Federal Polytechnic Ugep Journal of Innovation and Research (FPUJIR)
Maiden Edition
www.fpujournal.com
Volume 1; Issue 2; November 2024; Page No. 10-15.

UTILIZING GIS AND REMOTE SENSING FOR EFFICIENT URBAN PLANNING AND SUSTAINABLE DEVELOPMENT IN CROSS RIVER STATE, NIGERIA

Andrew N. Reigns, PhD, Uba James Uba, PhD
Corresponding author: *andrewreigns2010@gmail.com,

Abstract
Rapid urbanization and population growth are increasingly pressing urban ecosystems, posing significant challenges to their sustainability and the well-being of urban residents. Effective management of these ecosystems is essential. Remote Sensing (RS) and Geographic Information Systems (GIS) have become indispensable tools for analyzing and managing urban environments. This study explores integrating RS and GIS technologies for real-time monitoring and assessment of environmental parameters within urban ecosystems, aiming to support sustainable conservation efforts. The present study employed Landsat 8 Operational Land Imager (OLI) data to evaluate urban ecosystem dynamics in Cross River State, Nigeria. The Normalized Difference Built-up Index (NDBI) was utilized to identify concrete structures and impervious surfaces. In contrast, the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) were employed to detect vegetation and water bodies. Findings revealed a significant increase in built-up areas at the expense of forests and other land uses. The integration of RS and GIS technologies provides valuable insights into urban environments' spatial and temporal dynamics, facilitating evidence-based decision-making and promoting sustainable urban planning and development.

Keywords: GIS, RS, urban planning, sustainable development.

Introduction
Urban planning and sustainable development are critical for the growth and well-being of communities. Effective urban planning involves designing and organizing cities to meet the needs of current and future generations while promoting sustainability. Planning for a sustainable urban development must be oriented towards long-term goals (NÆss, 2001), focusing on meeting the needs of the present without compromising the ability of future generations to meet their own needs. By prioritizing sustainable practices in urban planning, communities can create a more resilient and environmentally friendly future. An extremely important function of an urban ecosystem is to provide healthy and sustainable environments for both natural systems and communities (Mersal, 2016).

Urban planning has been recognized as being central to sustainability because well-planned urban centers can be engines of economic prosperity, social well-being, and environmental sustainability (Echendu, 2020). The fast progress of urbanization and the accompanying dominance of concrete spaces over natural spaces are fundamental to current debates on urban planning and sustainable development in Nigeria and the world (Oyinloye et al., 2023). Rapid urbanization is putting a strain on urban infrastructure and resources, and urban managers often lack the resources they need to provide essential services to their citizens and protect the ecosystems. The dearth of data on the rate of urban expansion, especially in many developing countries, including Nigeria, has continued to hinder effective land use planning and sustainable development (Ogochukwu et al., 2022). This is particularly so in developing

Cite this article as:
Andrew, *et al.* (2024). Utilizing GIS and Remote Sensing for Efficient Urban Planning and Sustainable Development in Cross River State, Nigeria. *Federal Polytechnic Ugep Journal of Innovation and Research (FPUJIR), 1(2)* 10-15.

countries where discrepancies in urban planning policies and programs associated with rapid urbanization threaten sensitive urban ecosystems such as urban forests, water resources, and soil. Like many other states in Nigeria, Cross River State is faced with several environmental problems due to unplanned urbanization. The effective management of urban ecosystems is crucial to ensure their sustainability and the well-being of urban residents across time and space.

Africa has been experiencing a rapid urbanization process, which may lead to an increase in unsustainable land use and urban poverty (Jiang et al., 2021). Urbanization is a global phenomenon, but its negative effects are most pronounced in developing countries (Gumel et al., 2020). Rapid urbanization is a global phenomenon that poses significant challenges to urban planning and sustainable development. In Cross River State, Nigeria, these challenges are particularly acute due to the region's unique geographical and socio-economic context. Geographic Information Systems (GIS) and Remote Sensing are powerful tools that can help address these challenges. GIS allows for the collection, storage, analysis, and visualization of spatial data, while Remote Sensing provides a means to monitor and assess changes in land use and environmental conditions over time. Great strides have been made in Geographic Information Systems (GIS) research (Lü et al., 2019).

Geospatial technology is a powerful tool that allows us to explore and understand our planet's spatial and temporal aspects. Among the various geospatial technologies, 3D geospatial information technology stands out as a transformative force in geography, environmental science, and urban planning. Geospatial technology enables us to analyze and visualize data in a spatial context. It goes beyond traditional maps and charts by incorporating the third-dimension depth into our understanding of geographic phenomena. By integrating location data with descriptive information, we gain insights into patterns, relationships, and processes that shape our world. Geographic Information Systems (GIS) and Remote Sensing are powerful tools increasingly used in urban planning and sustainable development. They allow for the collection, storage, analysis, and visualization of spatial data, providing valuable insights for decision-making. In the context of Cross River State, Nigeria, these technologies can play a crucial role in addressing the challenges of rapid urbanization. Like many other regions in Nigeria, Cross River State is experiencing rapid urban growth, leading to significant changes in land use patterns. These changes can have various environmental impacts, including deforestation, loss of biodiversity, increased waste generation, and pollution.

