Geospatial Analysis of Wetlands Degradation in Makurdi, Nigeria

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Author's contribution

This work was carried out in collaboration between both authors. Author PA designed the study, performed the statistical analysis, and wrote the protocol. Author FU wrote the first draft of the manuscript. Both authors managed the analyses of the study and the literature searches, read and approved the final manuscript.

Original Research Article	

ABSTRACT

Aims: The study aims to identify wetlands from different study epochs using remote sensing images and also detect any changes in their extent or existence; correlate changes with nearby land use and land cover over time; identify wetland losses within the stipulated epochs; and, also project future levels of degradation (up to 2026) based on the trend observed between 1996 and 2016.
Place and Duration of Study: The study area covers Makurdi LGA in Benue State, Nigeria. The study focused between the periods 1996 through 2016 to 2026.
Methodology: To estimate the land use/cover change in Makurdi, Landsat ETM, ETM+ and OLI satellite data for 1996, 2006 and 2016, were respectively utilised. The study adapted the Kappa index for assessing the accuracy of the land use/cover maps generated from the analysis to improve the efficiency of results. An accuracy level of 80 to 91% was achieved. The land

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consumption rate (LCR) and land absorption coefficient (LAC) were applied to establish the role population increase plays in the rate of land consumption over specific spatio-temporal scales.
Results: The results reveal an overall significant increase in built-up area and other land uses at the expense of wetlands from 26.3% in 1996 to 18.1% in 2016. Further analysis includes the land consumption rate (LCR) and land absorption coefficient (LAC) which reveals the role of population expansion in the recorded levels of wetland losses recorded in this study. The study projects a further decline of wetland cover by 33.15 km2 (or by 22.57%) in 2026 if steps are not instituted to control the current rate of decline.
Conclusion: Given the findings and limitations of the study, some critical suggestions are made for further studies in line with the red list index (RLI) and to align with and incorporate into policy the strategic need to adopt the provisions of the SDGs (especially goal 15) at the level of Makurdi.

1. INTRODUCTION

Many different sub-classes of wetlands exist, but each can be defined as an area saturated with water for a duration that is sufficient to sustain various types of hydrologic and biological activities [1]. Wetlands typically possess high levels of biodiversity, help regulate watershed hydrology, and are a source of carbon sequestration [2]. Although wetlands only cover roughly 6% of the Earth's land surface, they are considered an immensely important part of the global ecosystem [3,4].

Environmental researchers in recent decades have detected a trend of diminishing wetlands regarding the areal extent and health/quality, primarily linked to numerous anthropogenic interactions and indirect forces of the changing climate [5;6](Eppink et al., 2004; Hartig et al., 2003). Explanations presented by [6] and [7], ecological fragmentation is often linked to human development in wetlands, generating a desire for management to establish a reasonable degree of land use that will generate a state of sustainability in these areas.

As the impacts of climate change and land use practices in the environment have become more abundantly apparent, remote sensing becomes a vital tool for the assessment of the status and well-being of wetlands [8], and in maintaining accurate records of the state of wetlands which is crucial in their preservation [9,10].

One of the main aspects that can be carefully monitored remotely is the overall behaviour of wetlands over time [9,10] using a series of images from different years [2]. A wealthy amount of information can be extracted through the comparison of multiple images, and this data can sometimes be extrapolated to predict future changes [9,10]. The flexibility of GIS allows the analyst to control the scale of their research, depending on the data available.

A significant step towards the preservation and conservation of wetlands begins with understanding the level of degradation of these fragile ecosystems at regional and local spatial scales. Thus, providing an accurate evaluation of the spread and health of the world's forest, grassland, water, and agricultural and land resources has become an important priority [11]. Therefore, this study maps the status of wetlands in Makurdi Local Government Area (LGA) over a 20-year period (1996-2016) to estimate the rich alluvial wetlands that can also be used for urban agriculture but is being lost to urban expansion and related land uses. An understanding of this status would aid in proffering suggestions towards developing policies for sustainable use of the environment of the study area.

Using the information available on wetlands, as well as the literature regarding wetlands and remote sensing as a basis, this study aims to accomplish the following objectives:

i. Identify wetlands for different study epochs in Makurdi local government area (LGA) of Benue State using remote sensing and detect any changes in their extent or existence;
ii. Correlate changes with nearby land use and land cover over time;
iii. Identifying wetland losses within the stipulated epochs; and,
iv. Project future levels of degradation (up to 2026) based on the trend observed over the last 20 years (1996-2016).

