

SPATIO-TEMPORAL ANALYSIS OF BUILT-UP AREA EXPANSION IN PORT HARCOURT METROPOLIS

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DOI: 10.5281/zenodo.22675715

Abstract

Urban expansion, defined as the physical growth of cities and urban areas, has become a prominent global phenomenon, particularly in developing countries such as Nigeria. This study presents a spatio-temporal analysis of built-up area expansion in Port Harcourt Metropolis and examines its implications for the natural environment. Using a quantitative approach within a post-positivist philosophical framework, the study adopted a longitudinal research design and wall to wall analysis of Port Harcourt and Obio/Akpor local government areas. Landsat satellite images for five epochs (1984, 1994, 2004, 2014, and 2024) with 15 m panchromatic and 30 m multispectral resolutions (UTM Zone 32N) were analysed alongside field observations. The dynamics of urban growth were examined over the 1984 - 2024 period; the spatial accuracy of Open-Street-Map (OSM) data was evaluated using handheld GPS measurements. Results revealed a substantial expansion of built-up areas, increasing by over six-fold (+66.43%) between 1984 and 2024. This expansion was accompanied by marginal declines in freshwater (–0.47%) and saltwater bodies (–1.90%), as well as significant losses in freshwater vegetation (–40.92%) and mangrove forests (–7.87%), indicating increasing ecological stress. The comparison between OSM and GPS data demonstrated satisfactory spatial accuracy. Pearson's correlation analysis ($r = –0.20, p = 0.116$) indicated a weak, negative, and statistically non-significant relationship between built-up area expansion and drainage values. The study recommends the integration of drainage management into urban planning, strengthening monitoring using GIS and remote sensing, and enhanced community participation and policy enforcement to promote sustainable urban environmental management in Port Harcourt Metropolis.

Keywords: Built-up; land-use/land-cover change; Port Harcourt; spatio-temporal; urban expansion.

1.0 Introduction

All over the world, there is surge in urban population as a result of migration from rural areas to urban areas and the fact that urban dwellers continue to procreate. Urban dwellers carry out one form of development or the other in order to meet their needs as humans. These surges in population and developments by urban dwellers result in urban expansion. The World Bank (2019) described urban expansion as the physical growth of cities and urban areas which results in the conversion of natural habitats and agricultural land use into residential, commercial, industrial, recreational, institutional land uses.

Urban expansion causes impervious surfaces; it results in a decrease in the infiltration rate of rainwater and an increase in the surface runoff. This eventually results in flood occurrence and loss of lives and property (Nabegu, 2014). Other consequences of urban expansion is the fact that it causes loss of natural habitats and biodiversity (McKinney, 2002), results in traffic congestion, longer commuting distances and greater dependence on private automobiles, which can increase vehicle emissions and contribute to urban air pollution (Lu *et al.*, 2021), exerts pressure on the available resources thereby causing inefficient use of the resources (Newton, 2017), exacerbate social and economic

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segregation because of the fact that the elites move from lower-income communities to more affluent locations (Galster, 2013).

There cannot be urban expansion without development. Development is a physical and socioeconomic change which are drastic and touches all layers of the society (Ezenagu, 2009). The Nigerian Urban and Regional Planning Decree 88 of 1992 (NURPL; LFN 138, 2004) defined development as the carrying out of any building, engineering, mining, and other operations in, or, over or under land or the making of any environmentally significant change in the use of any land or demolition of building, including the falling of trees and the place of free standing erections used for the display of advertisement on the land. Rivers state has experienced tremendous physical development over the years. The development is in form of construction of road, flyovers, residential buildings, non-residential buildings such as offices, stores, markets, schools, manufacturing industries, recreational centres, shopping malls, administrative structures and others. Growth in Port Harcourt has been experienced in terms of population and space (Brown & Wachukwu, 2015). According to Owei and Ikpoki (2006), Port Harcourt is one of the fastest growing cities in Nigeria with annual growth rate that is over five percent (5%). Truly, there have been spatial dynamics of settlements in Port Harcourt metropolis, these dynamics refers to changes in land use, population and infrastructure over time (Brown & Wachukwu, 2015).

