EVALUATING THE EFFECTS OF REAL ESTATE DEVELOPMENT IN OWERRI, IMO STATE, NIGERIA: EMPHASIZING CHANGES IN LAND USE/LAND COVER (LULC)

CASMIR CHUKWUEMEKA AKAOLISA[1], OKECHUKWU EBUKA AGBASI[2*], SUNDAY EDET ETUK[3], ROWLAND ADEWUMI[4,5]; EMEKA AUSTIN OKOLI[1]

[1]*Department of Geology, Federal University of Technology, Owerri, Nigeria*
[2]*Okna Geophysical Services, Eket, Nigeria*
[3]*Department of Physics, University of Uyo, Uyo, Nigeria*
[4]*Department of Civil Engineering, Faculty of Engineering, University of Abuja, Nigeria*
[5]*Zephyrgold International Limited, Abuja, Nigeria.*
**Corresponding author email: agbasi.okechukwu@gmail.com*

Received: 19th July 2023, **Accepted:** 19th September 2023

ABSTRACT

Analysis of the impacts of real estate development on biodiversity within the confines of Imo State, Nigeria, was the main objective of this study. The investigation included a look at how land use and land cover (LULC) changed between 2017 and 2022. The study made use of Sentinel-2 image with a spatial resolution of 10 m. The research team used supervised classification algorithms to classify the imagery, which were then compared to find changes in land use and land cover (LULC). The following categories apply to the land use and land cover (LULC) of the study area: In 2017, trees accounted for 58.84 % of the total land surface and covered the most land, covering an area of 315.05 km^2. The amount of developed land, or 30.23 % of the total land area, was assessed to be 161.84 km^2. Approximately 61.91 % of the entire land surface in 2018, or 331.47 km^2, was covered by arboreal vegetation, which dominated the landscape. Comparatively, urbanised regions made up 177.41 km^2, or 33.14 % of the total land area. With trees making up 59.434 % or 318.22 km^2 of the total land area in 2019, trees were found to be the most prevalent kind of land cover. Concurrently, built-up areas accounted for 34.30 % of the land, or 183.66 km^2. The LULC map for 2020 showed a comparable pattern, with trees covering 58.46 % (equivalent to 313.02 km^2) of the total land area and built-up areas covering 34.71 % (equivalent to 185.88 km^2). According to the research, the impact of real estate development on the environment is primarily negative, resulting in habitat depletion, ecosystem fragmentation, and the introduction of pollutants. The researchers advised using sustainable development practises to mitigate the aforementioned negative effects.

Keywords: Ecosystem fragmentation, Sentinel-2 imagery, Supervised classification techniques, Sustainable development practices

INTRODUCTION

In many regions of the world, including Owerri, Imo State, Nigeria, real estate development has become a major driver of economic growth and urbanization (Lin & Yi, 2011; Turok & McGranahan, 2013). However, this form of development frequently results in changes in land use and land cover (LULC), which can have serious consequences for biodiversity (Awoniran *et al*., 2014; Arowolo *et al*., 2018; Olorunfemi *et al*., 2018; Obiahu & Elias, 2020; Obiahu *et al*., 2021). The loss of natural habitats and ecosystem fragmentation induced by real estate development can lead to a fall in plant and animal populations, resulting in a reduction in biodiversity overall (Kleijn *et al*., 2011; Yohannes *et al*., 2021).

According to Haylemariyam (2018), the bulk of human activities occur on land, and many of the resources used in these activities are derived from it. However, according to Weng (2001), anthropogenic activities are the primary source of LULC. LULC are two separate concepts that are frequently used interchangeably (Rawat & Kumar, 2015). LU is defined as any human intention or goal directed at modifying or sustaining a specific portion of land (Verburg *et al*., 2006). LC, on the other hand, describes the physical and biological state of the Earth's surface and the subsurface beneath it (Lambin *et al*., 2003). Because of its prevalence at the local level and globally acknowledged environmental trend, LULC has become a significant component of global environmental change and sustainable development (Lambin *et al*., 2003; Verburg *et al*., 2006). With the rapid expansion in world population, there has been an increase in agricultural and industrial activity, resulting in major changes in LULC and increased demand for natural resources contained in the land (Hegazy & Kaloop, 2015).

It is critical to detect LULCC to better understand how the landscape evolves over time. Researchers, planners, and politicians use this data to assess urban growth patterns and natural resource changes and to design effective land management strategies. However, because of anthropogenic activities, climate change, and rapid population expansion, developing countries frequently lack LULCC planning (Hassan *et al*., 2016; Chen *et al*., 2018; Halder & Bandyopadhyay, 2021). Deforestation, overgrazing, industrial and residential zones, agriculture, and logging have all had negative impacts on biodiversity, water, radiation budgets, trace gas emissions, and climate (Olorunfemi *et al*., 2018). Deforestation and forest degradation, in particular, account for 20 % of total anthropogenic carbon emissions, making them the primary sources of CO_2, methane, and nitrous oxide emissions (Chapin *et al*., 2008). As a result, climate change and global warming are exacerbated. LULCC quantification and identification are critical for developing targeted policy interventions to encourage more sustainable land management practices.

Despite growing concerns about the effects of LULCC on sustainable development and the environment, research on LULCC in southeastern Nigeria has only recently begun (Echebima *et al*., 2019). The majority of existing LULCC research in the region has concentrated on specific areas, with major cities garnering attention for urban sprawl dynamics (Obiahu *et al*., 2021; Uko & Offiong, 2021). Natural resource availability, dynamics, and management, on the other hand, vary widely over area and time, and the factors promoting LULCC are dependent on the precise conditions of humans and their ecosystems.

The purpose of this study is to examine the impact of real estate development on biodiversity in Owerri, Imo State, Nigeria, with a focus on changes in LULC. It will use remote sensing and GIS methods to analyze LULC trends over time as they are influenced by real estate development. Furthermore, the study will investigate how geoscience data and analysis can be utilized to drive community siting and design in order to prevent the negative implications of real estate development on biodiversity, such as habitat loss, ecosystem disruption, and species displacement. The project aims to educate legislators, urban planners, and environmental managers in Owerri, Imo State, about sustainable land-use laws and practices.

