



Article

Impact of Urbanization on Agriculture and Wetland Management in Makurdi LGA of Benue State, Nigeria

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Abstract

Wetlands are among the most productive ecosystems, providing essential ecological, hydrological, and socio-economic services, including flood regulation, groundwater recharge, water purification, biodiversity conservation, and agricultural support. However, rapid urbanization has accelerated the conversion of wetlands to built-up areas and agricultural land, threatening their ecological integrity. This study assessed the impact of urbanization on agriculture and wetland management in Makurdi Local Government Area, Benue State, over a twenty-year period (2004–2024). The specific objectives were to examine the spatial distribution and extent of wetlands, evaluate the relationship between urban growth and wetland dynamics, and determine the extent of wetland encroachment resulting from urban development. The study employed Geographic Information Systems (GIS) and Remote Sensing techniques using Landsat 7 ETM+, Landsat 8 OLI/TIRS, and Landsat 9 OLI-2/TIRS-2 satellite imagery acquired for 2004, 2014, and 2024. Image preprocessing, supervised classification, change detection, cross-tabulation matrix analysis, and accuracy assessment were performed in ArcGIS and ERDAS Imagine, while field observations and GPS data were used for ground-truthing and validation. Seven land-use/land-cover classes were identified: wetlands, farmland, shrubland, forest, water bodies, sandbars, and settlements. The findings revealed significant land-use and land-cover changes over the study period. Wetland coverage declined from 4,478.76 ha (5.37%) in 2004 to 2,664.36 ha (2.39%) in 2024, while settlements expanded from 1,182.60 ha (1.42%) to 5,119.22 ha (4.61%) during the same period. Farmland increased from 39.23% to 41.09%, indicating continued conversion of natural ecosystems to agricultural and urban uses. Cross-tabulation analysis further demonstrated substantial transitions of wetlands and farmlands into settlement areas, confirming that urban expansion has become a major driver of wetland degradation in Makurdi. Classification accuracy assessments yielded overall accuracies ranging from 72.15% to 75.93%, with Kappa coefficients between 0.60 and 0.68, indicating that the classified maps were sufficiently reliable for land-use change analysis. The study concludes that rapid urbanization has significantly contributed to wetland loss and fragmentation and has increasingly encroached on agricultural lands, posing serious threats to ecosystem sustainability, biodiversity conservation, flood regulation, and long-term food security. To address these challenges, the study recommends strengthening wetland protection policies, implementing continuous GIS-based monitoring, promoting sustainable urban development, and establishing institutional frameworks to conserve and effectively manage wetlands and agricultural lands in Makurdi

Keywords: Urbanization; Wetlands; Land Use/Land Cover Change; Geographic Information Systems (GIS); Remote Sensing; Change Detection.

1. Introduction

Urbanization is a leading global trend, with over 55% of the world's population expected to reach 68% by 2050 living in cities, characterized by the permanent concentration of people in small areas. This is more due to birth increase in cities and movement of people from rural areas to urban centers, World Health Organization (2025). Urbanization is a phenomenon marked by population growth and rural migration to cities; it has become a primary driver of environmental change worldwide (Grimm et al. 2008). According to Bradbury 2002, this trend is particularly evident in developing countries like Nigeria, where urban expansion exerts pressure on ecosystems and reshapes social economic, and environmental dynamics. Urban growth not only reorganizes places and economies but also intensifies pressure on natural resources, leading to unprecedented environmental strain. According to a government report, Nigerian urban population in the last three decades has been growing at the rate of about 5.8%. (FMHUD,2025)

Nigeria's urban population is currently estimated at 135 million people, accounting for roughly 55.8 % of the country's total population. The country is experiencing a rapid urbanization rate of 3.9% annually with projections expecting the urban dwellers to reach 264 million by 2050 (FMHUD, 2025). Due to pressure of urbanization most of the cities are growing fast and sometimes they develop beyond the planned limits, the situation which certainly poses great sustainable environmental challenges particularly as it affects natural ecosystems like wetlands.

