Geospatial Analysis of Wetland Areas in Lokoja, Kogi State, Nigeria

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Abstract

This study measured the areal extent of wetland sites; analyzed the spatial pattern of the ecosystem between 1986 and 2007 and identified the factors that are responsible for the changes in the size of wetlands in the study area. Topographical map of the study area was used as a guide to locate the wetland areas. A set of remotely sensed data (Landsat TM 1986, Landsat ETM+ 2001, Landsat ETM + 2005 with 30m spatial resolution and SPOT-5, 2007 with 10m spatial resolution) were used to map and measure the areal extent and pattern of wetland areas. The images were enhanced, geo-referenced, re-sampled and classified using supervised classification method. Ten communities within the study area were randomly selected for the survey. Questionnaires were administered to the head of household residing around the wetland areas. Various human activities on and around the wetland areas were examined to be able to establish the factors that are responsible for the changing pattern of the ecosystem. The respondents were randomly selected using the table of random numbers. The data were analyzed using descriptive statistics. The result of image analysis shows that the areal extent of wetlands decreased from 4,487.28 hectares in 1986 to 1,937 hectares in 2007, representing the total loss 2,550.28 hectares. The result of the field survey corroborated the discovery of the image data and attributed the decline to the growth of settlement resulted from increase in human population. The results also identified other driving forces responsible for the changing pattern of wetlands, which include conversion of wetlands to residential and commercial land uses. In conclusion, periodic inventory of wetland areas is recommended owning to the unprecedented benefits of wetlands to social and natural environment.

Keywords
Wetlands; remotely sensed images; anthropogenic factors; Lokoja, Nigeria

Background

A wetland is land that is seasonally or permanently covered by shallow water, as well as land where the water table is close to or at the surface (Mitsch and Gosselink, 2007). In either case, the presence of abundant water has caused the formation of hydric soils and favoured the dominance of either hydrophytic or water tolerant plants. These unique areas represent a combination of terrestrial and aquatic characteristics, and are further categorized by type as marsh, swamp, fen and bog. The water found in wetlands can be saltwater, freshwater, or brackish. Wetlands are considered the most biologically diverse of all ecosystems. Plant life found in wetlands includes mangrove, water lilies, cattails, sedges, tamarack, black spruce, cypress, gum, and...
Animal life includes many different amphibians, reptiles, birds, and furbearers (Mitsch and Gosselink 2007; Mitsch, et al., 2009).

In spite of the benefits wetlands offer to waterfowl, wildlife and people, limited knowledge on the benefits of resources and their associated functions and values resulted into their reclamation in many countries, and the impact of their loss is being realized in different forms. Studies revealed that wetlands are among the world’s most threatened ecosystems, owing mainly to continued over-exploitation, urbanization, drainage, pollution, or other unsustainable uses of their resources (Tiner, 1989; Novitzki et al., 1993). Nigeria is richly endowed with both coastal and inland wetlands, which altogether cover about 3% of the country’s land surface. These wetlands resources are currently being threatened by various anthropogenic and bio-geophysical factors. Notable among which are population pressure, rapid rate of urbanization, mining, oil and industrial waste pollution, uncontrolled tilling of land for crop production, over-grazing, logging of wood, unprecedented land reclamation, construction of dams, transportation routes and other physical infrastructure, marine and coastal erosion, subsidence, ocean water intrusion, invasion by alien floral and faunal species, sand storm, desertification, and drought ((Uluocha and Okeke, 2004). The alarming rate at which Nigeria’s wetland is vanishing obviously portends some dire consequences. In particular, wetland destruction is affecting water supply and water resources management in various parts of the country, as noted by Mashi et al., (2008).

Finlayson and Spiers (1999) observed that the lack of baseline wetland inventory and limited accessibility to the available ones have been the major limitations for sustainable use and management of wetland resources. The need for a universal platform for up-to-date information on mapping, inventory and assessment of wetlands was first recognized by the Ramsar Wetland Convention of 1971; this is an international partnership who proposed to support the development of a multiple-scale global initiative to promote the ‘wise use’ and ‘sustainable management’ of wetland ecosystem at global, regional and national level (Rebelo et al., 2007).

