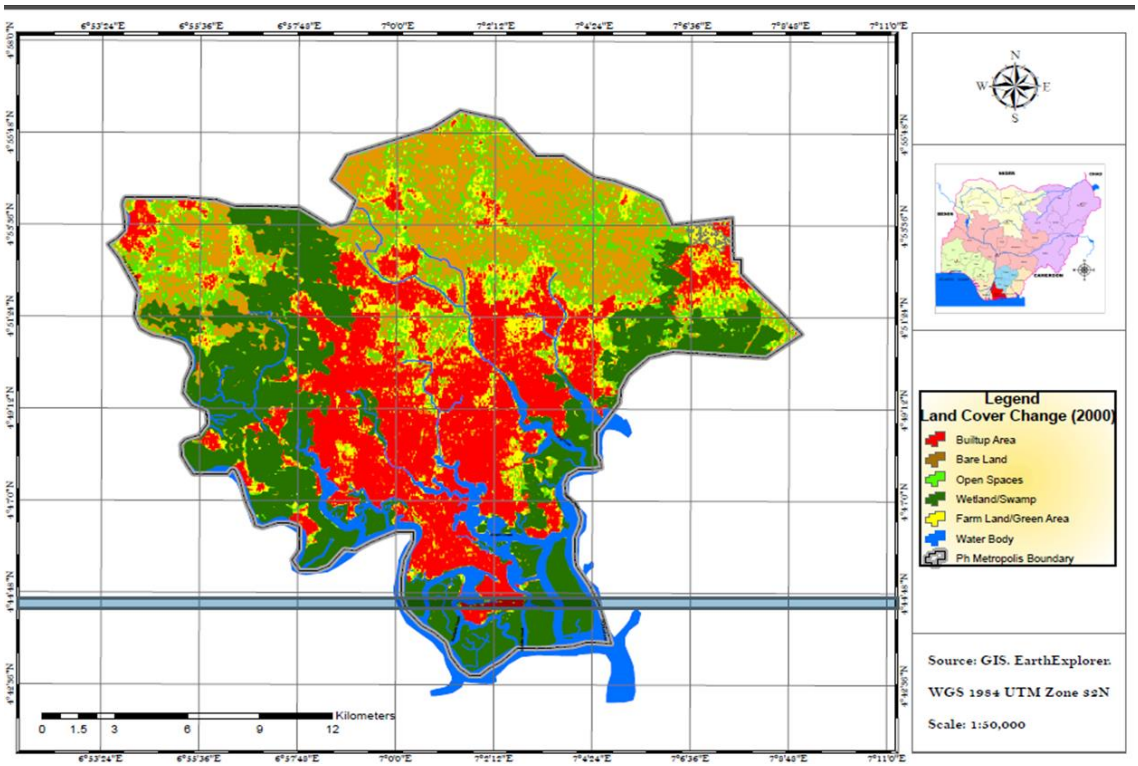


Fig. 4: Land use/ land cover of Port Harcourt Metropolis for 2000
Source: Researcher's GIS Earth Explorer, 2024

