Sustainability and Biodiversity Conservation

The Effects of Urbanization on Wetland Ecosystem and Aquatic Biodiversity in Makurdi Metropolis, Nigeria

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Abstract

Wetland ecosystems provide multiple benefits to human settlements, nonetheless, they are threatened by human activities associated mainly with urban growth. Therefore, the study assessed the impact of urbanization on wetlands in the Makurdi metropolis on aquatic biodiversity conservation through focus group discussion and satellite imageries. Three multi-date Landsat satellite imageries, TM of 1985, ETM+ 2000, and OLI 2020, were utilized to generate data, analyze, and monitor changes that have occurred over time and space. The Normalized Difference Built-up Index (NDBI) was adopted to extract built-up features within the study locations with indices ranging from -1 to 1. The extent of land use change (urbanization) was analyzed by subtracting the reference year (2020) from the base year. The highest rate of urban growth was observed during the third period of urbanization (2000 to 2020) in which the built-up area increased more than twice by 163.69km^2 (19.81%) over wetlands. The magnitude of change in wetland areas for 35 years between 1985 and 2020 showed that wetlands decreased by -26.41 km^2 representing a change (-42.97%) of the total change for the period. Wetland had an annual rate of change of -15.04% within the study years while cultivated land had the least annual rate of change (3.30%). This indicates that there was rapid urbanization in the study area between 2000 and 2020 compared to 1985 and 2000. Wetland ecosystems are under pressure in the area, and thus, have a detrimental effect on the aquatic biodiversity of the study area, through displacement, decrease, and death of aquatic species such as C*rocodylusniloticus, Trichechussenegalensis,* crabs, and water snails. Human activities that degrade wetlands should be reduced, restricted, or regulated.
Keywords: Aquatic ecosystem, biodiversity, human settlement, wetland

Introduction

Urbanization is an inevitable trend in human society and the planet Earth is becoming urbanized (Rojas et al., 2022). Though urbanization is a step in a country's modernization, it is at the same time impacting negatively on the wetland ecosystem. Environmental degradation such as loss and fragmentation of wetland areas, negatively impacts both social benefits and biodiversity, Rapid urbanization altered processes of the wetland environment through watershed change due to the combined influence of natural and human factors (Johnson, et al., 2013; Xiaomian, et al., 2023). It also alters abiotic and biotic environments (Johnson Marc & Munshi-South, 2017). These impacts are of particular concern to wildlife conservation and ecologists. The effects of urbanization on the structure and function of wetland ecosystems can be analyzed from three aspects: the hydrological effects of urbanization, the effects of urbanization on the water environment, and the impact of climate change (Jensen, 2000; Chidi & Ominigbo, 2010). Spatiotemporal change in wetland land use and the land cover types is prominently due to population increase, farmland cultivation, and increased built-up areas (Rojas et al., 2022). Wetlands are formed by the interaction between terrestrial systems and aquatic systems and are among the Earth's most productive ecosystems. Wetland ecosystems, including rivers, lakes, floodplains, and marshes, provide many services that contribute to human well-being and poverty alleviation (Millennium Ecosystem Assessment, 2015). However, they are increasingly subject to intense pressure from multiple human activities such as water diversion, pollution, over-exploitation of natural resources, and reclamation. Many of the hydrological and water resources problems currently experienced in Nigeria are a result of wetland degradation leading to continuous loss of aquatic biodiversity (Uluocha & Okeke, 2014). The present research investigated the impact of urbanization on wetland ecosystems and aquatic biodiversity.

Material and methods

Study area

Makurdi metropolis is the capital city of Benue state. It lies in the flood plains of the River Benue within the north-central region of Nigeria about the middle of the eastern half of Nigeria between 7°38'N - 7°50'N and longitude 8°24'E and 8°38'E (Figure 1). The population of Makurdi town was considered within a range of a few thousand people (Tyubee & Anyadike 2015). The growth of Makurdi town put pressure on natural resources within its environs including wetlands. Makurdi climate is characterized by wet and dry seasons. The mean duration of the rainy season is 182 days, with the highest monthly rainfall total of 221mmis recorded in August (Tyubee, 2005).