Weje and Wachukwu (2022) opined that there is rapid influx of people and socioeconomic activities in Port Harcourt which resulted in the city's expansion and growth but in an uncoordinated manner, thereby putting strains on the existing infrastructure and making the infrastructure inadequate for the growing urban population. Among other negative influences of the influx of people to Port Harcourt is flood caused by the blockage of waterways by developers (Wachukwu, Obinna & Weje, 2020).

2.0 Study Area

The study area covers Port Harcourt City and Obio/Akpor Local Government Area of Rivers State, Nigeria. Port Harcourt is the capital and administrative head of Rivers State and the indigenous home of the Ikwerre and Okirika speaking people. Obio/Akpor is the indigenous home of the Ikwerre speaking people. Both local government areas play host to their indigenes, people from other local governments, other states and foreigners at large.

Port Harcourt is an integral part of the sub-areas of the Niger Delta. The Niger Delta region covers an area of 75,000sqkm and occupies about 60% of the 800km of the Nigerian coastline located in South-South of Nigeria (Ibisiki, Wachukwu & Diepiriye, 2022). According to Weje and Wachukwu (2022), Port Harcourt metropolis is located within Latitudes $4^0$44'58.8" N and $4^0$56'4.60" N and Longitude $6^0$52'7.2" E and $7^0$7'37.7" E (Figure 1.1). It is bounded in the north by Ikwerre/Etche LGAs, in the south by Degema/Okirika LGAs, in the west by Emuoha LGA and in the east by Oyigbo/Eleme (Figure 1.1). The metropolitan area of Port Harcourt covers an area of 934sqkm (Ibisiki *et al*, 2022). Port Harcourt metropolis can be described as a coastal urban area.

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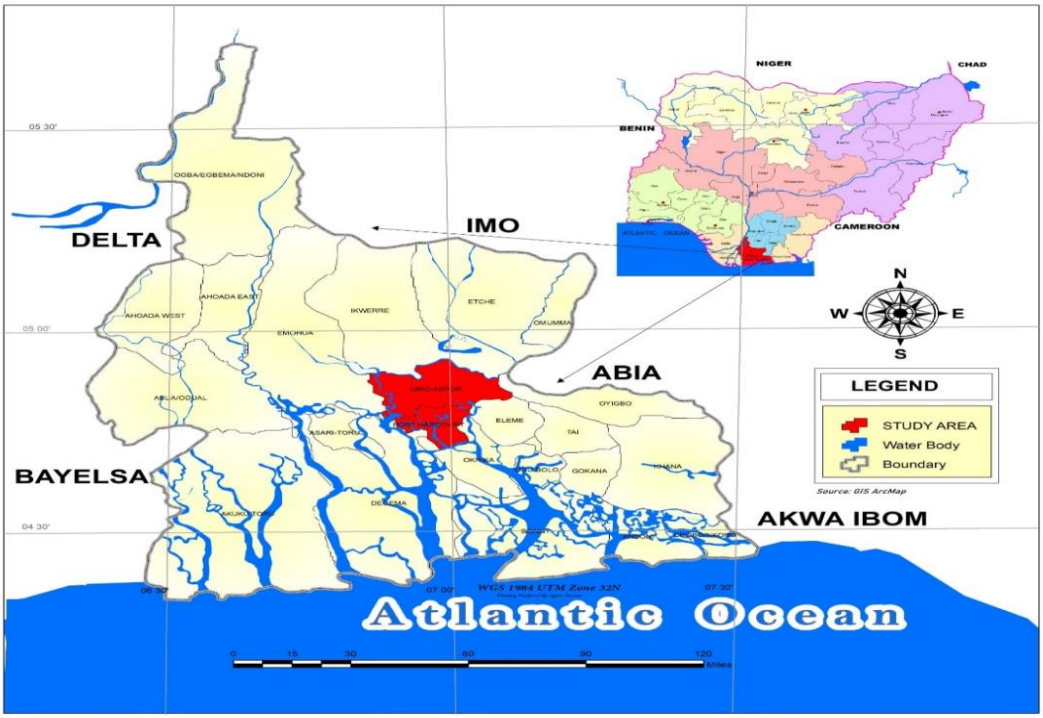