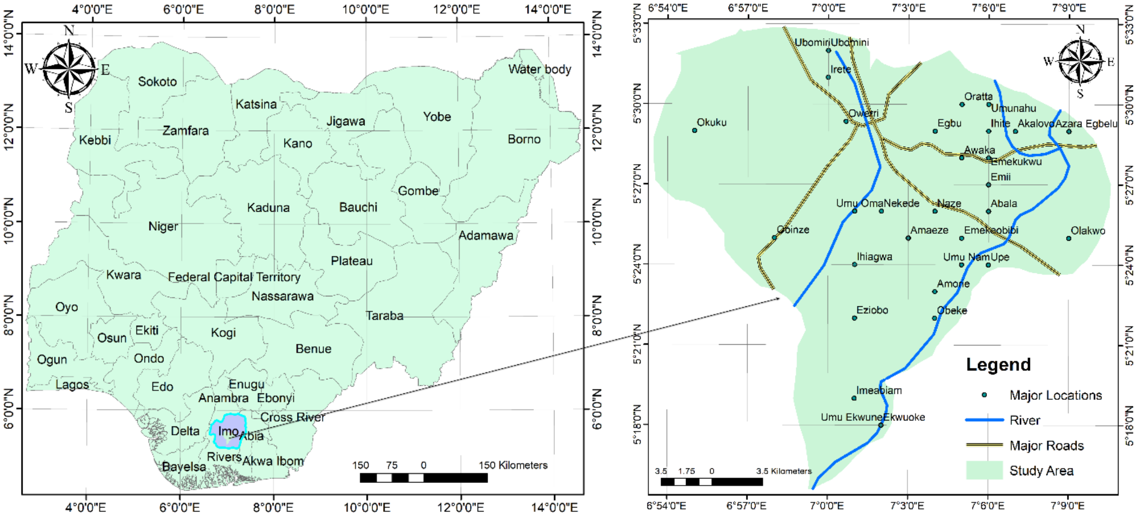
MATERIAL AND METHODS

Geographical and Demographic Overview of the Study Area

Imo State's capital is Owerri, which is located in Nigeria's south-east geopolitical zone. It is divided into three LGAs: Owerri Municipal, Owerri North, and Owerri West. Geographically, it is located in the southern portion of Imo State between Latitudes 5°31'0"N and 5°14'30"N and Longitudes 6°54'30"E and 7°11'0"E (Echebima *et al*., 2019). According to the National Population Commission, the estimated population of Owerri in 2017 was 775,000 which climbed to 945,000 in 2022. Owerri has a land area of approximately 551km^2 and is crossed by the Nwaorie and Otamiri rivers.

Owerri has two distinct climatic seasons, the dry season (between November to March) and the rainy season (between April to October). Temperatures in the dry season fluctuate between 24°C and 34°C, with a relative humidity of roughly 70 %. The relative humidity rises to almost 90 % during the wet season. Figure 1 depicts the map of the research region. Owerri serves as the principal centre for economic and industrial activities in Imo State, resulting in a significant growth in urbanisation in neighbouring rural communities and other states (Echebima *et al*., 2019).

Fig. 1: Map of Nigeria, Imo State and Owerri the Study Area



Data Acquisition and Analysis

The use of satellite images and geospatial analysis tools to investigate changes in land use and land cover (LULC) has gained prominence in recent years. The increased accessibility and abundance of remote sensing data can be linked to this phenomenon (Butt *et al*., 2015). The study of the effects of real estate development on biodiversity in Owerri, Nigeria, is an excellent example of how such approaches might be used to address critical environmental challenges.

The study is notable for its use of Sentinel-2 data from the European Space Agency (ESA) with a spatial resolution of 10 m. This special option allows for a thorough exploration of the area, allowing for in-depth analysis. Previous research has shown that using data pretreatment techniques such as error reduction and image quality enhancement can greatly improve the precision of the produced results. The use of ArcGIS 10.8, a widely used software application for geospatial analysis, provides a reliable method for identifying and analysing land cover data. Supervised classification algorithms have shown significant efficacy in identifying different land cover types. The use of training data from field surveys, in conjunction with validation using high-resolution pictures, improves the precision and reliability of the categorization process. The technique of post-classification comparison, which involves examining land cover maps that have been classified for separate time intervals, is a widely used method for analysing temporal variations in land use and land cover.

The methodology used in this study is similar to that used in a larger project aiming at producing comprehensive global maps of LULC. The study's uniqueness rests in its focus on assessing the impact of real estate development on biodiversity in Imo State, Nigeria. It focuses on changes in LULC, making an important contribution to the growing field of research on the effects of urbanisation and development on the natural environment. Supervised classification techniques entail utilizing training data to teach a computer algorithm how to classify pixels in a picture into various land cover categories (Keuchel *et al*., 2003). Using supervised classification algorithms, Sentinel-2 imagery was categorized into distinct land cover groups, such as urban areas, agricultural lands, forests, and water bodies, in this study. The study's training data came from field surveys and were confirmed using high-resolution photography (Keuchel *et al.*, 2003). This stage contributed to the training data accurately representing the various land cover categories in the research area. The classification accuracy was also increased by employing high-resolution photography to validate the training data.

Comparing classified land cover maps from different time periods to understand LULC variations through time is what post-classification comparison is all about. Post-classification comparison was utilized in this study to highlight variations in LULC in Imo State, Nigeria. The categorized land cover maps for different time periods were compared to find regions where land cover changed. Post-classification comparison is an important tool for assessing LULC changes over time since it aids in identifying trends and understanding the underlying drivers of change. It also aids in identifying places undergoing rapid change and those that may necessitate intervention to manage land use change.

In this work, the use of supervised classification approaches and post-classification comparison assisted in reliably classifying Sentinel-2 imagery into distinct land cover categories and identifying changes in LULC over time. This method is critical for monitoring environmental changes and identifying places where intervention is needed to manage land use change.

RESULTS

The researchers employed supervised classification methodologies to categorise Sentinel-2 imagery with a spatial resolution of 10 metres into distinct classes such as water, trees, flooded vegetation, crops, developed areas, clouds, barren ground, and rangeland. The accuracy of the categorization was enhanced through the utilisation of training data obtained from field surveys, which was afterwards validated by means of high-resolution photography. The post-classification comparison method was employed to examine land cover maps from distinct temporal intervals and detect locations where LULC alterations occurred. From 2017 to 2022, the findings indicated a decrease in the presence of trees and an increase in the extent of built-up areas and cultivated land. During the identical time frame, there was minimal fluctuation in the area of flooded vegetation and rangeland. The study additionally brought attention to areas where LULC experienced alterations, underscoring the significance of implementing methods to manage and control land use change in order to preserve biodiversity.