Wetlands play significant roles both at global and regional scales in their influence on biologic, ecological and hydrological processes (Adeli et al, 2020) and are considered as some of the most valuable ecosystems performing critical functions in maintaining balance on earth such as flood reduction, water retention, wetland habitat, erosion control, carbon storage, water quality improvement through filtering of agricultural and industrial waste as well as aquifers recharge. Wetland reduce shoreline erosion by absorbing wave action and protecting shoreline soils with root networks (Klemas, 2013). Wetlands play a role at a global scale in the global carbon cycle by generating a fraction of the global methane emissions and determining greenhouse gases (Adeli et al, 2020).

According to UN Environmental Program, (2026), wetlands are among nature's most powerful systems. Wetlands store water during drought, absorb floods, and filter pollution, helping provide clean drinking water and support crops and livelihoods. Universal Peace and violence Amelioration Centre (UPVA) (2026), reports that wetlands cover only 6% of the Earth's land but they support 40% of all plant and animal species and provide livelihood for 1 in every 8 people worldwide. From flood control and clean water to food security, climate protection, and mental wellbeing, wetlands are lifegiving ecosystems. Yet they are disappearing three times faster than forests, largely due to human activities and climate change.

Nigeria has an estimated 18,000km² of wetlands spread throughout the various ecological regions of the country, collectively representing 2.23 percent of Nigeria's total area (Oludayo 2007). Nigeria is part of the global effort to protect wetlands and is a signatory to the Wetland Protection Convention. It has designated the Nguru Lake and Marma Channel Complex, an estimated area of about 58,100 ha, as a wetland of international and historic importance. On the other hand, an estimated 7000km², about thirty-nine percent of Nigeria's wetland located in the coastal area is threatened by a projected sea-level rise due to climate change (Oludayo, 2007). Others, especially inland wetland, are also threatened due to urban growth and expansion as shown by the work of Adefioye and Ujoh (2012). This study examines the impact of urbanization on agriculture and wetland management in Makurdi LGA. The protection of wetlands is essential for people, nature, and our common future.

Wetlands are important in agriculture; they are known to be the best environment for rice farming which is a main staple for people in many parts of the world because of its high nutrients content for rice and high water and moisture retention ability. Despite this importance, wetland

globally and particularly in Nigeria are under extensive threats and steady decline due to increase in world population which has in turn increased human demand on wetland resources for agricultural expansion and urban development as well as increased global warming/climate change impacts through hydrological regimes alterations (Wu, 2017).

Makurdi is located astride predominantly wetland floodplains of the River Benue and has witnessed, over the years, increasing population growth and spatial expansion of its boundaries. Due to the presence of many higher institutions, church institutions, commercial activities, and administrative activities, which have, over the years, mobilized and continuously attracted labour, capital and entrepreneurship, all these have made the population of Makurdi increase tremendously. The seeming population explosion in the city is evident, such that all the hitherto rural villages such as Apir, Fiidi and Agan have been engulfed and formed part of Makurdi metropolis. Consequently, most of the hitherto wetland ecosystems have been threatened by human activities such as construction, building, and farming. Therefore, effective wetland management and use require adequate understanding of the factors influencing its changes, which in turn affect the entire ecosystem function (Wu, 2017). It is important to understand these alterations as they could assist in evaluating wetland ecosystems and providing information to the relevant agencies for informed decision-making process.

In Benue State and Makurdi in particular, few researches were carried out on the existing wetland and agricultural land management. These studies include Wetland loss in Makurdi and environs in North Central Nigeria: Implication for gender Stephen 2017, geospatial analysis of wetlands degradation in Makurdi, Nigeria (Peter & Fanan, 2018), and effect of urbanization on wetlands ecosystem and aquatic biodiversity in Makurdi metropolis, Nigeria (Yager et, al. 2024). These aforementioned studies have not considered the impact of urbanization on agriculture and wetland management in the study area. Therefore, this study assesses the extent to which urbanization has affected agriculture and wetland management in Makurdi LGA

The main focus of this study is to examine the impact of urbanization on the size, spatial distribution of wetland and extent of agricultural land in Makurdi, over a twenty-year period (2004–2024). Specifically, the study seeks to examine the spatial distribution and changes in the size of wetland and agricultural land within the Makurdi area between 2004 and 2024; assess the relationship between increasing urban growth and the changing in size and spatial distribution of wetland agricultural land; and explore the extent to which wetland agricultural land have been encroached upon as a result of urbanization processes and related activities during the period under study.