Figure 1: Rivers State Showing Port Harcourt Metropolis
Source: URP Department, Rivers State University, Port Harcourt (2024)

Urban Growth Machine Theory

According to Faridi (2020), the focus of Harvey Molotch's work is on how elites and entrepreneurs create the growth of a city. Urban growth machine theory posits that urban growth is strongly influenced by coalition of landowners, property developers, business interests and political actors whose interests are tied to intensifying land development and increasing the exchange value and profitability of land and property (Adua & Lobao, 2024). Coalition of actors and organisers share an interest in local growth since their actions affect land value, compete with growth machine elsewhere for scarce mobile capacity investment, while simutaneously attempting to gain the tacit support of local publics for such growth (Rodgers, 2009).

African City Model

It was created by geographer Harm de Blij in a work published in 1977. According to Elame (2022), the African City Model is a generalised representation of urban structure in sub-Saharan Africa, incorporating spatial and morphological elements associated with pre-colonial, European colonial and post-colonial periods. This model helps to create appreciation for the nature of urbanization in Africa with the mind set of having the largest city in Africa by the end of 21st century. The cities are characterised by urban macrocephaly, informality and colonial heritage (Zuma & Sawadogo, 2022).

Urban Expansion

Urban expansion has been experienced in many parts of the world, especially in developing nations. It is basically the physical growth of



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cities and urban areas, and such growth is characterised by low-density development rather than high density, a further fact being that the growth is disintegrated and dispersed (Galster, Hanson, Ratcliffe, Wolman, Coleman & Freihage, 2001). Urban expansion can manifest as urban sprawl, which refers to the rapid outward and dispersed physical growth of cities, often charaterized by fragmented development, low-density land-use patterns and increased dependence on private automobiles (Zietz & Kirchhain, 2023).

Urban expansion does not occur in isolation; there are factors that triggers it, among such factors is rapid population growth which further leads to quest for housing and other land uses that services the need of urban dwellers (Bhatta, 2010); increment in urban economy which creates vast employment opportunity (Fujita, Krugman, & Venables, 2001); and the development of transportation infrastructure which is the life wire of the urban environment.

The work of Koko et al (2021), says that Lagos, which is Nigeria's economic hub and one of Africa's fastest growing cities, has experienced remarkable urban growth. The city has recently faced persistent urban flooding due to unsustainable growth and inadequate data for proper planning. Therefore, analysis of urban growth and land cover change in Lagos, Nigeria, was done using multi-temporal datasets downloaded from the United States Geological Survey (USGS) at an interval of 10 years from 1990–2020. Maximum likelihood classification and post-classification change were employed to detect and analyse the city's urban growth and change dynamics.

The study revealed three phases of growth in Lagos and a substantial increase in the city's built-up area from 496 km^2 in 1990 to approximately 860 km^2 in 2000. This area increased further to 1113 km^2 in 2010, and presently over 1256 km^2. The result also revealed a substantial decrease in the city's vegetation, water bodies, and bare soil by approximately 398 km^2, 246 km^2, and 115 km^2, respectively, between 1990 and 2020. These changes contribute to urban flooding, the prominent natural and human-induced disaster in the city.

3.0 Methodology

The research utilised a quantitative approach within a post-positivist philosophical framework, it adopted a longitudinal research design, and wall to wall analysis of Port Harcourt and Obio/Akpor local government areas. Multi-temporal Landsat images for 1984, 1994, 2004, 2014, and 2024 with 15m panchromatic and 30m multispectral resolutions (UTM Zone 32N) were obtained and processed. Image pre-processing included geometric correction, radiometric normalisation, and atmospheric correction. Supervised classification using the maximum likelihood algorithm was employed to classify land use/land cover into built-up areas, vegetation, water bodies, and bare land. Post-classification comparison was used to quantify spatial changes across epochs. Classification accuracy was assessed using Cohen's Kappa coefficient.