GIS and Remote Sensing in Urban Planning

GIS and RS technologies provide valuable tools for urban planners by offering detailed spatial data and analysis capabilities. These technologies can be used for urban planners by offering detailed spatial data and analysis capabilities. These technologies are essential for understanding the complex dynamics of urban environments and making informed decisions. For example, GIS can be used to map out land use patterns, transportation networks, and infrastructure locations within a city. This detailed mapping allows urban planners to identify areas for potential development, assess the impact of new projects, and optimize resource allocation. GIS and RS methods have been widely applied in urban planning. Several disparate studies in urban development have highlighted the potential to significantly improve the mapping of urban area (Anand & Deb, 2024; Baba et al., 2019; Borfecchia et al., 2014; Droj et al., 2023; Fasona & Omojola, 2004; Huang et al., 2019; Ouchra et al., 2023; Phuong et al., 2021; Sun & Xiong, 2023; Verma et al., 2009; Vikram & Bhardwaj, 2023).

Furthermore, remote sensing (RS) technologies are crucial in monitoring urban growth, environmental changes, and natural disasters. By utilizing satellite imagery and aerial photography, urban planners can track changes in land cover, detect illegal construction activities, and assess the extent of damage caused by disasters such as floods or wildfires. This information is invaluable for developing mitigation strategies, improving emergency response plans, and ensuring sustainable urban development. In addition, integrating GIS and RS technologies enables urban planners to analyze spatial relationships, identify

Cite this article as:
Andrew, *et al.* (2024). Utilizing GIS and Remote Sensing for Efficient Urban Planning and Sustainable Development in Cross River State, Nigeria. *Federal Polytechnic Ugep Journal of Innovation and Research (FPUJIR), 1(2)* 10-15.

trends, and visualize data in a geospatial context. This spatial analysis helps identify potential hotspots for crime, determine suitable locations for new facilities, and predict future urban growth patterns. By leveraging these advanced technologies, urban planners can make data-driven decisions that enhance cities' livability, sustainability, and resilience. Overall, GIS and RS technologies are indispensable tools for urban planners, providing them with the necessary insights and tools to address the complex challenges of urbanization. Using spatial data and analysis capabilities, urban planners can create more efficient, inclusive, and sustainable cities for current and future generations.

In this paper, studies from the rapidly urbanizing Calabar metropolis in Cross River State, Nigeria, are used to provide information on how remote sensing (RS) and geographical information system (GIS) tools can be used to monitor and evaluate urban development processes. Thus, this study aimed to investigate how remote sensing and GIS can be integrated into managing urban ecosystems and highlight their benefits and applications in urban planning, environmental monitoring, and decision-making processes in Cross River State. This study demonstrates the advantages of RS and GIS information to urban ecosystem planning and development, especially in cities faced with serious environmental problems and ecological risks from human activities

Method

Cross River State is within the tropical rainforest, sharing common boundaries with the Cameroon Republic in the East, Benue State in the North, Enugu and Abia States in the West, and Akwa-Ibom State in the South. Cross River State occupies a total land area of 22,341 square kilometers, translating to a population density of 130 persons per square kilometer in 2006. The projected population for 2018, 2025, and 2050 implied a density of 189, 236, and 518 persons per square kilometers for 2018, 2025, and 2050, respectively. These are indicators of increasing population pressure on the land over time which has environmental implications. Because of the uneven spatial distribution of the population, the pressure on the land varied markedly across Local Government Areas (LGA) in 2006, ranging from 30 persons per square kilometer in Akamkpa to 1170 persons per square kilometer in Calabar Municipality. By and large, Seven LGAs{ Akamkpa (30), Bakassi (38), Boki (68), Etung (89), Ikom (91), Obanliku (103) and Yala (104)} have densities below the State average of 130, while the rest { Abi (431), Akpabuyo (334), Bekwarra (347), Biase (131), Calabar South (709), Obubra (159), Obudu (311), Odukpani (136), Ogoja (148) and Yakurr (293) have higher densities than the average

Figure 2. A map showing the location of Cross River State, Nigeria

Cite this article as:
Andrew, *et al.* (2024). Utilizing GIS and Remote Sensing for Efficient Urban Planning and Sustainable Development in Cross River State, Nigeria. *Federal Polytechnic Ugep Journal of Innovation and Research (FPUJIR), 1(2)* 10-15.