Study Area

The study area is the entire Makurdi Town of Benue State of Nigeria. The town is located between Latitude 7°20' 00'' and 7°50' 00''N and Longitude 8°15' 00'' E and 8°40' 00'' E. The local government area and metro region is estimated at approximately 490000 people, with a population density of approximately 463 – 552 people per square kilometer (National Population Commission, 2006). Makurdi city covers a land area of about 937.4 km² and has a rapidly growing population, projected to exceed 500,000 residents.

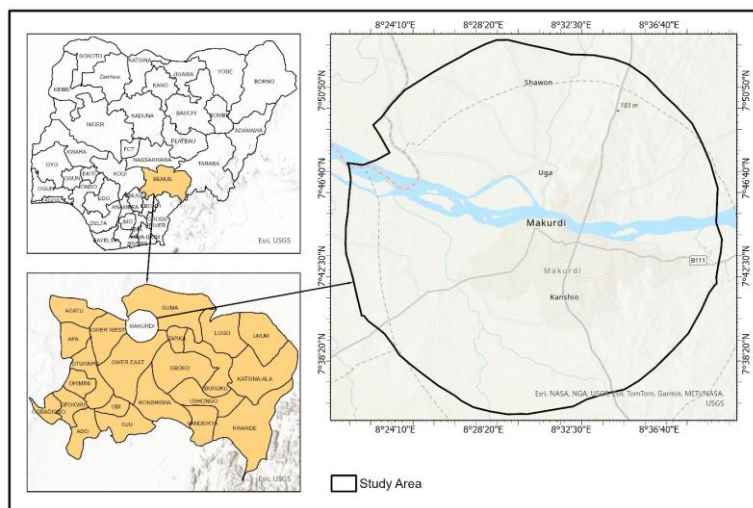


Fig:1 Map Showing Makurdi LGA.

Climate and Rainfall

The climate of Makurdi is characterized by dry and wet seasons, which is dominated by North-east and Southwest monsoon. The rainfall of Makurdi is influenced by these wind masses. The rainfall starts in April and stops in October. The mean rainfall duration of this area is about 182 days, with 221mm highest monthly rainfall in August, Nigeria Meterological Agency, (2026).

The study is centered on urbanization activities as it affects agricultural lands and wetlands within Makurdi LGA. Image pre-processing and land use and land cover classification analyses were conducted to categorize the various land use and land cover types in the study area. This was followed by an intensive fieldwork (ground truthing) in order to gather valuable information regarding the state of the wetlands and agricultural lands of the study area. The study covers the period of one year, including the seasons of dry, wet, and harmattan season.

2. Materials and Methods

The study used advanced innovated technology of remote sensing and GIS for its analysis which has been used by other similar studies, including Zubair (2006). According to Algharib, (2008) the integration Geographic Information System and Remote Sensing can provide a useful approach to analyzing data with high-level spatial details. In order to ascertain the authenticity of the remotely sensed data acquired and the quest for in-depth information on wetland, agricultural land (farmland) and settlement areas, field investigations were carried out. These include field observations, and GPS points were recorded across the study area. Sufficient random points were collected in the study area to be partly used as training samples for supervised classification and also for accuracy assessment.

The remotely sensed data: Point-by-point analysis of Landsat 7 ETM 2004, Landsat 8 OLI/TIRS 2014, and Landsat 9 OLI-2 /TIRS-2 2024 satellite imagery were processed using ArcGIS 10.5 image processing software.

Land-use/Land-cover change matrix: this was generated from ArcMap-Image Minus and the overlay operation. It was used in the analysis of the wetland, agricultural land (farmlands), and settlement change by comparing the statistics from the LULC matrix and output maps that were generated by the software in terms of land cover and land use changes between 2004, 2014 and 2024, respectively.

Data Acquired and Sources

Various types of data were used to carry out this study. These are satellite images which were analyzed to show the past and the present land use and land cover type of the study area (Makurdi).