4.0 Results and Discussion

Results reveal a persistent and accelerating increase in built-up land across all epochs. Built-up areas expanded from a compact urban footprint in 1984 to extensive spatial coverage by

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2024. Vegetation cover declined sharply, particularly freshwater vegetation, while mangrove forests experienced steady but less pronounced losses. Water bodies recorded marginal reduction, reflecting gradual encroachment and infilling of wetlands and creeks.

Urban Expansion in 1984

In 1984, saltwater covered 21,455,088sqm (2,145.09Ha) which represents 5.85% of the total area; the fresh water covered 4,888,818sqm (488.88Ha), representing 1.33% of the total area; the fresh water vegetation area covered 189,351,404.29sqm (18,935.14Ha), which represents 51.65% of the total area; the mangrove vegetation covered 48,500,548sqm (84,850.06Ha), representing 13.23% of the total area; the built-up area covered 46,175,117.81 (4,617.51Ha) which represents 12.60% of the study area; while bare land covered 56,237,345sqm (5,623.74Ha), representing 15.34% of the total area, (See figure 2).

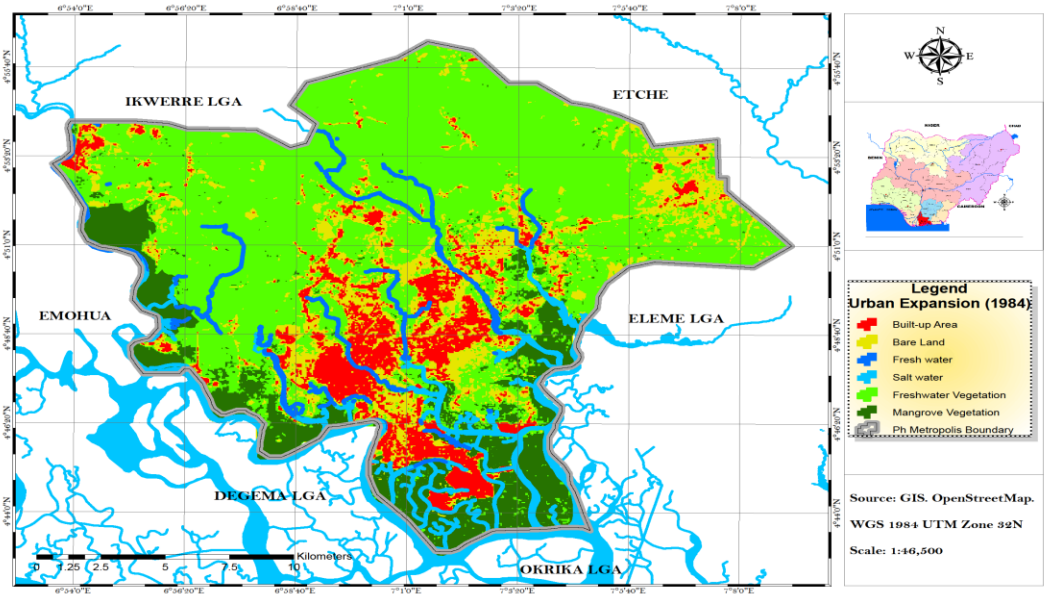


Figure 2: Level of Urban Expansion in 1984
Source: Researcher's Conceptualisation and GIS Open Street Map (2024)

Urban Expansion in 1994

In 1994, salt water reduced by 1.01%, leaving an area of 17,741,759sqm (1,774.18Ha); fresh water occupied 3,975,489sqm (397.55Ha) which is a 0.255% reduction from 1984; fresh water vegetation reduced by 3.68%, thereby occupying 175,861,953.08sqm (17,586.19Ha) of the total area; the mangrove vegetation reduced from 48,500,548sqm (4,850Ha) to 39,137,147.48sqm (3,913.75Ha), a 2.55% reduction; the built up area increased by 8.89% as it occupied 78,765,800.44sqm (7,876.58Ha) against 46,175,117.81sqm (4,617.51Ha) in 1984; the bare land lost 5,111,173sqm (511.12Ha) which represent 1.4% of the total area, (See figure 3).