The Rio+20 Outcome Document produced the sustainable development goals (SDGs) which are intended to be "action-oriented, concise and easy to communicate, limited in number, aspirational, global in nature and universally applicable to all countries, while taking into account different national realities, capacities and levels of development and respecting national policies and priorities [12], and should be focused on priority areas for the achievement of sustainable development. Building on the gains of the MDGs post-2015, it is imperative that progress continues to thrive at local and regional levels within the context of globally established sustainability frameworks as provided for in the SDGs. Wetlands are valuable yet fragile and sensitive ecosystems which have experienced extensive agricultural and other economic and socio-cultural exploitation which generally and cumulatively degrade their quality and quantity of wetlands.

In spite of the broad dimensions of the SDGs (which are generally aimed at sustainability in environmental resources utilization and human resource redistribution), of specific interest to this study is the SDG Number 15 which states, inter alia: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". This goal is to be achieved vide 5 targets along with the indicators listed for each target as shown below:

i. Target 15.1: By 2020 ensure conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular, forests, wetlands, mountains and drylands, in line with obligations under international agreements;

Indicators:

15.1.1: Forest area as a proportion of total land area;
15.1.2: Proportion of essential sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type;

ii. Target 15.2: By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests, and increase afforestation and reforestation (by a significant percentage) globally;

Indicator:

15.2.1: Progress towards sustainable forest management.

iii. Target 15.5: Take urgent and significant action to reduce degradation of natural habitat, halt the loss of biodiversity, and by 2020 protect and prevent the extinction of threatened species;

Indicator:

15.5.1: Red List Index (RLI) [13].

iv. Target 15.8: By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems, and control or eradicate the priority species;

Indicator:

15.8.1: Proportion of countries adopting relevant national legislation and adequately resourcing the prevention or control of invasive alien species.

v. Target 15.9: by 2020, integrate ecosystems and biodiversity values into national and local planning, development processes and poverty reduction strategies, and accounts.

Indicator:

15.9.1: Progress towards national targets established in accordance with Aichi Biodiversity.

vi. Target 2 of the Strategic Plan for Biodiversity 2011-2020.

The UN General Assembly's Resolution 68/261) recommends that "SDGs indicators should be disaggregated, where relevant, by income, sex, age, race, ethnicity, migratory status, disability and geographic location, or other characteristics, in accordance with the Fundamental Principles of Official Statistics". To the extent that statistics and data on the current state of wetlands is required for planning, this study is a focused attempt towards supporting the attainment of the SDG 15 (at the local level) through the laid down

indicators [14] supported by the red list index [15].

2. MATERIALS AND METHODS

2.1 Study Area

River Benue, the second largest river in Nigeria, is endowed with an extensive network of streams and a large expanse of wetlands forming the Benue valley. The river begins its 1,400 km stretch from the Adamawa Plateau of northern Cameroon and flows west through the towns of Garoua and Lagdo Reservoir (in Cameroon), into Nigeria through Jimeta, Ibi and Makurdi before confluence with the most significant river in Nigeria (the River Niger) at Lokoja. This study, however, specifically focuses on Makurdi LGA (Fig. 1), a strategic location within the River Benue basin area. Makurdi is a transit/nodal point (rail, road and in-land waterways) between the south-east and northern parts of Nigeria. The study area falls within the transitional belt from the densely vegetated southeastern Nigeria to the Sudano-sahelian region of northern Nigeria. According to the [16], the last population census in 2006 recorded the population of Makurdi LGA as 297,398. Makurdi as currently defined politically covers a radius of 16 Km^2 with an area of about $800km^2$. The average elevation of the area ranges between 250m – 450m above sea level.

2.2 Research Materials and Methods

Landsat TM, ETM+ and OLI for 1996, 2006 and 2016, respectively were downloaded from the Global Land Cover Facility (GLCF) database. The quality of the imageries used is shown in Table 1. Also, a base map of Makurdi LGA was obtained from the Ministry of Lands and Survey, Benue State Government, Nigeria.