Table 1. Data types, Resolution and Sources

Data type	Resolution	Source
Landsat 7 ETM+ (Enhanced Thematic Mapper Plus)	30m	USGS Earth explorer
Landsat 8 OLI/TIRS (Operational land Imager & Thermal Infrared Sensor)	30m	USGS Earth explorer
Landsat 9 OLI-2/ TIRS-2	30m	USGS Earth explorer
Ancillary Data		Field Surveys.

Source: Author 2026

The Image Classification was done by converting the raw satellite imagery into thematic maps such as land cover, based on knowledge of the area and ground truthing carried out mainly for the study. Seven (7) feature classes were created to represent the LULC type of the study area. These include: wetland, farmland, shrubland, forest, waterbody, sandbars, and settlement. Features such as single houses and apartments, industrial and commercial facilities, shopping centers, highways and major streets, and associated properties and parking lots all formed the settlement (Urban).

The data analysis involved image correction and rectification using ERDAS Imagine software in order to remove error and distortions from the images for proper visual interpretations. While ArcGIS 10.5 was used for the land use and land cover analysis aimed at determining the changes that have occurred over time between twenty the period of 2004 to 2024. The analysis formed the frame for achieving the objectives of the study.

3. Results

The various images required for different years (2004, 2014 and 2024) were processed and analyzed for their results and seven (7) different feature classes were generated for the Land use and Landcover (LULC) of the study area and these include wetland, farmland, shrubland, forest, waterbody, sandbars, and settlement.

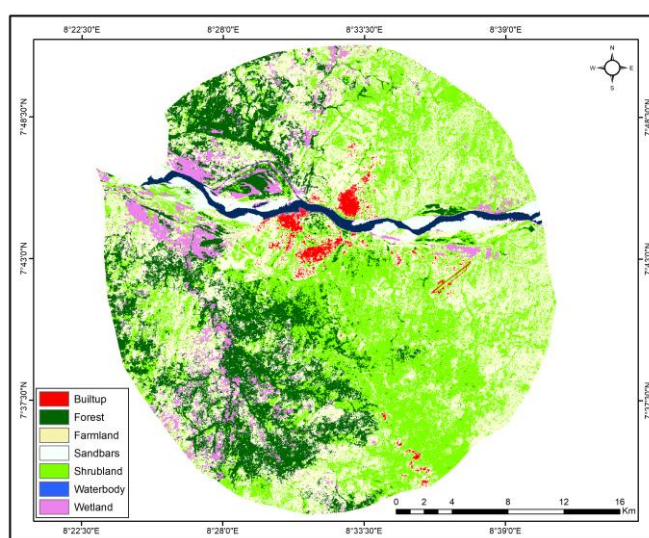


Figure 2: 2004 Land Use Classification of Makurdi (Source: National Centre for Remote Sensing, Jos)

The study placed more emphasis on the changes that have occurred in wetlands, farmlands and settlements. See figure 2, 3 and 4. A supervised image classification technique was used in the

analysis of the Landsat data sets using appropriate band combinations of OLI to display in false color composite (Red, Green and Blue) to enhance wetlands depiction.

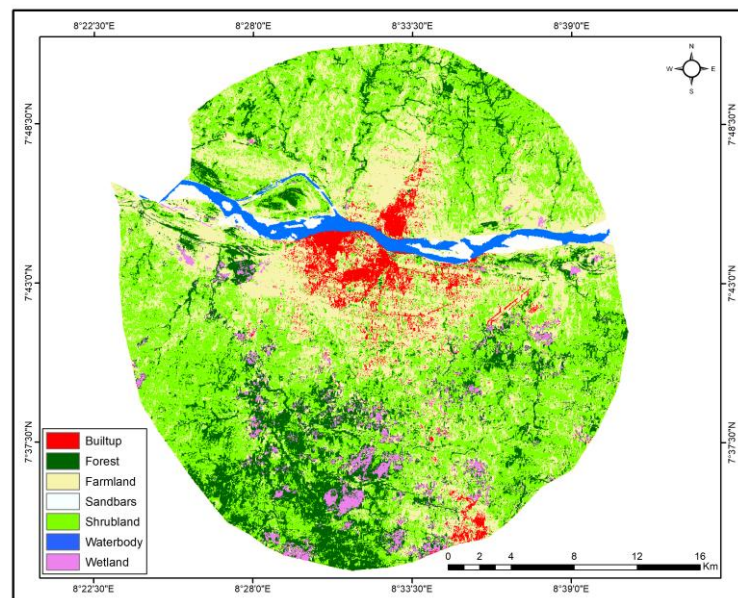


Figure 3: The 2014 Land Use Classification of Makurdi (Source: National Centre for Remote Sensing, Jos)