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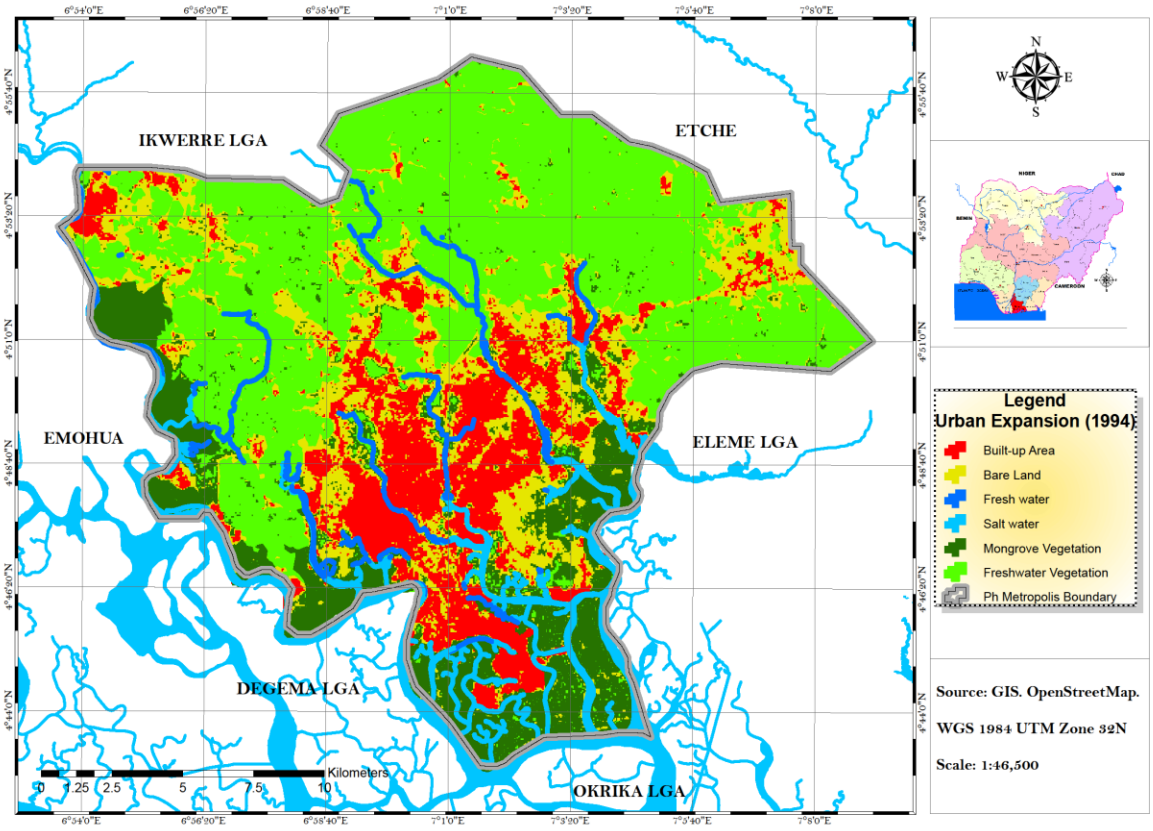


Figure 3: Level of Urban Expansion in 1994
Source: Researcher's Conceptualisation and GIS Open Street Map (2024)

Urban Expansion in 2004

In the year 2004, the salt water reduced by 0.22% and fresh water reduced by 0.14% from the previous epoch; the salt water now covers 15,624.150sqm (1,562.42Ha) which represent 4.62% of the total area as against 4.84% of the previous epoch; whereas fresh water covers 3,457,880sqm (345.79Ha) which represent 0.94% of the total area as against 1.08% of the previous epoch. For the vegetation, the fresh water vegetation reduced by 9.66% as it now covers 140,434,306.40sqm (14,043.43Ha) representing 38.31% of the total area; the mangrove vegetation reduced by 2.15%, it now occupies 31,261,944sqm (3,126.19Ha) which represent 8.53% of the total area. The built up area increased by 13.87% as it now covers 129,620,910.70sqm (12,962.09Ha) which represents 35.36% of the total area. The bare land occupies 46,209,130.08sqm (4,620.91Ha) which is 12.60% of the total area, it records 1.34% reduction from previous epoch, (See figure 4).