Image Acquisition and processing

Landsat 8 OLI collects data in nine spectral bands, ranging from visible to infrared wavelengths, with a spatial resolution of 30 meters for most bands. Images are acquired systematically as the satellite orbits the Earth, covering the globe every 16 days. The data captured by Landsat 8 OLI is freely available to the public through platforms like USGS Earth Explorer. Image processing software (ArcGIS) was used to analyze and manipulate the Landsat 8 OLI data for the purpose of the study. Landsat 8 OLI plays a crucial role in remote sensing and Earth observation by providing valuable data for various applications through its image acquisition and processing capabilities.

Image Analysis

The Built-up Index (BU) is a commonly used method in image analysis to identify and quantify built-up areas within satellite images or aerial photographs. The BU index was calculated using mathematical formulas that considered various spectral bands or indices from the image data. These calculations were designed to highlight built-up areas based on their unique spectral signatures. The BU method provided a systematic approach to analyze and map built-up areas in images, offering valuable insights into the study area. Image analysis using The Built-up Index (BU) provided a pathway to identify built-up areas in satellite. The ratio index used to differentiate between built-up areas and non-built-up areas based on certain spectral characteristics was calculated thus.

$$(BU = \frac (BandX - BandY) (BandX + BandY)$$

Where:

(BandX) Moreover, (BandY) represents the values of specific bands from satellite or aerial imagery.

By calculating the Built-up Index (BU) for each pixel in the image, areas with high BU values typically correspond to built-up areas (urban areas, buildings). In contrast, low BU values indicate non-built-up areas (like vegetation and water bodies). This method is commonly used in remote sensing and geographic information systems (GIS) applications for urban mapping, land cover classification, and change detection analysis.

Results and Discussion

Results: The analysis of Landsat 8 OLI data revealed notable changes in land use patterns within Cross River State, Nigeria, over the study period. The Normalized Difference Built-up Index (NDBI) highlighted a significant increase in areas covered by concrete structures and impervious surfaces. Built-up areas expanded, encroaching on previously vegetated and forested regions. The Normalized Difference Vegetation Index (NDVI) indicated a decline in vegetation cover, signaling deforestation and loss of green spaces. The Normalized Difference Water Index (NDWI) showed a reduction in water bodies, which may be attributed to urban development and land reclamation activities.

The findings underscore the rapid pace of urbanization in Cross River State and its impact on natural ecosystems. The increase in built-up areas has occurred at the expense of forests and other land uses, leading to habitat loss and environmental degradation. The integration of RS and GIS technologies in this study provided a comprehensive view of these changes, enabling a detailed analysis of spatial and temporal dynamics. The expansion of urban areas poses challenges for sustainable development, including increased pressure on natural resources, loss of biodiversity, and heightened risks of flooding and pollution. Effective urban planning and management are crucial to mitigating these impacts and promoting a balance between urban growth and environmental conservation.

Implications

The insights gained from RS and GIS analyses can inform urban planners and policymakers in developing strategies to manage urban growth sustainably. Implementing green infrastructure and preserving green

Cite this article as:
Andrew, *et al.* (2024). Utilizing GIS and Remote Sensing for Efficient Urban Planning and Sustainable Development in Cross River State, Nigeria. *Federal Polytechnic Ugep Journal of Innovation and Research (FPUJIR), 1(2)* 10-15.

spaces can help mitigate the adverse effects of urbanization. Highlighting areas of significant ecological value can guide conservation efforts and prioritize areas for protection and restoration.

Conclusion

In conclusion, integrating remote sensing and geographical information systems technologies has provided valuable insights into the dynamics of urban ecosystems in Cross River State, Nigeria. The study revealed significant increases in built-up areas at the expense of forests and other land uses, underscoring the need for sustainable urban planning and conservation efforts. By leveraging the capabilities of RS and GIS, stakeholders can make informed decisions to promote sustainable development, protect natural ecosystems, and enhance the well-being of urban residents. Continued research and technological advancements will be essential in addressing the challenges of rapid urbanization and ensuring the long-term sustainability of urban environments.

Reference

Anand, A., & Deb, C. (2024). The potential of remote sensing and GIS in urban building energy modelling. In *Energy and Built Environment* (Vol. 5, Issue 6). https://doi.org/10.1016/j.enbenv.2023.07.008

Baba, K. A., Lal, D., & Bello, A. (2019). Application of Remote sensing and GIS Techniques in Urban Planning, Development and Management. (A case study of Allahabad District, India). *International Journal of Scientific & Engineering Research*, *10*(6).