According to Figure 2a and Table 1, the LULC for the study area as of 2017 is as follows: Water covers an area of 2.33 km^2, which is approximately 0.44 % of the total area. Trees cover the largest area, with 315.05 km^2, accounting for approximately 58.840 % of the total area. Flooded vegetation covers an area of 1.22 km^2, representing approximately 0.23 % of the total area. Crops cover an area of 12.27 km^2, which is approximately 2.29% of the total area. The area covered by built-up areas, such as cities and towns, is 161.84 km^2, representing approximately 30.23 % of the total area. Clouds cover an area of 2.52 km^2, which is approximately 0.47 % of the total area. Bare ground covers an area of 2.65 km^2, representing approximately 0.50 % of the total area. Rangeland, which is land used for grazing livestock, covers an area of 37.54 km^2, accounting for approximately 7.01 % of the total area.

According to Figure 2b and Table 1, the land cover in the specified area in 2018 was dominated by trees, which covered 61.91 % of the total area, representing a staggering 331.47 km^2. Built-up areas also occupied a significant portion of the landscape, accounting for 33.14 %, or 177.41 km^2, of the total area. Water bodies, including rivers, lakes, and oceans, covered 0.49 % of the area, spanning over 2.63 km^2. Meanwhile, flooded vegetation covered a minute fraction of the landscape, accounting for only 0.00 %, or 0.01 km^2, of the total area. Crops, including crops for human consumption, fodder, and fiber, covered an area of 6.47 km^2, representing 1.21 % of the total area. The determination of the percentage of bare ground was not possible due to a lack of data on this particular aspect. Rangeland, which refers to grasslands and shrublands used for animal grazing, covered 17.42 km^2, or 3.25 % of the total land area. The remaining land cover was discovered to be primarily occupied by clouds, which accounted for a small amount of the terrain, specifically 0.00 % or 0.02 km^2. It is critical to acknowledge that the region's exposed terrain lacks data, which is a huge barrier to completely appreciating the environment's overall structure.

Figure 2c and Table 1 show the results of a LULC analysis done in Owerri, Nigeria, in 2019. According to the survey results, water bodies covered an area of 3.00 km^2, accounting for 0.56 % of the total land area. The land cover analysis found that trees were the most common land cover type, accounting for 59.43 % of the total area (318.22 km^2). The amount of flooded vegetation was negligible, accounting for only 0.001 km^2 or 0.000 % of the total area. The cultivated land accounted for a comparatively modest fraction of the overall area, accounting for only 0.65 % or 3.49 km^2. Built-up areas, including urban settlements and infrastructure, covered 34.30 % of the area, corresponding to 183.66 km^2. Clouds occupied a small portion of the area, covering only 0.00 % or 0.03 km^2. Bare ground was also present, covering 0.06 % of the total area, which is equivalent to 0.29 km^2. Rangelands, which consist of grasslands and shrublands used for grazing, covered 4.99 % of the total area, corresponding to 26.73 km^2.

Fig. 2: LULC map of the study area for the year (a) 2017 (b) 2018 (c) 2019 (d) 2020 (e) 2021 (f) 2022

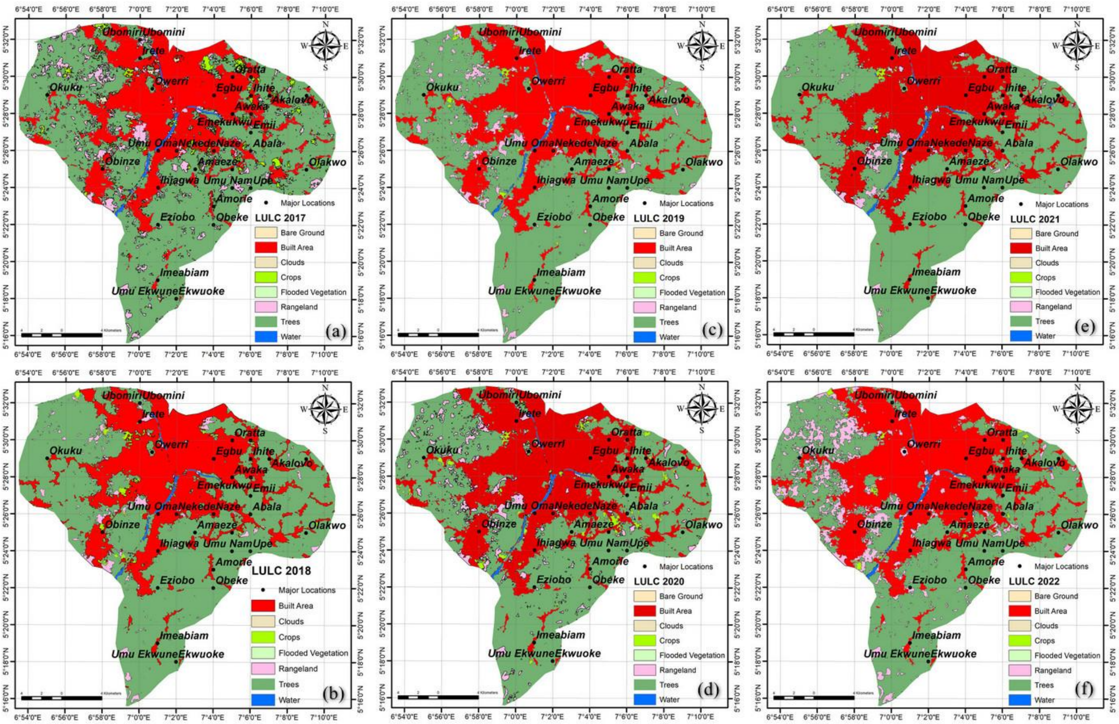


Table 1: LULC Distribution in the Study Area between 2017 to 2022

	2022	2021	2020	2019	2018	2017
LULC	Area (km^2)	Area (km^2)	Area (km^2)	Area (km^2)	Area (km^2)	Area (km^2)
Water	3,180,805.95	3,200,473.89	2,949,375.64	2,996,118.77	2,627,054.27	2,329,436.90
Trees	253,030,507.91	310,466,287.53	293,979,528.88	318,223,753.18	331,471,211.03	315,045,322.90
Flooded Vegetation	260,189.09	13,317.42	6,458.40	1,739.71	10,996.60	1,224,375.53
Crops	4,610,028.00	2,997,774.79	10,192,585.42	3,492,378.66	6,471,453.20	12,270,217.68

Built Area	218,148,437.57	200,684,301.85	200,364,090.91	183,657,674.72	177,409,431.91	161,841,902.50
Clouds	36,370.76	462,309.39	2,9481.47	32,661.07	15,411.74	2,522,915.41
Bare Ground	81,799.66	163,478.87	10,400.11	291,985.77		2,651,190.34
Rangeland	56,074,385.66	17,434,878.47	27,891,745.41	26,726,039.98	17,415,943.38	37,537,999.78

In 2020, the LULC map of the study area is represented in Figure 2d, and the LULC distribution is presented in Table 1. According to the table, water bodies covered 2.95 km^2, which is 0.55 % of the total area. Trees were the most dominant land cover, occupying 54.91 % of the total area or 293.98 km^2. Flooded vegetation covered a minimal fraction of the landscape, with an area of 0.00 km^2 or 0.00 %. Crops covered only 1.90 % of the area, accounting for 10.19 km^2. The overall land area covered by built-up areas, which included urban settlements and associated infrastructure, accounted for 37.42 % of the region's total land area, or 200.36 km^2. Cloud cover concealed a little portion of the territory, precisely 0.01 % or 0.03 km^2.