ERDAS Imagine 9.2 software was used for pre-processing of the images which were subsequently imported into Arcmap 10 for image classification. All processes were performed in a raster environment except for vector data used for defining the study area. A Garmin Etrex 32 handheld GPS was used to record coordinates for training sites. Determination of appropriate classes was done based on Level I of the Landuse/cover classification of the United States Geological Survey (USGS) reviewed by [17]. Six (6) classes were identified (Table 2).

2.3 Image Classification

2.3.1 Training stage

The image classification process was carried out using ERDAS Imagine image Classification tool. Although the clumping of pixels is performed automatically by the software, the procedure followed in this study involved manual input. The quality of these inputs is instrumental in generating an accurate classified image. These inputs existed in the form of training sites, which were polygons digitised within the boundary of several different feature classes. The placement of these polygons was based primarily on the spectral reflectance of pixels as seen in different wavelength band combinations. Some useful combinations of the red, green, and blue bands used during the training stage were 4, 3, 2 for Landsat 7 and 5,4,3 for Landsat 8 for visualisation and better object determination. The result was effective in identifying wetlands.
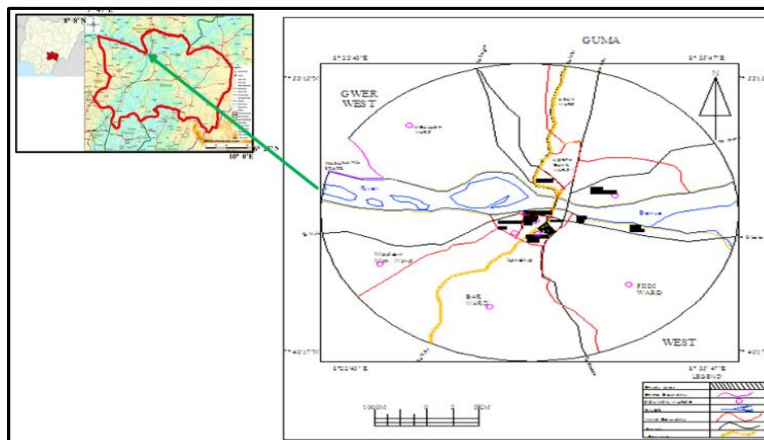

Fig. 1. Makurdi LGA, the study area

Table 1. Characteristics of lansat images used for study

Landsat sensor	Date of imagery	Spatial resolution	Path/row
TM (Band 1-7)	Nov 1996	30m	188/55
ETM$^+$ (Band 1-7)	Nov 2006	30m	188/55
OLI$^+$ (Bands 1-11)	Dec 2016	30m	188/55

Table 2. Characteristics of lansat images used for study

Land use	Code	Description	Appearance color
Waterbody	WA	Open water field: freshwater, perennial streams, human-made ponds and Natural lakes	Dark blue
Built-up/Urban Area	BU	High populated areas may be cities, towns or Settlements, roads or any other kind of physical infrastructure.	Cyan
Wetland	W	Seasonally flooded areas covered with erect, rooted, herbaceous hydrophytes.	Green and dark pink
Forest	FO	Areas dominated by natural trees, such including riparian forest	Dark Red
Mixed farming area	MFA	Cultivated regions with field crops rice, maize, beans or vegetables, etc.	Pink and dark blue
Barren land	BS	Soil or sand areas not covered by grass, sod or other live ground covers.	Dark Brown or Brown and white

Adapted and modified from [17]

2.3.2 Supervised classification

A Maximum Likelihood classification was executed for each image. This method assumes a normal distribution of DN values, allowing the function to determine the probability of a pixel belonging to a specific feature class and assign each pixel to the highest probability class [18]. Classifications were often repeated numerous times after additional training sites were added to achieve satisfactory results. Wetland areas were occasionally classified as grassland, requiring additional polygons to be digitised to properly classify the image.

2.3.3 Post-classification processing

The classification process often misclassified pixels in outlying areas that are not an accurate representation of reality; individual or small clusters of pixels that are apparently segregated from other groups of the same class were often misclassified. Cells with DN values that fall midway between two distinct classes were sometimes misclassified, creating a generous amount of noise within the image. Two filters were used to manage these problems. Isolated cells whose class did not match adjacent cells were changed to match the class of the majority of neighboring cells. This filter adjusted cells with four orthogonal neighbors of another class. The pixels along the boundaries of the resulting layer's classes were then smoothed by expanding and shrinking the pixels, reducing clutter along the boundaries shared by two classes. These post-processing tools were useful for eliminating misclassified pixels regardless of the image's resolution. With filtering complete, each classified image was clipped to the same extent.