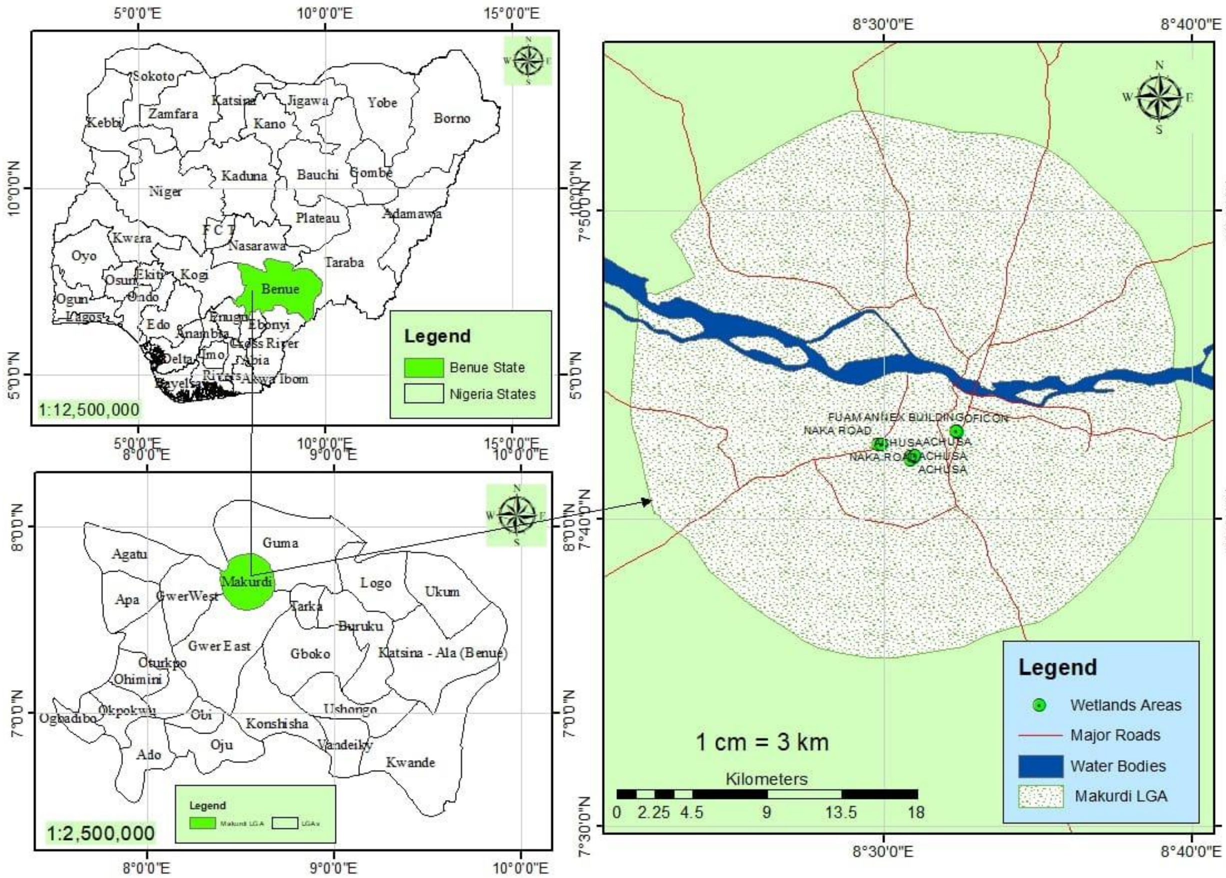

Figure 1. Map of the Study area showing major wetlands

Satellite Image Data Acquisition

The study used data from the USGS-Global visualization (GloVis) platform. Image data for 1985 and 2000 were downloaded from Landsat 4 and 7 (thematic mapper) and Landsat 7 (enhanced thematic mapper) platforms respectively. However, the 2020 image scene was acquired from the operational land imager. Table 1 shows the specifications of the satellite data used for the study.