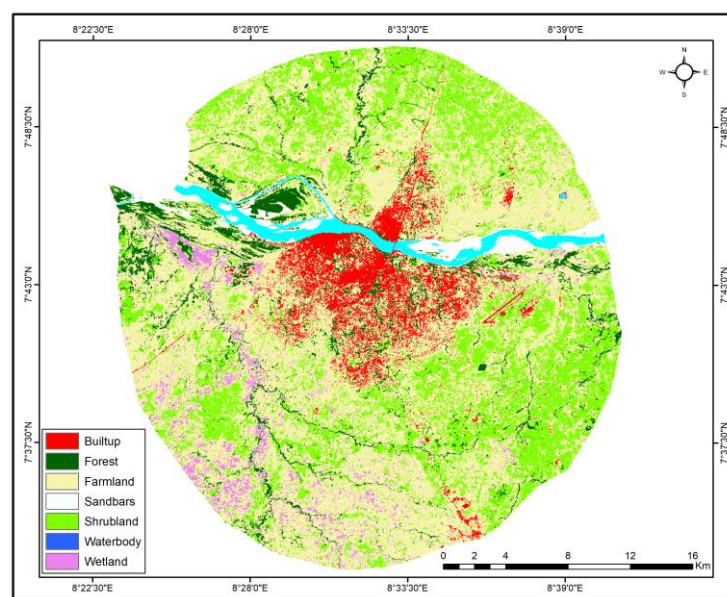


Figure 4: The 2024 Land use Classification of Makurdi (Source: National Centre for Remote Sensing, Jos).

From Figures 1, 2, and 3 above, the visual representation of the classified feature classes showed that there was a progressive increase in settlement (urbanization) within the study area between 2004 to 2024. Wetland and Agricultural land suffered a consequent decline as a result of encroachments from urbanization activities between 2004 and 2024.

Table 2: Statistical Results from 2004 Classification

Class Name	Ha	%
Wetland	4478.76	5.37
Farms	32705.55	39.23
Shrubland	28123.02	33.73
Forest	14538.51	17.44
Waterbody	1416.96	1.70
Sandbars	923.94	1.11
Settlement	1182.6	1.42
Total	83369.34	100

Results from Table 2 above showed that out of the total land area in 2004, wetlands occupied 4478.76 hectares which represented 5% of the total land area. While farmland occupied the largest part of the study area with approximately 32705.55 hectares (39.32%). This is followed by shrubland as the second highest with a total land area of about 28123.02 hectares (33.73 %). Also, forest area occupied approximately 14538.51 hectares, representing 17.44% of the total land area of the study area. Water bodies occupied approximately 1416.96 hectares (1.70%) of the total land area. While sandbars occupied the least land area, with a total coverage of 923.94 hectares (1.11%). Settlements (built-up areas) in 2014 occupied approximately 1182.34 (1.42%) hectares of the total land area.

Table 3: Statistical Results from 2014 Classification

Class Name	Ha	%
Wetland	2348.91	2.82
Farmland	27507.6	32.99
Shrubland	34289.91	41.13
Forest	12865.05	15.43
Waterbody	1929.15	2.31
Sandbars	1343.34	1.61
Settlement	3085.38	3.70
Total	83369.34	100

Results from Table 3 indicated that wetlands occupied approximately 2348.91 (2.82%) hectares. While farmland occupied about 27507.6 hectares (32.99%) of the total land area. The table further showed that shrubs occupied the highest land area with a total of about 34289.91 hectares, representing 41.13%. Furthermore, water bodies had a total of about 12865.05 hectares (2.31%) area coverage. Sandbars, with a total of 1343.34 hectares (1.61%), had the least area coverage as indicated in the table results. Also, the settlement result in the table showed that it occupied a total land area of about 83369.34 hectares, which represents (3.70%) of the total land area.