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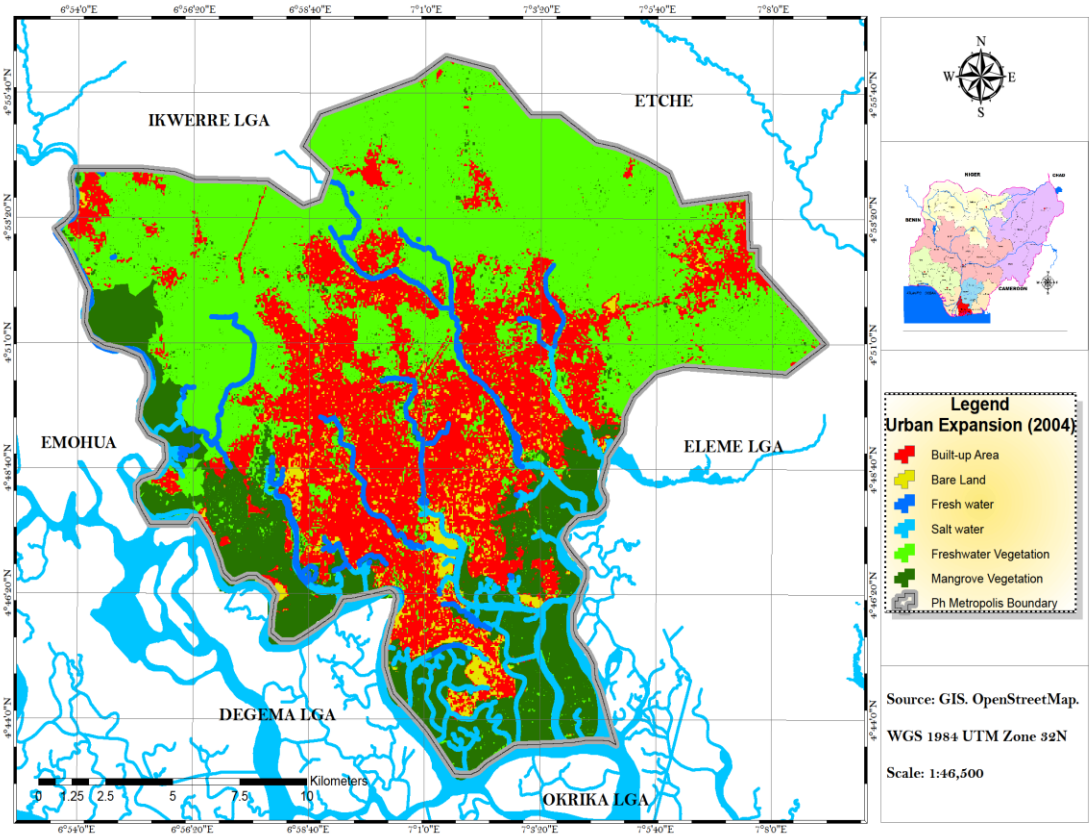


Figure 4: Level of Urban Expansion in 2004
Source: Researcher's Conceptualisation and GIS Open Street Map (2024)

Urban Expansion in 2014

The fourth epoch did not record tremendous changes of the water bodies as salt water and fresh water reduced by 0.18% and 0.05% respectively. The salt water now occupies 14,953,744sqm (1,495.37Ha) while fresh water occupies 3,267,474sqm (326.75Ha) which represent 4.08% and 0.89% respectively. The freshwater vegetation covers 91,892,946.04sqm (9,189.30Ha), a figure that indicates 13.24% reduction from the previous epoch; 2,000,000.40sqm (200.00Ha) of the mangrove vegetation was lost, a figure representing 0.55%, thereby leaving the total mangrove vegetation area at 29,261,943.60sqm (2,926.19Ha). The built-up area records the highest jump in this epoch as it increased by 24.76%, leaving the total built environment at 220,402,972.21sqm (22,040.30Ha) which represent 60.12% of the total area. The bare land reduced from 46,209,130.08sqm (4,620.91Ha) in the previous epoch to 6,829,241.15sqm (682.92Ha), a 10.74% reduction.