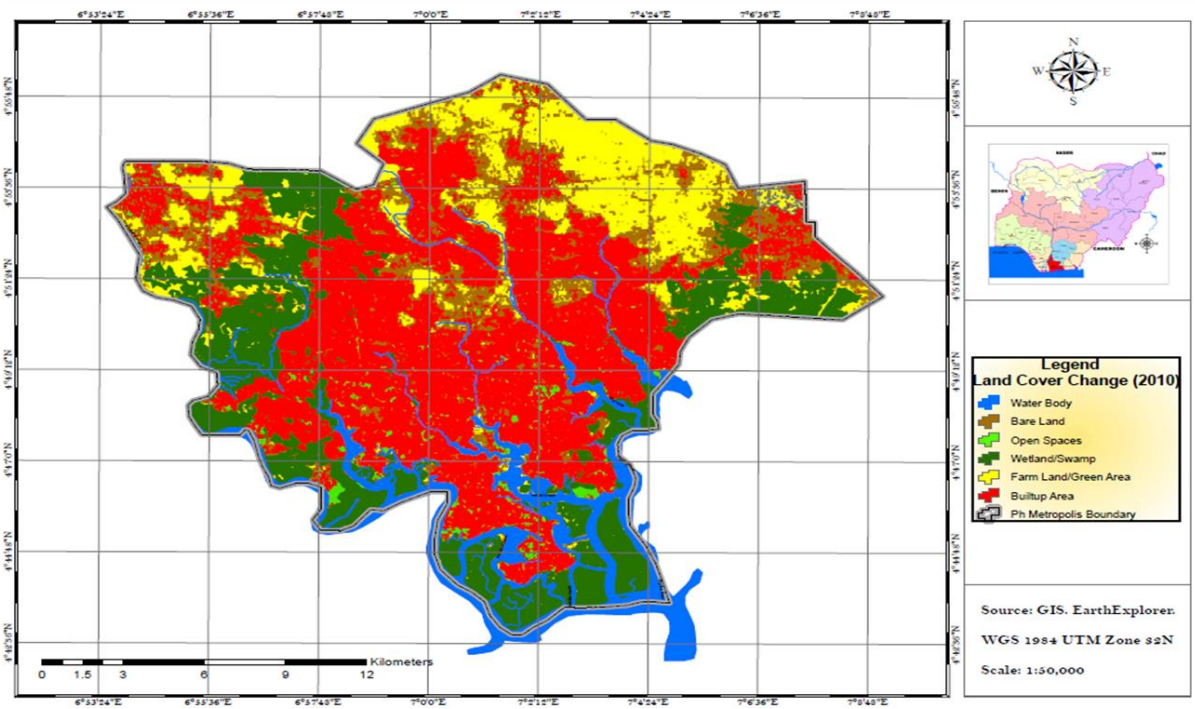


Fig. 5: Land use /land cover of Port Harcourt Metropolis for 2010
Source: Researcher's GIS Earth Explorer, 2024