Table 3. Results of accuracy assessment of classified images

Year	Accuracy %	WA %	BU %	MFA %	BL %	FO %	W %	Overall %	Kappa
1996	User	100.00	71.43	88.24	75.00	77.78	83.33		
	Producer	50.00	71.43	83.33	81.82	87.50	88.24	85.00	0.8156
2006	User	100.00	80.00	88.89	87.50	100.00	68.75		
	Producer	100.00	80.00	80.00	87.50	100.00	91.67	86.67	0.8289
2016	User	75.00	100.00	100.00	83.33	100.00	85.71		
	Producer	75.00	66.67	66.67	83.33	100.00	80.00	83.33	0.7887

(WA=Water body, BU=Built up, MFA=Mixed Farming Area, BL=Barren land, FO=Forest, W=Wetland)

Table 4. Conditional Kappa for each LU category

Makurdi land use	Conditional Kappa for each lu/lc category 1996 to 2016		
	1996	**2006**	**2016**
Barren land	0.7934	0.8558	0.8148
Mixed farming areas	0.7992	0.7647	0.6552
Wetland	0.860	0.8400	0.8200
Built up	0.6928	0.7818	0.6296
Forest	0.8476	1.0000	1.0000
Water body	0.4949	1.0000	0.7321

2.3.4 Accuracy assessment

The accuracy of each classified image was tested by randomly generating a series of points within ERDAS Imagine software, manually identifying the land cover type at each location, and subsequently comparing the land cover with the classified image. Two hundred (200) points were generated for each image. The resulting accuracies are shown in Table 3 while the conditional Kappa for each category is presented in Table 4.

2.4 Data Analysis

The Land Consumption Rate (LCR) and Land Absorption Coefficient (LAC) [19;20] were adopted for this study, using the following functions:

$$LCR = \frac{A}{P} \tag{1}$$

$$LAC = \frac{A^i_2 - A^i_1}{P^i_2 - P^i_1} \tag{2}$$

Where

A = area extent of the study area in hectares;
P = the population,
A^i_1 and A^i_2 = the area extents (in hectares) for early and later years;
P^i_1 and P^i_2 = population figures for the early and later years respectively.

The population estimates method was adopted from [20] and is given as follows:

$$n = r/100 * Po \tag{3}$$

$$Pn = Po + (n * t) \tag{4}$$

Where:

Pn = estimated population (1996 & 2016);
Po = base year population (1991& 2006 Census);
r = growth rate (3.0%);
n = annual population growth; and,
t = number of years projecting for.

The LCR and LAC are applied to establish the role population increase plays in the rate of land consumption over specific spatio-temporal scales.

3. RESULTS AND DISCUSSION

3.1 Quantifying Land Use/Cover of Study Area (1996-2016)

The quantification of various land use/cover classes within the study area is presented in Tables 5 and 6, while Figs. 3, 4 and 5 show actual composition of classes of land cover for years 1996, 2006 and 2016, respectively. The false color composite (FCC) is shown on Fig. 2. Clearly, wetlands cover is the land cover that has experienced the most significant decline among the land uses classes.

6

Table 5. Landuse composition of study area (Km2) in 1996, 2006 & 2016

Makurdi land use	Total area in 1996 (km^2)	Total area in 2006 (km^2)	Total area in 2016 (km^2)
Barren land	140.975	121.137	102.649
Mixed farming areas	202.03	183.096	173.313
Wetland	213.17	185.45	146.864
Built up	96.567	169.456	235.64
Forest	136.67	124.183	116.341
Water body	20.947	27.642	35.236
Total	810.359	810.964	810.043