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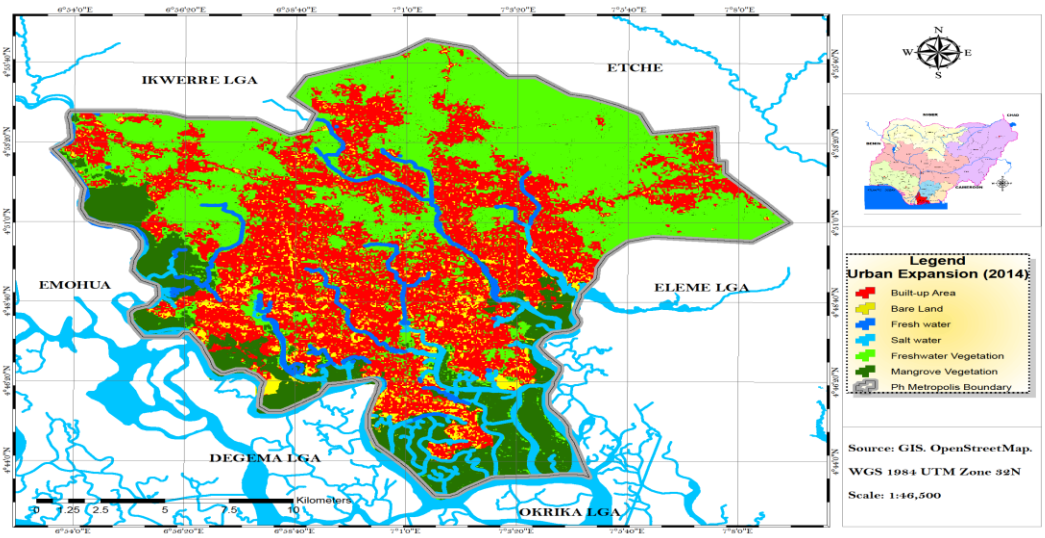


Figure 5: Level of Urban Expansion in 2014
Source: Researcher's Conceptualisation and GIS Open Street Map (2024)

Urban Expansion in 2024

The last epoch records slight differences from the previous epoch. Salt water reduced by 0.13% thereby covering 14,488,217.47sqm (1,448.82Ha), a 3.95% of the total area; fresh water area reduced by 0.03% but covers 3,161,947.49sqm (316.20Ha) of the total study area. The fresh water vegetation now covers 10.73% of the total area, a 14.34% reduction from the previous epoch, which means that it now covers 39,333,970.67sqm (3,933.40Ha); the mangrove vegetation covers 19,636,316.60sqm (1,963.63Ha), a figure representing 5.36% of the total area and a 2.62% reduction from the previous epoch. The built up area has taken majority of the total area (79.03%), it now covers 289,714,188.11sqm (28,971.42Ha), it is 18.91% increase from the previous epoch. The bare land of Port Harcourt metropolis is almost gone as only 273,680.67sqm (27.37Ha) representing 0.07% of the total metropolis is left.