The waves of concern on the sustainable use of the ecosystem have translated into a number of researches. In the last few decades wetlands have come under intensive scientific study owning to the knowledge and appreciation of its benefits. For instance, studies on the value of wetlands revealed that wetlands provide food, water, and shelter for fish, shellfish, birds, and mammals, and they serve as a breeding ground and nursery for numerous species (Barbier, et al., 1997; Bardecki 1998; Kreutzwiser, 1981; Raphael and Jaworski, 1979). According to Ramsar convention in Iran (1971), Scientific evidence suggests that wetland ecosystems (inland/coastal) are essential for human survival, and play a crucial role in managing natural calamities such as hurricanes, floods, cyclones, among others, along with providing community needs. Some researchers based their researches on the inventories of wetland ecosystem. For instance, Orimoogunje, (2009) examined the causes of wetlands degradation and assessed the ecological and socio-economic effects of wetland within Ilesa between 1986 and 2008. Taylor (1995) opines that resource inventories of wetland areas provide indication of location, biological productivity, potential multiple uses and biodiversity profiles of wetland ecosystems. Finlayson et al (2001) designed a wetland monitoring program including methodology and data reporting steps of wetland. Marshi et al (2008), designed techniques for mapping areas favorable for fadama farming in Gwagwalada.

In spite of much research works on wetlands, more studies are still needed especially on the changing pattern of wetland areas for better management of the ecosystem. Besides, features or activities on wetland areas are dynamic and varies from urban wetland area to the other, which has not been focus of the existing studies. Moreover, the areal extent of wetland areas at both local and national levels including the study area is not known with any accuracy. There is therefore, need to examine the areal extent of the ecosystem since literature is sparse on this issue. The various anthropogenic activities on and around wetlands needed to be explored for sustainable management of wetland ecosystem.

To further the frontier of knowledge on the state of wetlands, this present study therefore, measured the areal extent of wetland sites; assessed and analyzed the pattern of the ecosystem between 1986 and 2007.
and finally examined the factors that are responsible for the pattern.

THE STUDY AREA
Rationale for the choice of study area

The study area (Lokoja) is a confluence town and is contiguous to a lot of water bodies and wetland areas. As a result of rapid population growth in recent times, many anthropogenic activities that are capable of degrading or removing the wetland areas are springing up. Presently, there is no adequate support, management and monitoring of wetland areas, which led to frequent conversion to residential and industrial development. It is in this context, an inventory of the wetlands is essential. Besides, the availability of remotely sensed data gave an impetus for the choice of the area.

Physical setting

It is located between Latitude 7°45’27.56″ and 7°51’04.34’’ N and Longitude 6°41’55.64″ and 6°45’36.58″ E, within the lower Niger trough. It has an estimated landmass of 63.82 sq. km. It shares common boundaries with Niger, Kwara, Nassarawa and the Federal Capital Territory to the north. To the East, it is bounded by Benue State, to the south by Adavi and Okehi LGAs respectively and to the west by Kabba LGA (Figures 1 and 2). Annual Rainfall is between 1016mm and 1524mm with its mean annual temperature not below 27°C. The rainy season lasts from April to October. The dry season, which lasts from November to March, is very dusty of cold as a result of the northeasterly winds, which brings in the harmattan. The land rises from about 300 metres along the Niger-Benue confluence, to the heights of between 300 and 600 metres above sea level in the uplands. Lokoja is drained by the Niger and Benue rivers and their tributaries. The confluence of the Niger and Benue rivers which could be viewed from the top of Mount Patti is located within the study area. The River Benue is navigable as far as Garua in the rainy season floods, but up to Makurdi in Benue State in the dry season (Ogunjumo, 2000). The general relief is undulating and characterized by high hills. The flood plains of the Niger and Benue river valleys in Lokoja have the hydromorphic soils which contain a mixture of coarse alluvial and colluvial deposits. The alluvial soils along the valleys of the rivers are sandy, while the adjoining laterite soils are deeply weathered and grey or reddish in colour, sticky and permeable. The alluvial soils found along the Niger and Benue rivers show light accumulations of organic matter but are often, under traditional management practices, too wet during the rainy season for crops other than rice. The main vegetation type in Lokoja is Guinea savannah or parkland savannah belt with tall grasses and some trees. These are green in the rainy season with fresh leaves and tall grasses, but the land is open during the dry season, showing charred trees and the remains of burnt grasses.
Population and Occupation

Lokoja has a population of about 77,516 in 1991 which has increased to 195,261 in 2006, with 100,573 males and 94,688 female (National Population Commission, 2006). Agriculture serves as the main occupation of the people. Majority works in the public institutions like the Kogi State Polytechnic, Specialist Hospital and other governmental offices. Wetland areas have great advantages for farmers because they provide opportunities for planting different crops such as, rice, sugar cane, corn, vegetables, among others throughout the year. The major means of transportation is by road, sometimes by water using boat to areas which are not motorable.