Table 6. Landuse composition of study area (%) in 1996, 2006 and 2016

Makurdi land use	Total area in 1996 (%)	Total area in 2006 (%)	Total area in 2016 (%)
Barren land	17.397	14.937	12.672
Mixed farming areas	24.931	22.578	21.396
Wetland	26.306	22.868	18.130
Built up	11.917	20.896	29.090
Forest	16.865	15.313	14.362
Water body	2.585	3.409	4.350
Total	100.000	100.000	100.000
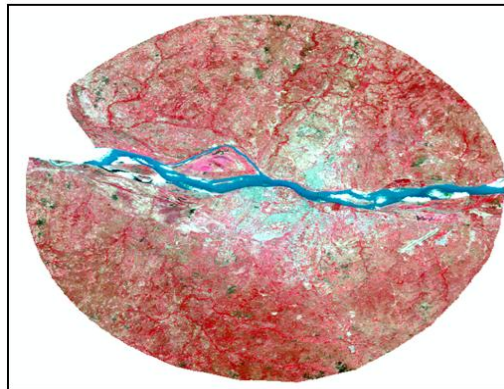
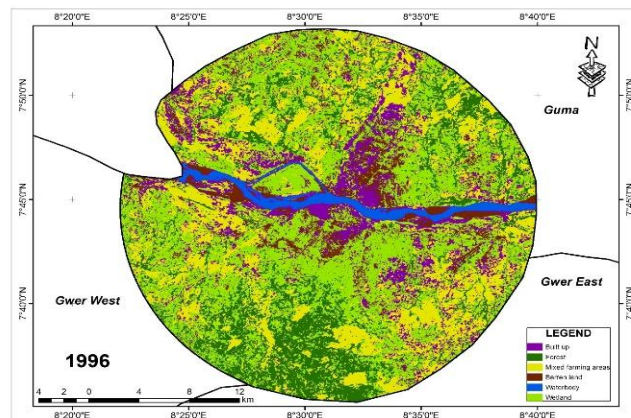**Fig. 2. False color composition of study area**

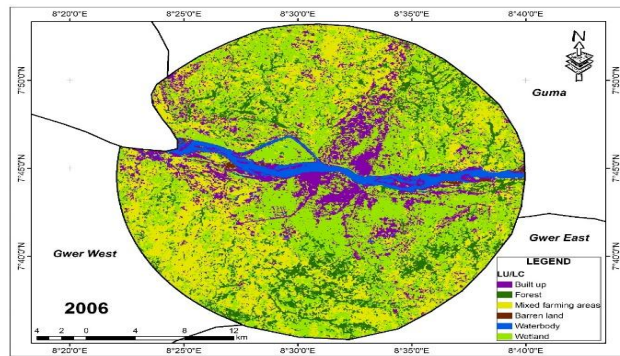**Fig. 3. Landuse composition of study area in 1996**

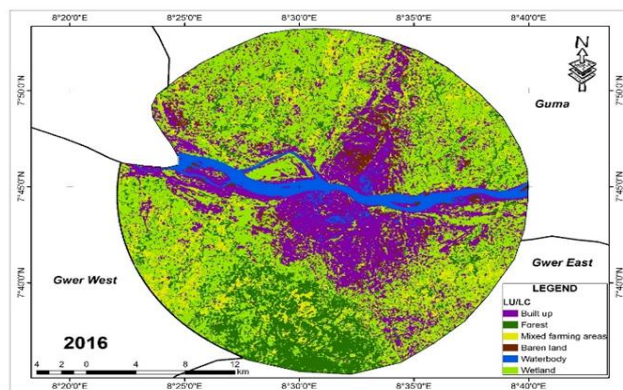**Fig. 4. Landuse composition of study area in 2006**

Fig. 5. Landuse composition of study area in 2016

3.2 Quantification of Wetland Loss

Wetlands within the study area experienced huge losses to mixed farming over the last 20 years. This is due to the fact that much of the Benue State Government's and the Federal Government of Nigeria's policies in the past 2 decades had focused on agricultural expansion as an economic strategy to diversify to dependence on non-oil sectors. Additionally, the study area is known for its vast agricultural production potential and is christened "Food Basket of Nigeria". Perhaps the positive gain is the conversion of wetlands into forest-like areas, especially in areas that are difficult to access for farming and habitation due to poor infrastructure within the region. Detailed wetland losses have been sequentially captured between 1996 and 2016 as presented in Figs. 7, 8, 9 and 10.

3.3 Land Consumption Rate (LCR) and Land Absorption Coefficient (LAC)

The LCR and LAC (Table 7) were recorded as high between 1996 and 2006, a period that

coincides with the return of Nigeria to democratic rule which saw a huge influx of elected politicians and their supporters into Makurdi, the Benue State capital and seat of Government. However, a decline in the LCR and LAC were recorded in the following decade (2006-2016) in spite of the rapid increase in population within the same period. This is perhaps a result of the economic recession which gradually commenced from 2009 up till second quarter of 2017.