Image preprocessing and enhancement

Image preprocessing represents a useful calibration procedure as it enables the recorded pixel values to be corrected and establishes a significant relationship between the acquired data and the biophysical phenomena (Coppin et al., 2004). Atmospheric corrections were done by the zero-brightness method (using the dark object subtraction algorithm in the semi-automatic classification plugin). Image enhancement was done to improve visual interpretation by increasing apparent contrast among various features in the image, radiometric correction to correct the sun elevation was performed on the raw data, and a band combination of 2,3,4 was used for 1985 and 2000 images while 3,4,5 combination was used for the 2020 Landsat 8 (OLI) because it produces superior results due to the sensitivity of band 4 and 3 to vegetation cover and sensitivity of band 4 to water contents.

Land cover Land-use Classification

Before the classification, all features were extracted to predetermine land cover classes within the wetland's areas. Five (5) land cover classes were visually obtained and characterized (i.e., built-up areas, wetlands, grassland, cultivated land, water bodies, and sand bar)

Table 1. Characteristics of Landsat Images Used for the Study

Date of Acquisition	Sensor	Path	Row	Multispectral Band	Thermal Band	Spectral Range (micrometers)	Spatial Resolution (pixel spacing)	Source
1985	TM	188	55	1to5 and 7	6	10.45-12.45	30	
2000	ETM+	188	55	1to5 and 7	6	10.45-12.45	30	USGS
2020	OLI and TIRS	188	55	1to7 and 9	10 and 11	10.60-12.51	30	

Source: Field Survey, 2022

Focus discussant group

Information on wetland existence and associated aquatic biodiversity was obtained from twenty persons (10 persons per group discussant) within the study locations. The selected group discussant was based on house proximity to the wetland and those that lived in the area for more than 35 years.

Data Analysis

Analysis of the extent of urbanization in the Study Area

The extent of land use change was analyzed by subtracting the reference year (2020) from the base year. It is represented mathematically as:

E_T=B-A

A= the base year (1985)

B=the reference year (2020)

E_T =total extent of wetland land

Change detection techniques

Three main change detection methods which have been previously applied by (Ikusemoranand Olokor, 2014) were employed, they are:

Change analysis by area calculation

There are three steps in calculating change detection by area calculation

a) The first step is the calculation of the magnitude of change, which is derived by subtracting the observed change of each period of years from the previous period of years.

b) The second step was the calculation of the trends, that is, the percentage change of each of the land use, by subtracting the percentage of the previous land use from the recent land use divided by the previous land use and multiplying by 100 (B-A/Ax100).

c) The last is the calculation of the annual rate of change by dividing the percentage change by 100 and multiplying by the number of the study years, that is, 35 years (1985-2020).

Results

Examination of Land use/Land covers Dynamics (1985, 2000 and 2020)

The classification results for the LULC dynamics are presented using tables, plates, and figures for illustration and interpretation of all land use/land cover classes in the three epochs 1985, 2000, and 2020 for the various study areas so as to quantify the changes that have taken place over time and space. Each of the study areas was discussed based on sub-themes such as the general land area as well as the magnitude and rate of change.

Analysis of land use/land cover Classification of 1985 Satellite Imagery for Makurdi

Figure 2 indicates the maximum likelihood supervised classification for Makurdi which shows the area extent covered by the six-land use and land cover categories; these are (built-ups, wetlands, grassland, cultivated lands, sand bar, and water body). The result reveals that grassland is the major land cover type in the area as of 1985. It covers an area of 414.99 km^2 (50.23%) of the total area. This is seen scattered across the study area, especially outside the city center. It is followed by cultivated land which occupies an area of 238.74 km^2 (28.90%) while built-up covers an area of 67.32 km^2 (8.15%). Wetlands, water bodies, and sand bars covered 61.45 km^2 (7.44%), 17.61 km^2 (2.13%), and 26.13 km^2 (3.16%), respectively. The total land area is 826.24 km^2.