The LULC map of the specified study area, specifically for the year 2021, is shown in Figure 2e and Table 1. The total area of water bodies was discovered to be 3.20 km^2, accounting for 0.60 % of the total land area. The study region's land cover was predominantly made up of trees, which accounted for 57.99 % of the total land area, or 310.47 km^2. Inundated vegetation occupied a miniscule part of the terrain, spanning about 0.01 km^2, or 0.00 % of the total area. A mere 0.56 % of the entire area was cultivated land, equating to a surface area of 3.00 km^2. The total area covered by built-up areas, which included urban settlements and associated infrastructure, accounted for 37.48% of the total land area, or 200.68 km^2. Clouds covered 0.09 % or 0.46 km^2 of the area. Bare ground covered 0.03 % or 0.16 km^2, while rangelands, which comprise grasslands and shrublands used for grazing, covered 3.26 % of the total area or 17.44 km^2.

Figure 2f and Table 1 describe the LULC of the study area in 2022. Water covers an area of 3.18 km^2, accounting for approximately 0.60 % of the total area. Trees cover the largest area, with 253.03 km^2, which is approximately 47.26 % of the total area. Flooded vegetation covers a much smaller area of 0.26 km^2, accounting for approximately 0.05 % of the total area. Crops cover 4.61 km^2, representing approximately 0.86 % of the total area. The area covered by built-up areas, such as cities and towns, is 218.15 km^2, which is approximately 40.74 % of the total area. Cloud cover covers only 0.04 km^2, accounting for only 0.01 % of the total surface area. The whole area is around 0.08 km^2 of bare ground, representing only 0.02 % of the total area. Rangeland, defined as land dedicated for the purpose of grazing animals, covers a total area of 56.07 km^2, accounting for an estimated 10.47 % of total land area.

The degree of water covering has followed a very consistent trend, with just minor fluctuations over the years. The extent of tree covering has decreased, yet maintaining the most significant component in terms of overall land area. The area of submerged vegetation and cultivated crops has shifted. From 2017 to 2022, the extent of land occupied by built-up areas, on the other hand, has shown a constant increase tendency. The degree of cloud covering has varied, with the most extensive coverage observed in the year 2021. The extent of bare terrain and rangeland has changed over time. The tabulated data in Table 2 gives a study of the LULC percentages from 2017 to 2022, allowing for a more comprehensive knowledge of the environmental's temporal fluctuations. Water coverage increased gradually from 0.44 % in 2017 to 0.60 % in 2022. Tree coverage began at 58.84 % in 2017, peaked at 61.91 % in 2018, and then gradually decreased to 47.26 % in 2022. Flooded vegetation had negligible contributions in the early years, with only 0.00 % coverage in 2018 and no coverage in 2019, before increasing to 0.05 % in 2022. Crop coverage was highest in 2017 at 2.29 % but declined over time, reaching a low of 0.56 % in 2021 before rising to 0.86 % in 2022. The coverage of built-up areas steadily increased from 30.23 % in 2017 to 40.74 % in 2022. Rangeland had its highest coverage in 2017 at 7.01 %, declined to 3.25 % in 2018, and gradually increased to 10.47 % in 2022.

Table 2: Percentage change in LULC 2017 to 2022 in Owerri

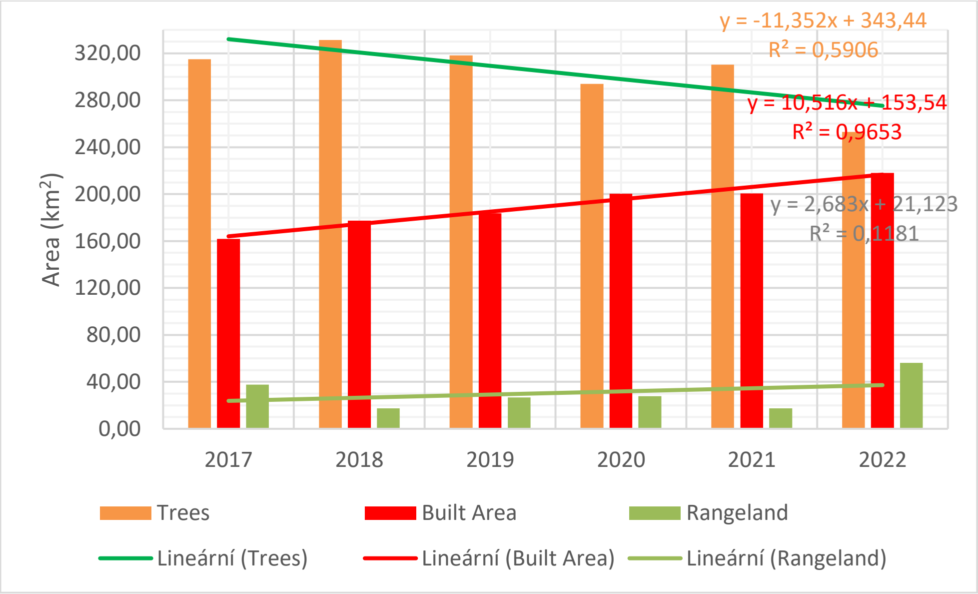
LULC	Water (%)	Trees (%)	Flooded Vegetation (%)	Crops (%)	Built Area (%)	Clouds (%)	Bare Ground (%)	Rangeland (%)
2022	0.59	47.26	0.05	0.86	40.74	0.01	0.02	10.47
2021	0.60	57.99	0.00	0.560	37.48	0.09	0.03	3.26
2020	0.55	54.91	0.00	1.90	37.42	0.01	0.00	5.21
2019	0.56	59.43	0.00	0.652	34.30	0.01	0.06	4.99
2018	0.49	61.91	0.00	1.21	33.14	0.00	0.00	3.25
2017	0.44	58.84	0.23	2.29	30.23	0.47	0.50	7.01

The LULC data for Owerri, Imo State, Nigeria, reveals that trees cover a significant portion of the land. However, the percentage of trees in 2022 decreased compared to the previous year, which may be due to deforestation, tree cutting for fuelwood, and the expansion of built areas and crops. Furthermore, the proportion of developed space has increased significantly over time, emphasising the negative ecological repercussions of local real estate expansion. The proportion of trees, flood-prone vegetation, bare ground, and rangeland has decreased as urban development has increased.