Table 4: Statistical Results from 2024 Classification

Class Name	Ha	%
Wetland	2664.36	2.398638794
Farmland	45640.27	41.08847837
Shrubland	20721.34	18.65475612
Forest	5589.27	5.031842489
Waterbody	1898.19	1.708880246
Sandbars	1736.69	1.698671204
Settlement	5119.22	4.608734403
Total	83369.34	100

Results in Table 4 showed that wetlands occupied a total land area of about 2664,36 hectares, which represents (2.39%). While farmland occupied the largest land area with a total of about 45640.27 hectares (41.08%) land area. Also, shrubland occupied a total area of about 20721.34 hectares, representing (18.65%) of the total land area. The table also indicated that forest occupied approximately 5589.27 hectares, representing (5.0%). Water bodies occupied 1898.19 hectares, which represent (1.70%) of the total land area. Sandbars with a total of 1736.69 hectares representing (1.69%) had the least percentage land coverage in the table. While settlement occupied a total area of about 5119.22 hectares, representing (4.60%) of the total area.

CROSS-TABLE MATRIX

This is used to compare land cover/use from two different periods or compares predicted map classes against actual ground data. This uses rows and columns to show the quantity of land transition from one category to another. To read the table, the Diagonal numbers (cells) showed the areas of land that remained unchanged between two periods. While Off-Diagonal Numbers (Cells) represents the conversion from one feature class to another. For the purpose of the study more emphasis will be on farmland, settlement and wetland.

Table 5: Cross-Table Matrix of 2004-2014

		2014							
	Class Name	Farm-land	Forest	Sand-bars	Settle-ment	Shrub-land	Water-body	Wetland	Grand Total
2004	Farm-land	10942.98	3480.939	135.386	1189.759	13949.401	92.306	2186.2751	31977.050
	Forest	2126.685	4568.698	17.498	80.762	6584.5097	12.967	1207.5127	14598.632
	Sand-bars	138.4641	23.84172	823.926	16.664	60.696237	553.272	176.69176	1793.556
	Settle-ment	217.4932	1.604714	9.242	798.682	10.733951	11.400	3.3239014	1052.480
	Shrub-land	9391.227	3710.364	60.411	874.346	12765.891	23.771	1271.0439	28097.054
	Water-body	21.64389	0.117621	326.161	9.532	0.2184276	1057.265	5.3392786	1420.277
	Wetland	1152.396	883.7824	89.351	27.400	1359.1162	181.606	736.64184	4430.295
	Grand Total	23990.89	12669.35	1461.976	2997.145	34730.567	1932.588	5586.8284	83369.344

The study cross matrix table 5 above showed that out of the total 31977.050 Ha. of farmland in 2004, about 3480.939Ha. of the farmland changed to forest in 2014. While 135.886 Ha. changed to sandbars, 1189.759Ha. changed to settlement, 13949.401Ha. changed to shrubland, 92.306Ha. changed to waterbody and 2186.2751Ha. changed to wetland respectively. While in between 2004 to 2014 approximately 217.4932Ha. of settlement changed to farmland, 1.604714 was changed to forest, 9.242Ha. changed to sandbars, 10.733951Ha. changed to shrubland, 11.400Ha. changed to waterbody and 3.3239014Ha. changed to wetland respectively. The study also showed that portions of wetlands also changed to other classes in 2014. A total of 1152.396ha. of wetland changed to farmland, 883.7824ha. changed to forest, 89.351Ha. changed to sandbars, 27.400Ha. changed to settlement, 1359.1162Ha. changed to shrubland, 181,606Ha. Changed to waterbody and 736.64184 remained unchanged from wetland.