Analysis of land use/land cover Classification of 2000 Satellite Imagery for Makurdi

Figure 3 shows the classified land use cover map of Makurdi for the year 2000, the map reveals that there were changes in the area extent covered by the six-land use and land cover categories, these are (built-ups, wetland, grassland, cultivated lands, sand bar, and water body). Findings also indicate that cultivated was now the major land cover type in the area as of 2000. It covers an area of 291.36 km^2 (35.27%) of the total area. This is seen scattered across the study area, especially between built-up areas and other land use categories. There was an increase of 6.37% in cultivated land between 1985 and 2000. This is followed by grassland which occupied an area of 414.99 km^2 (50.23%) in 1985 but reduced to 275.49 km^2 (33.35%) in 2000.

Furthermore, built-up areas covered an area of 67.32 km^2 (8.15%) in 2000 but increased to 102.84 km^2 (12.45%), an increase of 4.30% which has resulted in a drastic increase in wetland and other land use categories impacts. On the other hand, Wetland areas increased from 61.45 km^2 (7.44%) in 1985 to 111.80 km^2 (13.53%) in 2000. Water bodies increased from 17.61 km^2 (2.13%) in 1985 to 30.90 km^2 (3.74%) while sand bars reduced from 26.13 km^2 (3.16%) in 1985 to 13.75 km^2 (1.66%) in 2000.

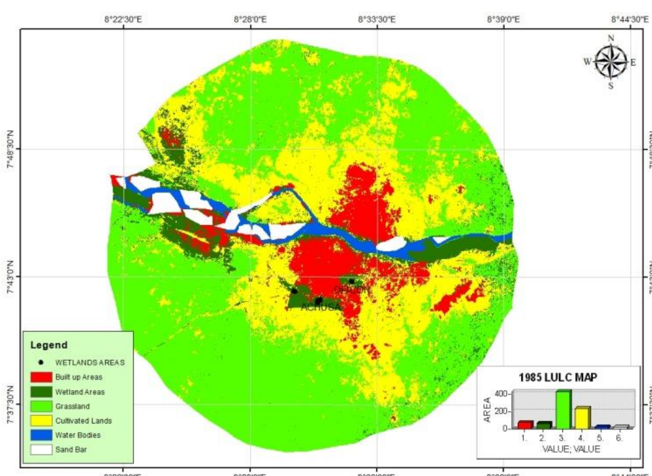

Figure 2. Makurdi 1985 LULC Distribution Map Generated from LandSat 4 TM

Source: Author's Analysis, 2022

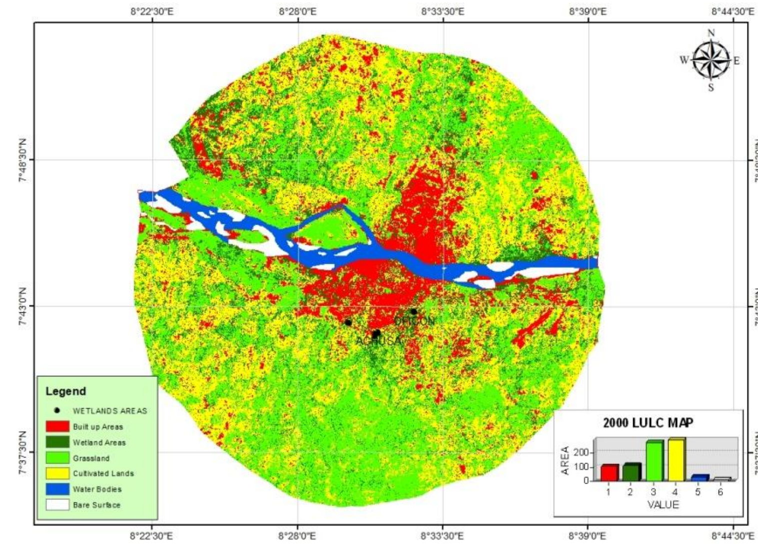

Figure 3. Makurdi 2000 LULC Distribution Map Generated from Landsat 7 ETM

Source: Author's Analysis, 2022

Analysis of land use/land cover Classification of 2020 Satellite Imagery for Makurdi