The share of cultivated crops has increased significantly over time, possibly due to the expansion of agricultural activity in the region. Nonetheless, it is critical to recognise that the expansion of agricultural production contributes to the decline of tree covering, flood-resistant flora, and grazing land. Throughout the observed time period, the quantities of water, flooded vegetation, and clouds have remained steady.

The data on LULC show that the expansion of urbanised areas and agricultural agriculture is having a significant impact on the ecological conditions in Owerri, Imo State, Nigeria. The observed decline in the proportion of trees, flood-prone vegetation, bare ground, and rangeland is a visible manifestation of the negative impacts of real estate development and agricultural operations on biodiversity in the area. As a result, regulations that enable the adoption of sustainable land use practises are critical in order to protect the environment and foster biodiversity conservation.

Fig. 3: Trend analysis for major contributors of LULC in the study area



The trend analysis in Figure 3 shows significant changes in the three LULC categories over time. The built-up area, in particular, has steadily expanded, while the tree cover and rangeland have oscillated. Further investigation of these patterns could provide useful insights into the underlying causes of these variations and their ecological consequences.

Fig. 4: Change in LULC map between 2017 and 2022 for the study area

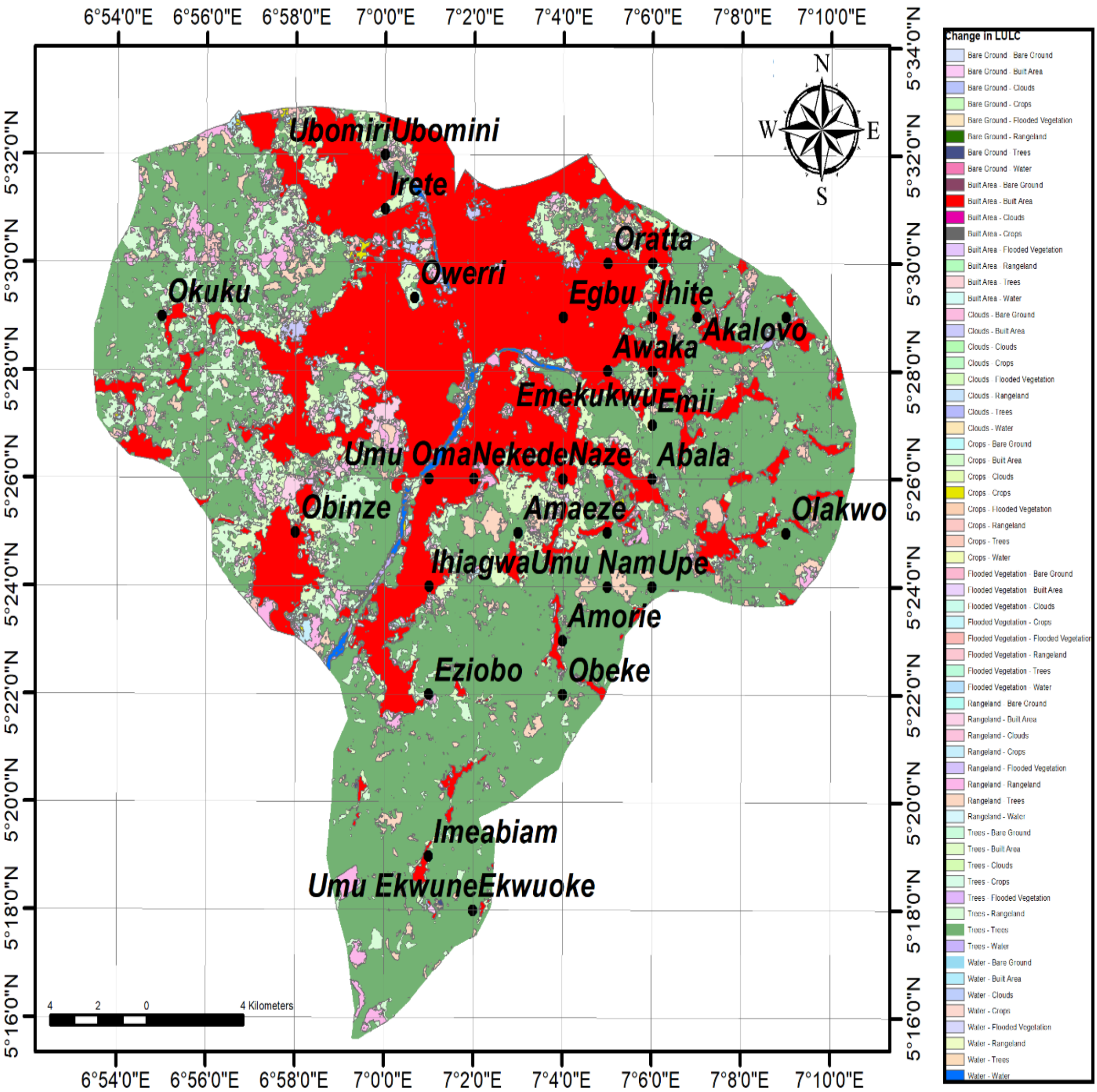


Figure 4 depicts dynamic changes in terrain caused by land cover types throughout a five-year period from 2017 to 2022. The observed changes can be attributed to a range of variables, including urbanisation, land management practises, climatic fluctuations, and natural occurrences.

DISCUSSION

The city of Owerri, in Imo State, is currently experiencing substantial ecological implications as a result of the expansion of real estate activity. Owerri, a rapidly growing urban core, with a population of over one million people, necessitating increased demand for both residential and commercial real estate (Njoku & Igbokwe, 2021). The previously outlined issue has resulted in a significant increase in the construction of buildings, transportation networks, and various types of physical infrastructure. This has had a negative influence on the surrounding biological system and biodiversity. The obvious repercussions of habitat loss are the key indicators of the influence of real estate development on biodiversity in Owerri. Infrastructure construction, such as buildings and roads, has been shown to have negative effects on natural ecosystems, potentially resulting in the displacement or extinction of indigenous animal species (Njoku & Igbokwe, 2021). The implications of species extinction for the food chain and ecology are significant.