Table 6: Cross-Table Matrix of 2014-2024

		2024							
	Class Name	Farm-land	Forest	Sand-bars	Settle-ment	Shrub-land	Water-body	Wet-land	Grand To-tal
2014	Farm-land	15755.32	857.23	260.48	2316.96	4488.3	48.08	280.28	24006.64772
	Forest	6842.90	2218.87	9.88	65.25	3031.6	6.26	402.07	12576.8167
	Sandbars	88.30	40.65	944.10	32.20	30.7	346.18	0.69	1482.836082
	Settle-ment	696.50	55.68	22.60	2173.62	33.7	9.92	6.50	2998.479929
	Shrub-land	19053.27	2108.26	60.70	336.72	12662.2	20.00	490.34	34731.46587
	Water-body	2.46	2.68	437.21	36.23	2.2	1452.13	0.04	1932.957613
	Wetland	3880.43	331.91	138.30	66.34	924.6	19.66	278.90	5640.14
	Grand Total	46319.18	5615.29	1873.28	5027.32	21173.2	1902.24	1458.82	83369.34386

The study results in Table 6 revealed that between 2014 and 2024, farmland that remained unchanged was about 15755.32Ha. while 857.23Ha. of the farmland changed to forest, 260.84Ha. was changed to sandbars, 2316.96Ha. was converted to settlement, 4488.3Ha. also changed to shrubland, in addition, 48.08Ha. was changed to waterbody within that period and finally, 280.28Ha. of farmland changed to wetland. The table also showed that some portions of settlement were converted to other feature classes. A total of 6842.90Ha was converted from settlement to farmland in 2024. Other changes from settlement include 55.68Ha was changed forest, 22.60Ha. was changed to sandbars, 2173.62Ha. remained unchanged, while 33.7Ha. was changed to shrubland. That same period, about 9.92Ha. of settlement was converted to waterbody and 6.50Ha. changed to wetland. Furthermore, wetland between the period of 2004 to 2014 had some portions of it been changed to other feature classes. A total of 3380.43 of the wetlands was converted to farmland. While about 331.91Ha. changed to forest, 138.30Ha. was changed to sandbars, 924.6Ha also changed to shrublands. In addition, 19.66Ha. of wetlands also changed to waterbody, while wetlands that remained unchanged was approximately 278.90Ha.

In a nutshell, between 2004 to 2014 farmland that changed to settlement was about 1189.759. While between 2014 to 2024 the study recorded farmlands that changed to settlement was about 2316.96Ha. The changes showed an increase of about 1127.201Ha within those periods. While between 2004 to 2014 wetlands areas that changed to settlement was about 27.400Ha. While in between 2014 and 2004, approximately 66.34Ha. of wetlands area changed to settlement. this indicated an increase difference of about 38.98Ha.

Validation of the Land use/landcover Classification of Makurdi LGA

The accuracy assessment compared classified image pixels with reference (ground truth) data to determine how accurately each land cover class was identified.

Table 7: land use and landcover accuracy classification for 2004

Class Value	Wet-land	Farm-land	Shrub-land	Forest	Water-body	Sand-bars	Settle-ment	To-tal	U_Accu-racy	Kappa
Wetland	2	0	0	0	0	0	0	2	1	0
Farm-land	0	25	4	2	0	1	1	33	0.757576	0
Shrub-land	0	4	19	2	1	0	3	29	0.655172	0
Forest	0	1	3	8	0	0	0	12	0.666667	0
Water-body	0	0	0	0	2	0	0	2	1	0
Sand-bars	0	0	0	0	0	1	0	1	1	0
Settle-ment	0	0	0	0	0	0	0	0	0	0
Total	2	30	26	12	3	2	4	79	0	0
P_Ac-curacy	1	0.833333	0.730769	0.666667	0.666667	0.5	0	0	0.721519	0
Kappa	0	0	0	0	0	0	0	0	0	0.599631

The table 7 of the study showed that classification recorded an overall accuracy of 72.15% and a Kappa coefficient of 0.5996. This indicates moderate agreement between the classified image and the reference data, suggesting that the classification was acceptable but contained some errors.

Table 8; land use and landcover classification accuracy for 2014

Class Value	Wet-land	Farm-land	Shrub-land	For-est	Wa-ter-body	Settle-ment	To-tal	U_Accu-racy	Kappa
Wet-land	4	0	0	0	0	0	4	1	0
Farm-land	0	10	0	3	0	3	16	0.625	0
Shrub-land	0	6	14	0	0	0	20	0.7	0
Forest	0	0	1	9	0	0	10	0.9	0
Water-body	0	0	0	0	2	0	2	1	0
Settle-ment	0	0	0	0	0	2	2	1	0
Total	4	16	15	12	2	5	54	0	0
P_Ac-curacy	1	0.625	0.933333	0.75	1	0.4	0	0.759259	0
Kappa	0	0	0	0	0	0	0	0	0.682353

Results in table 8 of the study revealed that 2014 LULC classification achieved an overall accuracy of 75.93% with a Kappa coefficient of 0.6824, indicating a substantial agreement between the classified map and the reference data.