Figure 4. reveals the land use and land cover (LULC) map for the year 2020, it shows that built-up and grassland are on the increase while the other LULC types continue to show a fluctuating trend as a result of continuous anthropogenic activities in the study area. The areal extent for each of the LULCs indicates that grassland area is the most dominant land use and land cover type covering an area of 295.99 km^2 (35.83%) in 2020. This is followed by built-up areas which increased from 67.32 km^2 (8.15%) in 1985 to 231.02 km^2 (27.96%) in 2020 an increase of (19.81%) which ultimately resulted in the conversion of wetland areas into cultivated lands as well as built-up areas due to the level plain which encourages building in such areas. Also, wetland areas reduced tremendously from 111.80 km^2 (13.53%) in 2000 to 35.04 km^2 (4.24%) in 2020, thus representing 9.29%, thus, altered water quality, increased runoff volumes, diminished infiltration; reduced stream base flows and groundwater supplies, prolonging dry periods to mention just a few. Finally, water bodies decreased slightly to 26.92 km^2 (3.26%) while sand bare increased to 20.97 km^2 (2.54%) of the total land area. The highest rate of urban growth is observed during the third period of urbanization (2000 to 2020) in which the built-up area increased more than twice 163.69km^2 (19.81%) within 200 years as shown in Table 2. This is followed by 35.52

km^2 (4.3%) between the 1985 to 2000 period of urbanization respectively. The summary statistic of the study area is given in Figure 4.

Table 2. Land use and land cover Distribution Area Statistics for Makurdi (1985, 2000 and 2020)

LULC	1985		2000		2020	
Land Cover Category	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)
Built up Areas	67.32	8.15	102.84	12.45	231.02	27.96
Wetlands Areas	61.45	7.44	111.80	13.53	35.04	4.24
Grassland	414.99	50.23	275.49	33.35	295.99	35.83
Cultivated Lands	238.74	28.90	291.36	35.27	216.24	26.17
Water Bodies	17.61	2.13	30.90	3.74	26.92	3.26
Sand Bar	26.13	3.16	13.75	1.66	20.97	2.54
Total	826.24	100.00	826.24	100.00	826.24	100.00

Source: Field Survey, 2022

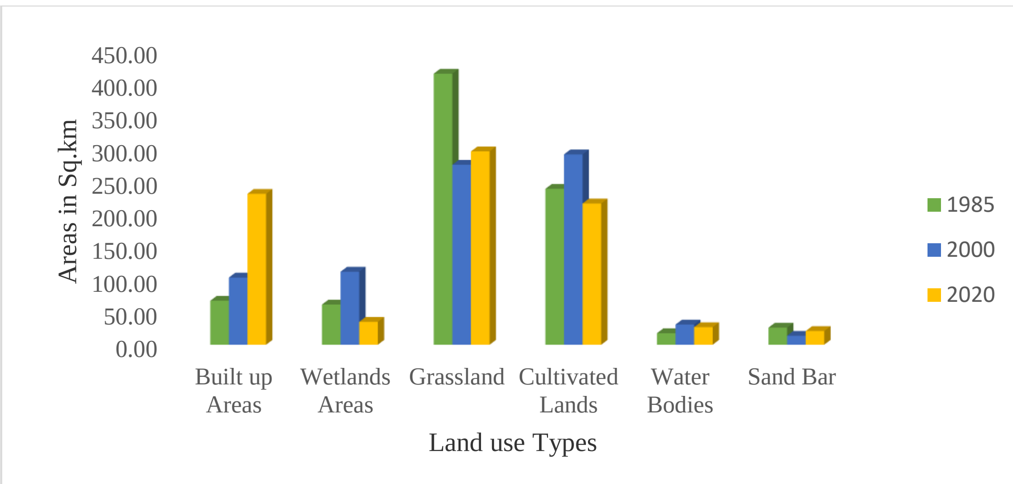

Figure 4. Summary of the Spatio-temporal Analysis of LULC of the study area

Magnitude and Percentage of Change in Land Use/Landover between 1985 to 2000; 2000 to 2020 and 1985 to 2020