Ecosystem fragmentation is an unexpected effect of real estate development that has a substantial impact on the diversity of organisms within an ecosystem. The presence of buildings and roads can cause habitat fragmentation, resulting in smaller, isolated areas. Animal mobility is restricted as a result of this fragmentation, which disrupts their regular migration patterns. According to Chukwuocha *et al.* (2017), the occurrence of this event has the potential to reduce genetic diversity, posing a serious risk to the long-term well-being of various species. Urbanisation is the process through which individuals and communities move from rural to urban areas, mostly motivated by economic opportunities and increased quality of life (Sridhar & Sathyanathan, 2022). The aforementioned transformation has ramifications for social hierarchies, land use patterns, and agricultural production practises (de Bruin *et al*., 2021). Beyond habitat loss and fragmentation, the impact of real estate development on biodiversity includes the risk of pollution. The inflow of people into the city has resulted in an increase in pollution from a variety of sources, including automobiles, industrial operations, and construction. The aforementioned occurrence can have a considerable impact on the well-being of indigenous fauna and lead to population declines (Chris, 2018; Edeme & Chibuzo, 2018).

Adopting environmentally friendly practises and sustainable agriculture technologies has the ability to mitigate negative effects on LULC (Englund *et al*., 2020; Northrup *et al*., 2021; Kupriyanchyk, 2021). Unsustainable practises, on the other hand, can lead to land degradation, deforestation, and biodiversity loss. Deforestation, a crucial component of LULCC, is a major concern because it entails the exploitation of forest resources for commercial gain (Kouassi *et al*., 2021; Oyediji & Adenika, 2022). Deforestation offers a twofold threat to natural habitats and ecosystems, while also contributing significantly to the phenomena of global warming. This is due to the release of carbon dioxide into the atmosphere caused by deforestation, which functions as a key driver of climate change (Bala *et al*., 2007). As a result, the economical endeavour to gain resources can have significant ecological consequences.

The study of LULCCs across time reveals notable patterns, as well as the various socioeconomic forces that affect these shifts. The significant increase in the "Built Area" indicator implies significant growth of urban areas and parallel infrastructure enhancement during a certain time frame. Growth has the potential to turn land cover classes such as "Bare Ground" and "Rangeland" into urbanised regions. The aforementioned transformation has the potential to have profound consequences for regional ecosystems and biodiversity. Furthermore, the observed increase in the occurrence of "Flooded Vegetation" suggests potential changes in hydrological patterns or changes in water management practises. Changes in precipitation patterns or changes in water management systems could be significant contributors. Similarly, the various combinations of "Clouds," "Crops," "Trees," and "Water" indicate probable changes in agricultural practises, forestry operations, and hydrological occurrences. A variety of factors, including land use rules, intensive agricultural practises, and climatic shifts, may influence the aforementioned changes.

The variety of land cover types emphasises the importance of continuing monitoring and efficient management of LULCCs. Monitoring is essential for guiding land management policies, urban planning projects, environmental conservation activities, and the promotion of sustainable resource use (Chang *et al*., 2018; Mohamed *et al.*, 2020; Keshtkar *et al*., 2022). It promotes a mutually beneficial coexistence between humans and the natural environment by facilitating the attainment of a condition of balance between economic advancement and environmental preservation.

The influence of real estate development on biodiversity in Owerri is substantial and should not be overlooked. The long-term ecological effects of decisions made by developers and policymakers, as well as the implementation of measures to mitigate negative environmental consequences, are critical (Chukwuocha *et al*., 2017). Examples include including green spaces into development plans, preserving natural ecosystems, and implementing sustainable building technology aimed at decreasing pollution and waste.

The protection of natural ecosystems, which comprises the conservation of green spaces and the application of restrictions on deforestation operations, can help to achieve sustainable development (Viccaro & Caniani, 2019; Bulgakova, 2022). This strategy helps to preserve biodiversity and improves the overall quality of life in the community. The incorporation of green places, such as parks and rooftop gardens, into development projects has the ability to improve air quality, reduce urban heat, and provide leisure options (Jaung *et al*., 2020). Sustainable building practises, such as the use of energy-efficient appliances and renewable energy sources, have the potential to reduce pollution and waste while also lowering operational costs. The consideration of long-term ecological repercussions is critical in development decisions since it assures the preservation of biodiversity and the well-being of local fauna while also improving people's quality of life.

CONCLUSION

The methods employed in this study utilised Sentinel-2 imagery and geospatial analysis techniques, which were found to be effective means of detecting alterations in land use and land cover (LULC). The research revealed that the process of real estate development in Owerri has notable adverse effects on biodiversity, encompassing the loss of habitats, fragmentation of ecosystems, and pollution.The findings of the study indicate a decrease in the number of trees and an increase in the extent of built-up areas and cultivated land from 2017 to 2022. The level of inundated vegetation and rangeland exhibited little fluctuations within the same time frame. The study placed significant emphasis on the necessity of implementing policies aimed at regulating land use change and preserving biodiversity. The study posits that the integration of sustainable development practises within the realm of real estate development has the potential to ameliorate adverse environmental consequences. By adopting this approach, developers and policymakers can effectively contribute to the preservation of the environment by ensuring that development activities are conducted in a manner that does not cause harm.

In recent years, Owerri, has seen a substantial surge in urbanisation and real estate development. Concerns have been expressed about the conservation of the region's critical natural and semi-natural ecosystems as a result of the region's development of human activities. The goals of our proposed study are to assess how real estate development affects biodiversity and to propose a green infrastructure solution to saving critical ecosystems. The following are the primary conclusions of the research region, which saw a 58.84 % rise in the percentage of land covered by trees, or 315.05 km^2, in 2017. By 2022, the proportion of trees had fallen to 56.26 % (301.63 km^2), while the proportion of built-up areas had risen from 30.23 % to 35.78 %.

Creating green corridors and urban green spaces should be part of a larger green infrastructure strategy aimed at preserving and restoring critical ecosystems. Zoning limitations must be implemented in order to preserve environmentally vulnerable areas and promote the adoption of sustainable land use practises. Encourage the adoption of sustainable practises in real estate development, with a focus on the construction of eco-friendly structures and the incorporation of energy-saving technologies. It is recommended that public awareness programmes be implemented to educate residents about the importance of biodiversity and green spaces. As a result of unrestrained urban growth, Imo State's biodiversity is experiencing serious challenges. The research emphasises the urgent need for green infrastructure measures to be adopted in order to preserve critical ecosystems and promote a sustainable and mutually beneficial cohabitation between nature and urban progress.