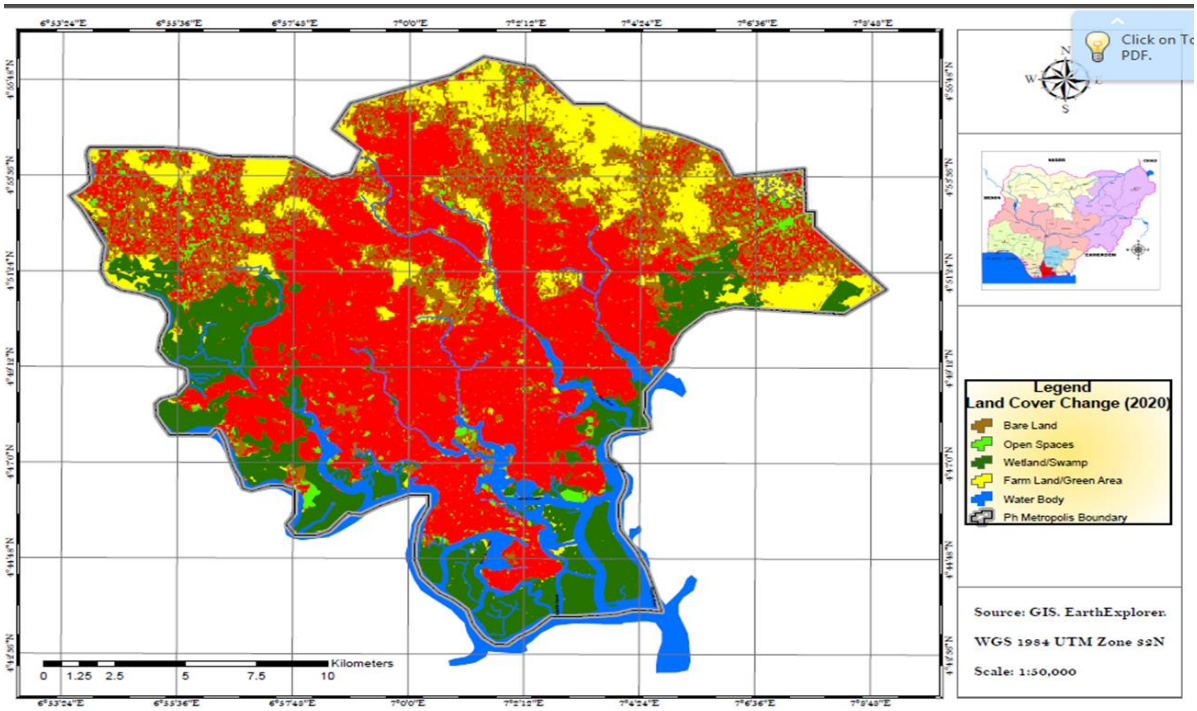


Fig. 6: Land use/ land cover of Port Harcourt Metropolis for 2020
Source: Researcher's GIS Earth Explorer, 2024

The study's findings also revealed the transformation of the natural landscape to built-up areas, a high level of incompatibility in land use, increased cases of mixed land use, land use conflict and land use class conversion and re-conversion. These findings are in line with the works of Nuissi and Siedentop (2021), who noted that the overall impacts of urbanization, land use and land cover changes can be observed in the changing environmental quality of the area, waste generation, land use conversion and land use class re-conversion, land use incompatibility and conflict as well as the general deterioration and pollution of the environment. Creutzig *et al.* (2019) also noted that in Port Harcourt Metropolis, improper land use planning has, in turn, affected the environmental quality, as the development of land in the city does not conform to laid down land use planning standards and planning principles.

From the preceding therefore, the findings of this study have revealed a significant change in land use and land cover pattern as evident in the increase in built-up areas and congested spatial arrangement in land use, due mainly to the sprawling and consequential causes of urbanization and land use dynamics which corresponds to the position of Ayotamuno *et al*. (2010), Ayotamuno and Gobo (2016), and Ayotamuno *et al.* (2022) on urbanization impacts and land use changes.

Test of Hypothesis

Ho: There is no significant statistical difference in land use change in the various epochs: 1990, 2000, 2010 and 2020 in the study area.

The ANOVA statistical test was performed using Table 3 to test this hypothesis, and the result of the analysis test is shown in Table 4.

The ANOVA test assesses whether the means of different groups are statistically different. In this context, it evaluates whether the mean land use changes observed in 1990, 2000, 2010, and 2020 significantly differ. The "Between Groups" sum of squares (12,583,223.56) indicates the variation in land use change attributable to the differences between the years. The "Within Groups" sum of squares (8,301,585,738) represents the variation within each year. The degrees of freedom (df) are 3 for the between groups and 24 for the within groups, leading to mean squares of 4,194,407.9 and 345,899,406, respectively. The F-value, the ratio of the mean square between the groups to the mean square within the groups, is 0.012. This extremely low F-value suggests that the variability between the groups (different years) is minimal relative to the group variability. The significance level (Sig.) is 0.998, far greater than the standard alpha level of 0.05.

Given that the p-value (0.998) is much higher than 0.05, the stated null hypothesis was not accepted. This indicates no statistically significant difference in land use change among the study area's epochs 1990, 2000, 2010, and 2020. Therefore, the data provides insufficient evidence to conclude that land use change varied significantly over these four periods.

IV. Conclusion

The study revealed substantial transformations in the land use and land cover of Port Harcourt metropolis, driven principally by rapid urbanization, infrastructural development, and increase in population density. The analysis emphasizes drastic reductions in vegetation cover, increase in urban sprawl, and conversion of green spaces into built-up areas. These changes have far-reaching consequences for environmental sustainability, urban planning, and resource management in the area.

The findings of this study underscore the demand for sustainable urban policies and resource management schemes to address the detrimental impact of urbanization. Hence, it is recommended that policymakers and urban planners contemplate the study's significance in their efforts to promote balanced and sustainable development. Strict land use zoning and urban green space preservation measures should be enforced to mitigate environmental degradation. Public awareness and local community involvement in urban planning processes should be increased to promote sustainable land use and environmental protection. Environmental monitoring should be integrated in urban planning, and further research should be conducted to continuously monitor these changes and examine innovative approaches to sustainable urban growth. In conclusion, this study accentuates the significant role of geospatial analysis in understanding and managing land use changes, providing a crucial tool to ensure that rapidly urbanizing areas like Port Harcourt metropolis maintain environmental sustainability.