The magnitude of change of wetland areas for 15 years between 1985 to 2000s showed that wetland increased by 50.35Sq. Km represents a change (81.93%) of the total change for the period. Wetland had an annual rate of change of 12.29% within the study years while grassland had the lowest annual rate of change of -5.04%. The period witnessed an increase in built-up and water bodies. The built-up land increased by 35.53 representing 52.77% of the total change at an annual rate of 7.92%, while cultivated land increased by 52.62 km^2 (22.04%) at an annual growth rate of 3.31%

as shown in Table 3. The magnitude of change in wetland areas for 20 years between 2000 to 2020 showed that wetlands decreased by -76.76 Sq. km representing a change (-68.66%) of the total change for the period. Wetlands had an annual rate of change of -13.73% within the study years while water bodies had the least annual rate of change of -2.58%. The period witnessed an increase in built-up and sand bars. The built-up land increased by 128.18 representing 124.63% of the total change at an annual rate of 24.93%, while cultivated land decreased by -75.13km^2 (-25.78%) at an annual growth rate of -5.16% as shown in Table 4. The magnitude of change of wetland areas for 35 years between 1985 and 2020 showed that wetlands decreased by -26.41Sq. km representing a change (-42.97%) of the total change for the period. Wetland had an annual rate of change of -15.04% within the study years while cultivated land had the lowest annual rate of change of -3.30%. The period witnessed an increase in built-up and water bodies. The built-up land increased by 163.71 representing 243.18% of the total change at an annual rate of 85.11%, while water bodies increased by 9.31km^2 (52.84%) at an annual growth rate of 18.50% as shown in Table 5.

Trend in Built-up Areas and Wetland Areas

Figure 6 shows the trend in built-up and wetland areas across the study domain, Result shows built-up areas had a drastic increase from 67.32 km^2 (8.15%) in 1985 to 231.02 km^2 (27.96%) in 2020 an increase of (19.81%) which ultimately result in the conversion of wetland areas to other uses while wetland areas, on the other hand, show a fluctuating trend, it indicates an increase of 9.29%.

Table 3. Magnitude and Percentage of Change in Land Use/Landover between 1985 and 2000

LULC Class	1985 Extent (sq. km)	2000 Extent (sq. km)	The magnitude of Change (sq. km)	Percentage of Change	Annual Rate of Change %
Built up Areas	67.32	102.84	35.53	52.77	7.92
Wetlands Areas	61.45	111.80	50.35	81.93	12.29
Grassland	414.99	275.49	-139.50	-33.62	-5.04
Cultivated Lands	238.74	291.36	52.62	22.04	3.31
Water Bodies	17.61	30.90	13.29	75.43	11.31
Sand Bar	26.13	13.75	-12.38	-47.38	-7.11
Total	826.24	826.14	303.77		

Table 4. Magnitude and Percentage of Change in Land Use/Landover between 2000 and 2020

LULC Class	2000Extent (sq. km)	2020 Extent (sq. km)	The magnitude of Change (sq. km)	Percentage of Change	Annual Rate of Change %
Built up Areas	102.84	231.02	128.18	124.63	24.93
Wetlands Areas	111.80	35.04	-76.76	-68.66	-13.73
Grassland	275.49	295.99	20.51	7.44	1.49
Cultivated Lands	291.36	216.24	-75.13	-25.78	-5.16
Water Bodies	30.90	26.92	-3.98	-12.88	-2.58
Sand Bar	13.75	20.97	7.22	52.55	10.51
Total	826.14	826.19			

Table 5. Magnitude and Percentage of Change in Land Use/Landover between 1985 and 2020

LULC Class	1985 Extent (sq. km)	2020 Extent (sq. km)	The magnitude of Change (sq. km)	Percentage of Change	Annual Rate of Change %
Built up Areas	67.32	231.02	163.71	243.18	85.11
Wetlands Areas	61.45	35.04	-26.41	-42.97	-15.04
Grassland	414.99	295.99	-119.00	-28.67	-10.04
Cultivated Lands	238.74	216.24	-22.51	-9.43	-3.30
Water Bodies	17.61	26.92	9.31	52.84	18.50
Sand Bar	26.13	20.97	-5.16	-19.73	-6.91
Total	826.24	826.19			