REFERENCE

Arowolo, A.O., Deng, X., Olatunji, O.A. and Obayelu, A.E. (2018). Assessing changes in the value of ecosystem services in response to land-use/land-cover dynamics in Nigeria. *Science of The Total Environment* 636, pp. 597–609. Available at: http://dx.doi.org/10.1016/j.scitotenv.2018.04.277.

Awoniran, D.R., Adewole, M.B., Adegboyega, S.A. and Anifowose, A.Y.B. (2014). Assessment of environmental responses to land use/land cover dynamics in the Lower Ogun River Basin, Southwestern Nigeria. *African Journal of Environmental Science and Technology* 8(2), pp. 152–165. Available at: http://dx.doi.org/10.5897/ajest2013.1607.

Bala, G., Caldeira, K., Wickett, M., Phillips, T. J., Lobell, D. B., Delire, C., and Mirin, A. (2007). Combined climate and carbon-cycle effects of large-scale deforestation. *Proceedings of the National Academy of Sciences*, *104*(16), pp. 6550–6555. https://doi.org/10.1073/pnas.0608998104

Bulgakova, M. A. (2022). Protection of natural ecosystems using forest resources. *IOP Conference Series: Earth and Environmental Science*, *981*(3), p. 032073. https://doi.org/10.1088/1755-1315/981/3/032073

Butt, A., Shabbir, R., Ahmad, S.S. and Aziz, N. (2015). Land use change mapping and analysis using Remote Sensing and GIS: A case study of Simly watershed, Islamabad, Pakistan. *The Egyptian Journal of Remote Sensing and Space Science* 18(2), pp. 251–259. Available at: http://dx.doi.org/10.1016/j.ejrs.2015.07.003.

Chang, Y., Hou, K., Li, X., Zhang, Y., and Chen, P. (2018). Review of Land Use and Land Cover Change research progress. *IOP Conference Series: Earth and Environmental Science*, *113*, p. 012087. https://doi.org/10.1088/1755-1315/113/1/012087

Chapin, F.S., Randerson, J.T., McGuire, A.D., Foley, J.A. and Field, C.B. (2008). Changing feedbacks in the climate–biosphere system. *Frontiers in Ecology and the Environment* 6(6), pp. 313–320. Available at: http://dx.doi.org/10.1890/080005.

Chen, H., Zhang, W., Gao, H. and Nie, N. (2018). Climate Change and Anthropogenic Impacts on Wetland and Agriculture in the Songnen and Sanjiang Plain, Northeast China. *Remote Sensing* 10(3), p. 356. Available at: http://dx.doi.org/10.3390/rs10030356.

Chris, O. I. (2018). Urbanization and the environment: The debate and evidence from two new cities in Nigeria. *Journal of Geography and Regional Planning*, *11*(5), pp. 61–79. https://doi.org/10.5897/jgrp2018.0681

Chukwuocha, N., Ngah, S.A. and Chukwuocha, A.C. (2017). Vulnerability Studies of Sensitive Watershed Areas of Owerri South East Nigeria Using Digital Elevation Models. *Journal of Geoscience and Environment Protection* 05(10), pp. 1–10. Available at: http://dx.doi.org/10.4236/gep.2017.510001.

de Bruin, S., Dengerink, J., and van Vliet, J. (2021). Urbanisation as driver of food system transformation and opportunities for rural livelihoods. *Food Security*, *13*(4), pp. 781–798. https://doi.org/10.1007/s12571-021-01182-8

Echebima, S.I., Obafemi, A.A. and Ndukwu, B.C. (2019). Assessment and Trend of Land Cover Land Use Changes in Owerri and Environs, South Eastern Nigeria. *Natural Resources* 10(07), pp. 284–298. Available at: http://dx.doi.org/10.4236/nr.2019.107018.

Edeme, R. K., and Chibuzo, N. P. (2018). Urban Population Growth and Environmental Sustainability in Nigeria. *Journal of Empirical Studies*, *5*(1), pp. 12–19. https://doi.org/10.18488/journal.66.2018.51.12.19

Englund, O., Börjesson, P., Berndes, G., Scarlat, N., Dallemand, J. F., Grizzetti, B., . . . Fahl, F. (2020). Beneficial land use change: Strategic expansion of new biomass plantations can reduce environmental impacts from EU agriculture. *Global Environmental Change*, *60*, p. 101990. https://doi.org/10.1016/j.gloenvcha.2019.101990

Halder, B. and Bandyopadhyay, J. (2021). Evaluating the impact of climate change on urban environment using geospatial technologies in the planning area of Bilaspur, India. *Environmental Challenges* 5, p. 100286. Available at: http://dx.doi.org/10.1016/j.envc.2021.100286.

Hassan, Z., Shabbir, R., Ahmad, S.S., Malik, A.H., Aziz, N., Butt, A. and Erum, S. (2016). Dynamics of land use and land cover change (LULCC) using geospatial techniques: a case study of Islamabad Pakistan. *SpringerPlus* 5(1). Available at: http://dx.doi.org/10.1186/s40064-016-2414-z.

Haylemariyam, M.B. (2018). Detection of Land Surface Temperature in Relation to Land Use Land Cover Change: Dire Dawa City, Ethiopia. *Journal of Remote Sensing & GIS* 07(03). Available at: http://dx.doi.org/10.4172/2469-4134.1000245.

Hegazy, I.R. and Kaloop, M.R. (2015). Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt. *International Journal of Sustainable Built Environment* 4(1), pp. 117–124. Available at: http://dx.doi.org/10.1016/j.ijsbe.2015.02.005.

Jaung, W., Carrasco, L. R., Shaikh, S. F. E. A., Tan, P. Y., and Richards, D. R. (2020). Temperature and air pollution reductions by urban green spaces are highly valued in a tropical city-state. *Urban Forestry & Urban Greening*, *55*, p. 126827. https://doi.org/10.1016/j.ufug.2020.126827

Keshtkar, M., Mokhtari, Z., and Sayahnia, R. (2022). Impact of Land Use/Land Cover Change on Soil Retention Service: A Case of Agricultural-Urbanized Landscape in Northern Iran. *Journal of Landscape Ecology*, *15*(2), pp. 34–58. https://doi.org/10.2478/jlecol-2022-0010

Keuchel, J., Naumann, S., Heiler, M. and Siegmund, A. (2003). Automatic land cover analysis for Tenerife by supervised classification using remotely sensed data. *Remote Sensing of Environment* 86(4), pp. 530–541. Available at: http://dx.doi.org/10.1016/s0034-4257(03)00130-5.