3.4 Future Projection of Wetland Status by 2026

The analysis on Table 8 shows the annual changes between epochs (1996-2006 and 2006-2016) and over the 20-year period (1996-2016). Using the simple overall average annual rate of decline in wetland cover between 1996 and 2016, the projected status of wetland cover in the study area is projected to further decline by 33.15 km^2(or by 22.57%) by 2026 if appropriate measures are not instituted to control current rates of decline.
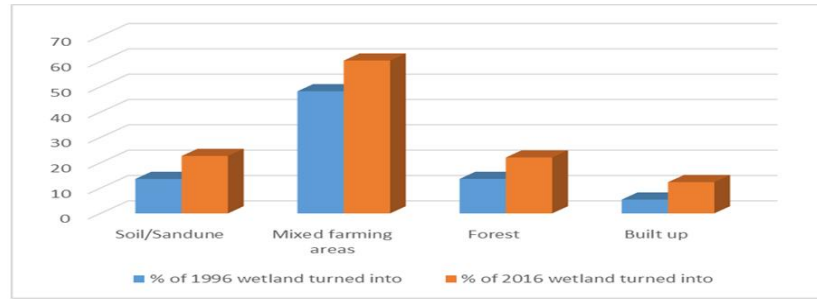
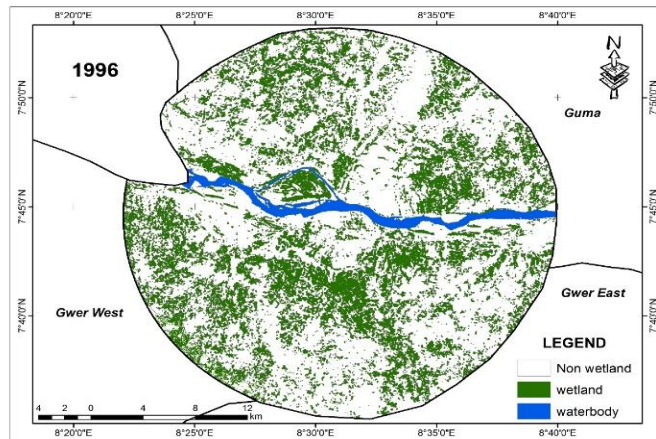**Fig. 6. Wetland loss to other land uses/cover**
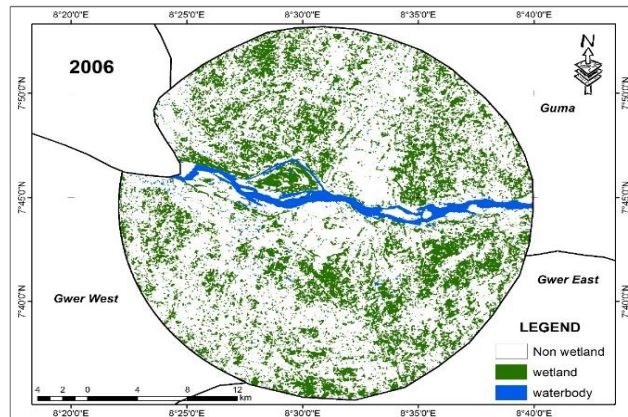

Fig. 7. Wetland cover in 1996

Fig. 8. Wetland cover in 2006

Table 7. LCR and LAC in study area (1996-2016)

Year	*Population	LCR	Study epoch	LAC	% Population increase
1996	275,872	0.2937	1996-2006	0.00281	7.80%
2006	297,398	0.0273	2006-2016	-0.00103	30.0%
2016	386,617	0.2095	-	-	-

* Projections using 3% population increase rate by NPC [21,16]
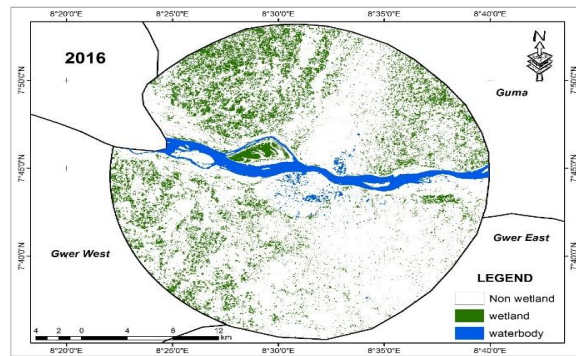
9