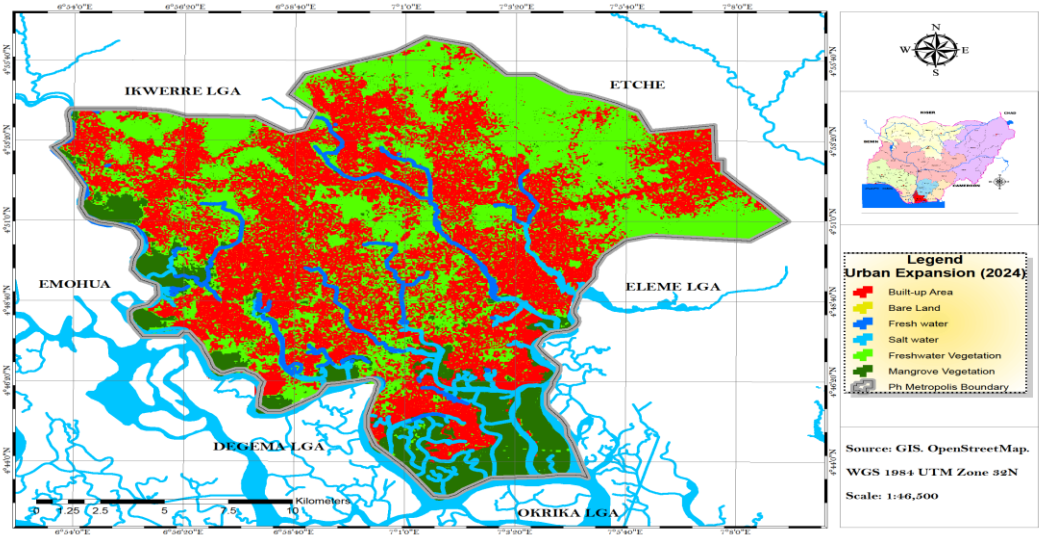


Figure 6: Level of Urban Expansion in 2024
Source: Researcher's Conceptualisation and GIS Open Street Map (2024)



Summary of Urban Expansion

Table 1 gives the total coverage area of the variables: salt water, fresh water, fresh water vegetation, mangrove vegetation, built up and bare land and the changes from 1984 and 2024. A Kappa value of 0.75 signifies substantial agreement between the classified LULC map and the reference (ground-truth) data, indicating that the classification correctly represents most land cover types beyond random chance. This level of agreement reflects strong thematic accuracy, suggesting that the classification model effectively distinguished between major land cover categories such as vegetation, built-up areas, bare land and vegetated areas.

Table 1: Summary of Urban Expansion

S/N	Variables	1984 (sqm)	2024 (sqm)	Change (sqm)
1	Saltwater	21,455,088.00	14,488,217.47	-6,966,870.53
2	Freshwater	4,888,818.00	3,161,947.49	-1,726,870.51
3	Freshwater vegetation	189,351,404.29	39,333,970.67	-150,017,433.62
4	Mangrove vegetation	48,500,548.00	19,636,316.60	-28,864,231.40
5	Built up	46,175,117.81	289,714,188.11	243,539,070.30
6	Bare land	56,237,345.00	273,680.67	-55,963,664.33

Source: Researcher's Conceptualisation and GIS Open Street Map (2024)

The statistical analysis using Pearson correlation ($r = -0.20$, $p = 0.116$) confirmed a weak, negative, and non-significant relationship between built-up area and drainage value, indicating that urban expansion alone does not significantly predict drainage decline, though the trend is consistent with theoretical expectations of reduced infiltration and drainage capacity due to urbanization.

The observed expansion pattern aligns with urban growth machine theory, which attributes spatial growth to land-based economic interests and speculative development (Adua & Lobao, 2024). The outward sprawl into peri-urban and low-lying areas reflects land scarcity in the urban core and weak enforcement of planning regulations (Weje and Ameme, 2022). These changes have significant implications for ecosystem services, hydrological processes, and urban resilience.

6.0 Conclusion and Recommendations

Urban expansion in Port Harcourt has been rapid, extensive, and largely unregulated. Strengthening spatial planning institutions, enforcing development control, and integrating environmental considerations into urban growth policies are critical for sustainable urban development.

The analysis of urban expansion dynamics revealed a rapid and sustained increase in built-up areas, expanding by over six-fold (+66.43%) between 1984 and 2024. This expansion occurred largely at the expense of vegetated areas and freshwater and saltwater ecosystems. Bare land and freshwater vegetation declined by –15.27%



and –40.92% respectively, indicating massive conversion of natural landscapes into urban land uses. The findings confirm that Port Harcourt Metropolis has undergone intense anthropogenic transformation, shifting from an eco-dominant to a human-dominated urban environment.

Therefore, Urban planning authorities should embed natural environment conservation into development regulations to prevent obstruction and loss of the natural environment; continuous monitoring of urban expansion and natural environment changes should be conducted using high-resolution satellite data and GPS validation to support evidence-based decision-making; and Government agencies should engage local communities in maintaining drainage systems and enforce regulations against illegal land reclamation and construction on floodplains.

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