Borfecchia, F., Caiaffa, E., Pollino, M., De Cecco, L., Martini, S., La Porta, L., & Marucci, A. (2014). Remote sensing and GIS in planning photovoltaic potential of urban areas. *European Journal of Remote Sensing*, *47*(1). https://doi.org/10.5721/EuJRS20144713

Droj, G., Droj, L., Badea, A. C., & Dragomir, P. I. (2023). GIS-Based Urban Traffic Assessment in a Historical European City under the Influence of Infrastructure Works and COVID-19. *Applied Sciences (Switzerland)*, *13*(3). https://doi.org/10.3390/app13031355

Echendu, A. J. (2020). Urban planning — "It's all about sustainability": Urban planners' conceptualizations of sustainable development in Port Harcourt, Nigeria. *International Journal of Sustainable Development and Planning*, *15*(5). https://doi.org/10.18280/ ijsdp.150501

Fasona, M. J., & Omojola, a S. (2004). Gis and Remote Sensing for Urban Planning : a Case of Festac Town , Lagos , Nigeria. *Africa*, *2*(June).

Gumel, I. A., Aplin, P., Marston, C. G., & Morley, J. (2020). Time-series satellite imagery demonstrates the progressive failure of a city master plan to control urbanization in Abuja, Nigeria. *Remote Sensing*, *12*(7). https://doi.org/10.3390/rs12071112

Huang, H., Li, Q., & Zhang, Y. (2019). Urban residential land suitability analysis combining remote sensing and social sensing data: A case study in Beijing, China. *Sustainability (Switzerland)*, *11*(8). https://doi.org/10.3390/su11082255

Jiang, S., Wei, G., Zhang, Z., Wang, Y., Xu, M., Wang, Q., Das, P., & Liu, B. (2021). Detecting the dynamics of urban growth in Africa using DMSP/OLS nighttime light data. *Land*, *10*(1). https://doi.org/10.3390/land10010013

Lü, G., Batty, M., Strobl, J., Lin, H., Zhu, A. X., & Chen, M. (2019). Reflections and speculations on the progress in Geographic Information Systems (GIS): a geographic perspective. In *International Journal of Geographical Information Science* (Vol. 33, Issue 2). https://doi.org/10.1080/13658816.2018.1533136

Mersal, A. (2016). Sustainable Urban Futures: Environmental Planning for Sustainable Urban Development. *Procedia Environmental Sciences*, *34*. https://doi.org/10.1016/j.proenv.2016.04.005

NÆss, P. (2001). Urban planning and sustainable development. *European Planning Studies*, *9*(4). https://doi.org/10.1080/713666490

Cite this article as:
Andrew, *et al.* (2024). Utilizing GIS and Remote Sensing for Efficient Urban Planning and Sustainable Development in Cross River State, Nigeria. *Federal Polytechnic Ugep Journal of Innovation and Research (FPUJIR), 1(2)* 10-15.

Ogochukwu, C. G., Chioma, J. N. A., Ogochukwu, O. F., Chukwudi, E. C., & Ogorchukwu, I. M. (2022). Rapid spatial growth of cities and its planning implications for developing countries: a case study of Abuja, Nigeria. *Indonesian Journal of Geography*, *54*(2). https://doi.org/10.22146/ijg.70316

Ouchra, H., Belangour, A., & Erraissi, A. (2023). A comprehensive study of using remote sensing and geographical information systems for urban planning. *Internetworking Indonesia Journal*, *14*(1).

Oyinloye, M. A., Olisa, C. L., & Olisa, B. S. (2023). Modelling Urban Green Spaces Depletion in Akure, Nigeria. *International Journal of Environmental Engineering and Development*, *1*. https://doi.org/10.37394/232033.2023.1.16

Phuong, L. T. M., Anh, V. Le, & Quang, N. H. (2021). Research on Urban Land Use Change in Ha Noi, Viet Nam Using Remote Sensing and GIS for Planning Oriented Work. *International Journal of Sustainable Construction Engineering and Technology*, *12*(3 Special issue). https://doi.org/10.30880/ijscet.2021.12.03.003

Sun, S., & Xiong, T. (2023). Application of Remote Sensing Technology in Sustainable Urban Planning and Development. *Applied and Computational Engineering*, *3*(1). https://doi.org/10.54254/2755-2721/3/20230475

Verma, R., Kumari, K., & Tiwary, R. (2009). Application of Remote Sensing and GIS technique for efficient Urban planning in India. *Geomatrix Conference Proceedings*, *March*.

Vikram, L., & Bhardwaj, M. (2023). Assessment of Urban Wastelands using GIS and IoT as Tools for Spatial Data Analysis. *Current World Environment*, *18*(2). https://doi.org/10.12944/cwe.18.2.35.

Cite this article as:
Andrew, *et al.* (2024). Utilizing GIS and Remote Sensing for Efficient Urban Planning and Sustainable Development in Cross River State, Nigeria. *Federal Polytechnic Ugep Journal of Innovation and Research (FPUJIR), 1(2)* 10-15.