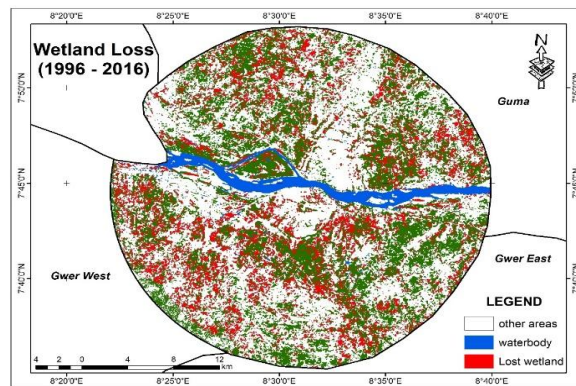**Fig. 9. Wetland cover in 2016**

Fig. 10. Wetland loss between 1996 and 2016

Table 8. Trend of change & projected wetland cover in study area by 2026

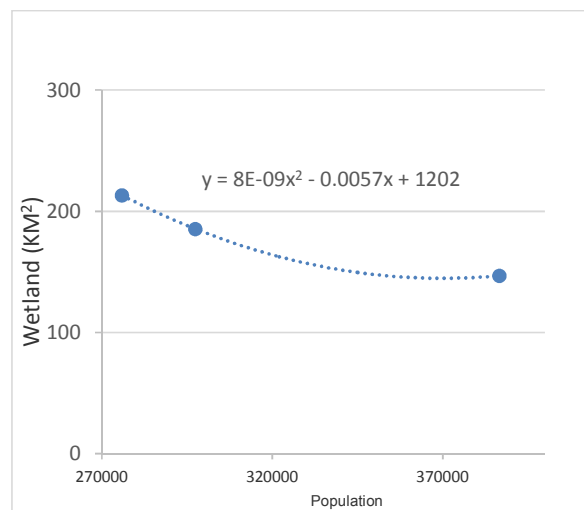| Year	Change		Average annual change
1996-2006	27.72 km^2	13.00%	2.772 km^2
2006-2016	38.59 km^2	20.81%	3.859 km^2
1996-2016	66.31 km^2	31.07%	3.315 km^2

Fig. 11. Wetland and population change

The population figures and wetland cover was used to plot a scattergram to indicate the changes in wetland that accompanied changes in population. A trendline was also inserted which was used to generate the projection function as shown in Fig. 11.

The projection function contained in Fig. 11 indicates a wetland cover (y) for any given population (x) within the study area.

4. CONCLUSION

This study is an attempt to monitor the wetlands within a specified spatial context using a time-series analysis technique of comparing remotely sensed images obtained from the Landsat platform. The link between human development and wetland recession can be measured through image classification, provided there is an availability of remote sensing data which is affordable for local level research studies. Although image quality is an essential factor in classification accuracy, moderate resolution imagery has proven to be appropriate for measuring wetland health. Considering that wetlands are so valuable to both human and wildlife, the need for a comprehensive and periodically updated wetland database for Makurdi is apparently a pre-condition for planning usage and conservation of wetlands. This is necessary as population expansion continues to exert pressure on limited but fragile and critical natural resources such as wetlands in Makurdi and elsewhere within Benue State [22].

The SDG 15 provides clear targets and indicators against which measurable progress can be tracked within space and over time. This study, and others such as Ujoh [23], is one of such efforts. However, the study was limited based on non-availability of high resolution images and respective software for deeper analyses and investigations. Based on the results and limitations of this study, it is suggested that further studies are carried out using images with relatively higher resolutions in order to compare results so as to establish a most suitable approach towards monitoring wetlands at the scale of Makurdi LGA. In addition to the remote sensing approach, a detailed study based on the red list index (RLI) should be contacted to assess the critical taxonomic groups (birds, mammals and amphibians) within the study area. The RLI is currently available for 4 taxonomic groups (birds, mammals, amphibians, and corals.) only. These are the groups which have had all species assessed, at least twice, and clearly demonstrates that the status of these major groups is still declining.

DISCLAIMER

This manuscript was presented in the conference "The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences" available link is " https://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XLII-2-W7/1075/2017/isprs-archives-XLII-2-W7-1075-2017.pdf"
Date:18–22 September 2017 , Wuhan, China, Volume XLII-2/W7, 2017 ISPRS Geospatial Week 2017. This submission is a revised version of the presentation made at above quoted conference.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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