Kleijn, D., Rundlöf, M., Scheper, J., Smith, H.G. and Tscharntke, T. (2011). Does conservation on farmland contribute to halting the biodiversity decline? *Trends in Ecology & Evolution* 26(9), pp. 474–481. Available at: http://dx.doi.org/10.1016/j.tree.2011.05.009.

Kouassi, J. L., Gyau, A., Diby, L., Bene, Y., and Kouamé, C. (2021). Assessing Land Use and Land Cover Change and Farmers' Perceptions of Deforestation and Land Degradation in South-West Côte d'Ivoire, West Africa. *Land*, *10*(4), p. 429. https://doi.org/10.3390/land10040429

Kupriyanchyk, I. (2021). The essence and role of environmentally friendly agricultural land use in agriculture. *Zemleustrìj, Kadastr Ì Monìtorìng Zemel'*, (2). https://doi.org/10.31548/zemleustriy2021.02.04

Lambin, E.F., Geist, H.J. and Lepers, E. (2003). Dynamics of Land-Use and Land-Cover Change in Tropical Regions. *Annual Review of Environment and Resources* 28(1), pp. 205–241. Available at: http://dx.doi.org/10.1146/annurev.energy.28.050302.105459.

Lin, G.C.S. and Yi, F. (2011). Urbanization of Capital or Capitalization on Urban Land? Land Development and Local Public Finance in Urbanizing China. *Urban Geography* 32(1), pp. 50–79. Available at: http://dx.doi.org/10.2747/0272-3638.32.1.50.

Mohamed, M., Anders, J., and Schneider, C. (2020). Monitoring of Changes in Land Use/Land Cover in Syria from 2010 to 2018 Using Multitemporal Landsat Imagery and GIS. *Land*, *9*(7), p. 226. https://doi.org/10.3390/land9070226

Njoku, O.I., and Igbokwe, J.I., (2021). Evaluation of the socio-economic impact of landcover / landuse changes in Owerri Municipal, Imo State, Nigeria using remote sensing and geographic information systems. *World Journal of Advanced Research and Reviews* 12(3), pp. 175–180. Available at: http://dx.doi.org/10.30574/wjarr.2021.12.3.0665.

Northrup, D. L., Basso, B., Wang, M. Q., Morgan, C. L. S., and Benfey, P. N. (2021). Novel technologies for emission reduction complement conservation agriculture to achieve negative emissions from row-crop production. *Proceedings of the National Academy of Sciences*, *118*(28). https://doi.org/10.1073/pnas.2022666118

Obiahu, O. H., Yan, Z., and Uchenna, U. B. (2021). Spatiotemporal analysis of land use land cover changes and built-up expansion projection in predominantly dystric nitosol of Ebonyi state, Southeastern, Nigeria. *Environmental Challenges*, *4*, p. 100145. https://doi.org/10.1016/j.envc.2021.100145

Obiahu, O.H. and Elias, E. (2020). Effect of land use land cover changes on the rate of soil erosion in the Upper Eyiohia river catchment of Afikpo North Area, Nigeria. *Environmental Challenges* 1, p. 100002. Available at: http://dx.doi.org/10.1016/j.envc.2020.100002.

Obiahu, O.H., Yan, Z. and Uchenna, U.B. (2021). Spatiotemporal analysis of land use land cover changes and built-up expansion projection in predominantly dystric nitosol of Ebonyi state, Southeastern, Nigeria. *Environmental Challenges* 4, p. 100145. Available at: http://dx.doi.org/10.1016/j.envc.2021.100145.

Olorunfemi, I.E., Fasinmirin, J.T., Olufayo, A.A. and Komolafe, A.A. (2018). GIS and remote sensing-based analysis of the impacts of land use/land cover change (LULCC) on the environmental sustainability of Ekiti State, southwestern Nigeria. *Environment*, *Development and Sustainability* 22(2), pp. 661–692. Available at: http://dx.doi.org/10.1007/s10668-018-0214-z.

Oyediji, O. T., and Adenika, O. (2022). Forest Degradation and Deforestation in Nigeria; Poverty Link. *International Journal of Multidisciplinary Research and Analysis*, *05*(10), pp. 2837–2880. https://doi.org/10.47191/ijmra/v5-i10-35

Rawat, J.S. and Kumar, M. (2015). Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. *The Egyptian Journal of Remote Sensing and Space Science* 18(1), pp. 77–84. Available at: http://dx.doi.org/10.1016/j.ejrs.2015.02.002.

Sridhar, M. B., and Sathyanathan, R. (2022). Assessment of Urban Expansion and Identification of Sprawl Through Delineation of Urban Core Boundary. *Journal of Landscape Ecology*, *15*(3), pp. 102–120. https://doi.org/10.2478/jlecol-2022-0020

Turok, I. and McGranahan, G. (2013). Urbanization and economic growth: the arguments and evidence for Africa and Asia. *Environment and Urbanization* 25(2), pp. 465–482. Available at: http://dx.doi.org/10.1177/0956247813490908.

Uko, I. E., and Offiong, R. A. (2021). Analysis of Land Use and Land Cover Changes in Ikot Abasi coastal Area from 1986-2016, Southern Nigeria, Using Landsat TM and ETM+ Images and GIS. *Journal of Advance Research in Food, Agriculture and Environmental Science*, *7*(2), pp. 01–11. https://doi.org/10.53555/nnfaes.v7i2.949

Verburg, P.H., Kok, K., Pontius, R.G. and Veldkamp, A. (2006). Modeling Land-Use and Land-Cover Change. *Land-Use and Land-Cover Change*, pp. 117–135. Available at: http://dx.doi.org/10.1007/3-540-32202-7_5.

Viccaro, M., and Caniani, D. (2019). Forest, Agriculture, and Environmental Protection as Path to Sustainable Development. *Natural Resources Research*, *28*(S1), pp. 1–4. https://doi.org/10.1007/s11053-019-09497-2

Weng, Q. (2001). A remote sensing-GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. *International Journal of Remote Sensing* 22(10), pp. 1999–2014. Available at: http://dx.doi.org/10.1080/01431160118847.

Yohannes, H., Soromessa, T., Argaw, M. and Dewan, A. (2021). Spatio-temporal changes in habitat quality and linkage with landscape characteristics in the Beressa watershed, Blue Nile basin of Ethiopian highlands. *Journal of Environmental Management* 281, p. 111885. Available at: http://dx.doi.org/10.1016/j.jenvman.2020.111885.