Source: Field Survey, 2022

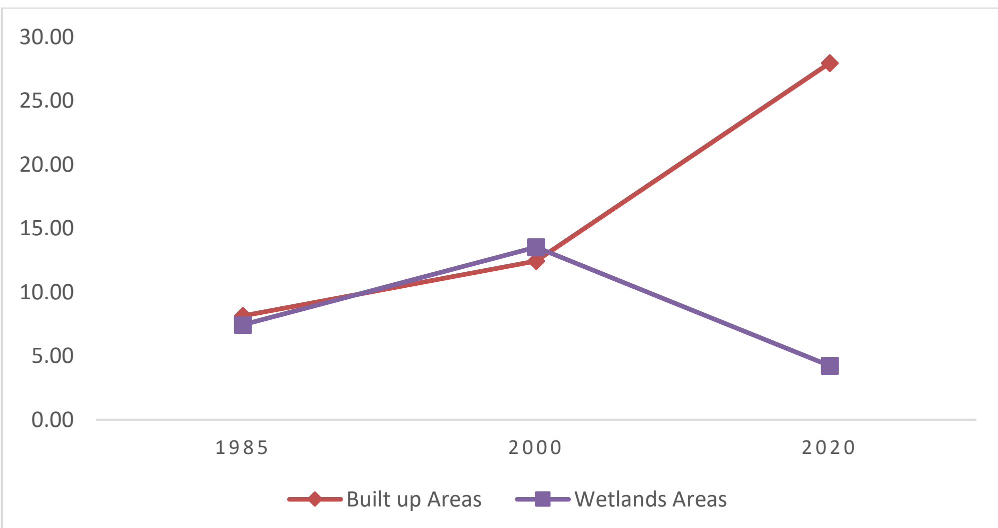

Figure 5. Built up and Wetland Trend Chart

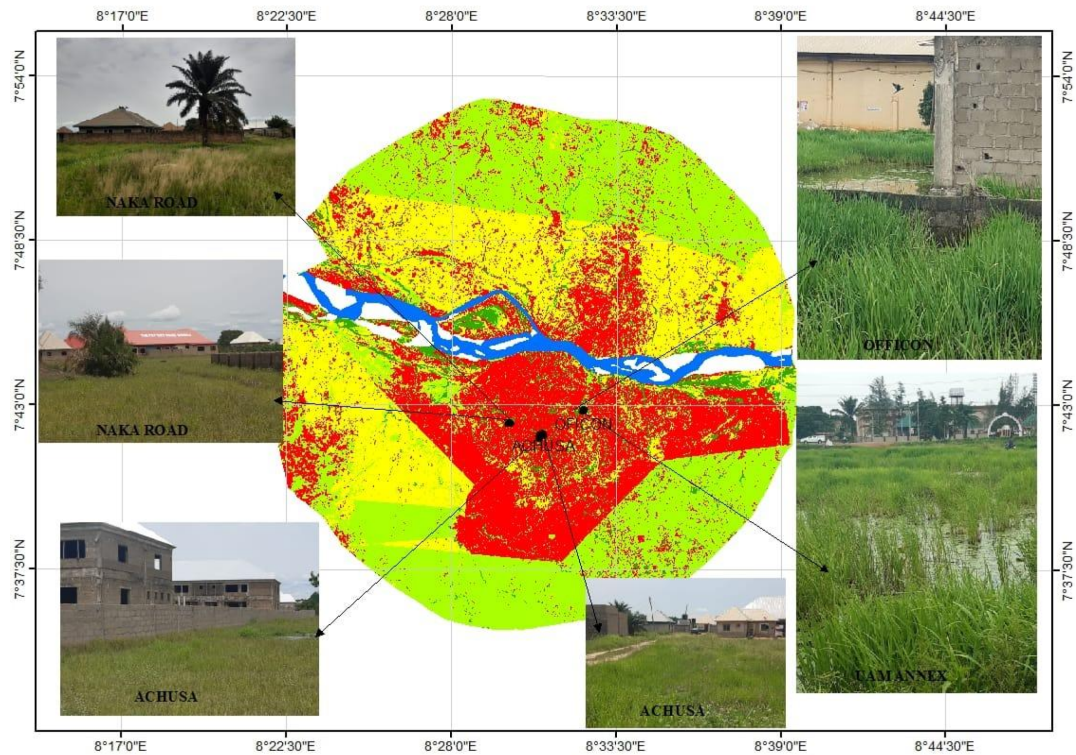

Figure 6. Geotagging of built-up structures within the wetland areas in Makurdi Metropolis
Study areas: the University of Agriculture Annex, Achusa, NAKA Road, and OFFICON Filling Station