Table 9: land use and Landcover classification accuracy for 2024

Class Value	Wet-land	Farm-land	Shrub-land	Forest	Water-body	Sand-bars	Settlement	Total	U_Accuracy	Kappa
Farm-land	0	28	8	2	0	0	3	41	0.682927	0
Shrub-land	0	2	7	0	0	0	0	9	0.777778	0
Forest	0	1	0	5	0	0	0	6	0.833333	0
Water-body	0	0	0	0	1	0	0	1	1	0
Sand-bars	0	0	0	0	0	2	0	2	1	0
Settlement	0	0	0	0	0	0	5	5	1	0
Total	1	31	15	7	1	2	8	65	0	0
P_Accuracy	1	0.903226	0.466667	0.714286	1	1	0.625	0	0.753846	0
Kappa	0	0	0	0	0	0	0	0	0	0.619187

Results from table 9 of the study indicated that the LULC classification produced an overall accuracy of 75.38% and a Kappa coefficient of 0.6192, indicating a substantial level of agreement between the classified image and reference data. The 2024 classification results show that farmland was successfully detected, but shrubland was significantly confused with agricultural areas. This was expected because seasonal vegetation in farmland often exhibits spectral signatures similar to natural shrub vegetation.

Trend Analysis

- The classification accuracy improved from 72.15% in 2004 to 75.93% in 2014, indicating better class separability and classification performance.
- The accuracy slightly declined to 75.38% in 2024, but it remained within the acceptable range for Landsat-based LULC studies.
- The Kappa coefficient followed a similar trend, increasing from 0.5996 in 2004 to 0.6824 in 2014, before declining slightly to 0.6192 in 2024.
- Water bodies and wetlands consistently achieved the highest accuracies because they possess distinct spectral characteristics.
- Farmland, shrubland, and forest recorded the greatest confusion due to similar vegetation reflectance patterns.
- Overall, all three classifications exceeded the commonly accepted 70% overall accuracy threshold for land use/land cover mapping, indicating that the maps are reliable for change detection and environmental analysis.

The accuracy assessment demonstrates that the Makurdi LULC classifications for 2004, 2014, and 2024 are of acceptable quality, with overall accuracies ranging from 72.15% to 75.93% and Kappa coefficients between 0.60 and 0.68. Although some confusion exists among vegetation-related classes such as farmland, shrubland, and forest, the classifications provide a reliable basis for evaluating land-use and land-cover changes in the study area over the 20-year period.

4. Conclusions

Between 2004 and 2014, farmland that was converted to settlement was about 1189.759 while between 2014 and 2024 the changes from farmland to settlement was about 2316.96Ha. This showed an increase of about 1127.201Ha. within the period. While between the period of 2004 to 2014, wetlands that was converted to settlement was about 27.400Ha. Approximately 66.34 ha of

wetlands were converted to settlement between 2014 and 2024, with an increase difference of about 38.98Ha. The study showed that there is a continuous decrease in wetland and agricultural land due to human activities. The trend in the amount of wetland and agricultural land lost in the study area is at an alarming rate and is dangerous to ecosystem functioning and the extinction of wetlands in the study area. The continuous depletion of farmlands will also pose a treat for national food security.

RECOMMENDATIONS

Based on the study findings, the following recommendations are suggested: Monitoring and control of wetland/agricultural land development should be adopted in the study area in order to support and protect wetlands/agricultural lands for the future ecological functioning and food security. The government should put in place measures that allow time-to-time evaluation of wetlands/agricultural lands within the study area. The remaining wetlands/agricultural lands should be protected through the establishment of institutional frameworks that prohibit encroachment on wetlands/agricultural lands but support sustainable development. Also, effort should be shifted from the immediate benefits derived from conversion to future/ sustainable benefit derivable for proper wetland and agricultural management. The study also recommends that more studies should be conducted on wetlands/agricultural lands of the area to protect the resources for sustainability

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