Discussion

This study revealed the negative impact of urbanization on wetlands and also pointed out the effect on aquatic biodiversity. Thus, urbanization needs to employ scientific guidance because it does not only encroach on wetland and forested land but threatens food security and urban insecurity as revealed by Chen, (2007). The rapid urbanization in the study area between 2000 and 2020 was high compared to 1985 and 2000. It could be a result of improved socioeconomic activities due to the increased population in the area since it is one of the major urban centers in Benue State. This is in line with the work of Ajibola et al., (2012) who examined the effects of urbanization on Lagos wetlands and found that urbanization had resulted in direct habitat loss, hydrologic changes, altered water quality, increased runoff volumes, reduced stream base flows and groundwater supplies, prolonging dry periods. All urban landscape patterns need to be used to encourage and promote economy and coordinated ecological sustainability (Ma, et al., 2022). The focus group discussant also identified degradation features caused by urbanization, specifically revealing some aquatic species such as C*rocodylusniloticus, Trichechussenegalensis*, crabs, and water snails to have been lost and displayed due to degradation on major wetlands of the study area. The findings were consistent with Wali (2015) in Portharcourt, Belachew & Workiye (2021) in Ethiopia and Xiaomian et al (2023) in China, that degradation of wetlands causes displacement and threat to aquatic species.

This calls for a better understanding of the capabilities and limitations of built-up indices as they relate encroachment to wetland ecosystems. Many tropical wetlands are being directly exploited to support human livelihoods as in the case of wetlands within the study areas. This is possible through the cultivation of the wetlands for food crop production, some are fishing from the rich wetlands, and others are for construction purposes (Escalera-Vázquez & Zambrano, 2010; Mansur, 2021). Globally, wetland ecosystems are under pressure from rapidly increasing urban populations in such areas. Therefore, wetlands, urban landscapes, and other ecological land should be protected to promote multiple ecological uses and enhanced sustainability. Urban centers have often developed in estuaries and today few of these remain unaffected by human activities and fragmentation. Wetland habitats can impact positively on fauna that depend on these ecosystems for habitat and food, particularly those with specific needs. However, the use of wetlands and aquatic fauna as an indicator of urbanization in this study is not only a yardstick for urbanization, but urbanization has also brought great contributions to socioeconomic indicators such as population and the economy (Wang, et al., 2022), thus more urbanization indicators should be considered in the future study.

Conclusion

This study analyzed spatial and temporal changes in the area extent of the existing wetlands in the Makurdi metropolis, the effect of human urbanization on the wetland ecosystem in the study area, simulated the effects of urbanization on the wetland ecosystem to the year 2020 in the study area and examine the potential of land-use planning for an effective wetland ecosystem in the study area. Landsat imageries were used for data analysis. Based on the findings, the study concluded that significant Spatio-temporal changes in wetland-land use and the land cover have occurred during the study period. The changes were attributed to population increase, farmland cultivation, and built-up areas between 1985 and 2020. Though disparities in area coverage and percentage distribution of the various land-use types and wetland depletion existed within and between the study locations, the general picture is that wetlands in the study locations are under severe and continuous threat from urbanization. The study also concluded that more rapid urbanization took place in the study area between 2000 to 2020. These had resulted in direct habitat loss, suspended solids additions, hydrologic changes, altered water quality, increased runoff volumes; and reduced stream base flows and groundwater supplies. Based on the predicted future results on the wetlands, the study concluded that Makurdi would have the largest built-up area.

i. There is a need for continuous monitoring by regulatory authorities to ensure compliance with extant laws on wetland ecosystem management.

ii. There should be enforcement of sustainable land-use policies and alternative income sources for the population that rely on the wetland as a means of livelihood.

iii. Human activities (both individuals and government) that degrade wetlands should be reduced, while efforts should be on those activities that encourage wetland conservation and preservation.

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