Materials and Methods

Materials

The study utilized topographical map of the study area, which was derived from sheet number 247 of 1963, scale 1:50,000, obtained from Federal Survey Office, Lagos to identify wetland areas. The remotely sensed images were also used to map and assess the pattern and changing pattern of the wetlands. These were Landsat TM 1986, Landsat ETM+ 2001, and 2005 and SPOT 5, 2007 (Plates 1, 2, 3 and 4). The attributes of the imageries are shown in Table 1. To explain the factors that are responsible for the changing pattern of wetlands, questionnaire was designed and administered on the people living around the wetland sites.

Methods

In the study, a common window covering the same geographical coordinates of the study area was extracted by specify the numbers of rows and columns of the study area from the scene of the image data. The sub map operation of ILWIS was afterwards applied to generate only the study area. These images were enhanced into natural colour composite. In Landsat TM 1986 and Landsat ETM+ 2001 and 2005 respectively, channel 7 was assigned to red plane, channel 4 to green plane, and channel 2 to blue plane. This gives Red, Green, Blue, bands (RGB-742), which produced natural colour composite. For SPOT 5, 2007, channel 1 was assigned red plane, channel 2 to green and channel 3 to blue plane. The band combination then consisted of Red, Green and Blue, (RGB-123) natural colour composite. In natural colour composite, vegetation is depicted as green, water in shades of blue and bare soil in shades of brown and gray. Re-sampling was carried out to equalize the spatial resolution of the datasets that possess varying spatial resolution. The procedure involved automatically adjusting one or more raster datasets to ensure that the spatial resolution of all datasets corresponds, to enable accurate spatial operations. The Landsat images have a spatial resolution of 30m while SPOT 5 image was 10m. Based on these differences, the SPOT image was re-sampled to the nearest neighbour.

Figure 2: Map and satellite image showing the study area
GIS data files must have a real-world coordinate system if they are to be valid coverage. To make the image data valid to real world, they were georeferenced to the same coordinate system using the topographical map of the area. The process of georeferencing in this study started with the identification of features on the image data, which can be clearly recognized on the topographical map and whose geographical locations were clearly defined. The intersections of streams and of the highways were used as ground control points (GCPs). The latitude and longitude of the GCPs of visible features obtained in the base map were used to register the coordinates of the image data. Using these ground-control points, the computer produced a number of equations that transformed the location of all the pixels on the distorted image to a properly orientated image. This is the reason for georeferencing. All the images were georeferenced to Universal Transverse Mercator projection of WGS84 coordinate system, zone 31N with Clarke 1880 Spheriod.

In this study, the satellite images were classified using supervised classification method. The combined process of visual image interpretation of tones/colours, patterns, shape, size, and texture of the imageries and digital image processing were used to identify homogeneous groups of pixels, which represent various land use classes of interest. This process is commonly referred to as training sites because the spectral characteristics of those known areas are used to train the classification algorithm for eventual land use/cover mapping of the remainder of the images. To validate the tonal values recorded on the satellite images with the features obtained on the ground and also to know what type of land use/cover is actually present, the study engaged in ground truthing. Before the ground truthing, map of the study area was printed and was used as guide to locate and identify features both on ground and on the image data. The geographical locations of the identified features on the ground were clearly defined. These were used as training samples for supervised classification of the remotely sensed images. Six land uses/land covers were clearly identified during ground truthing and these were classified as wetlands, vegetation, bare soils, water body, bare rocks and built-up areas. Since the pre-occupation of the study is to assess the current status of wetland in the study area, only the land cover was segmented, polygonized and analyzed.

The designed questionnaires were administered on people residing around the wetland areas to enable the study determine the human activities affecting the ecosystem. Besides, the socio-economic characteristics of respondents and environmental implications of wetland depletion were investigated in the survey. One hundred copies of questionnaire were purposively administered on the people living around the area. This number was believed to be representative as wetland locations are not many. Descriptive statistics was used to analyze the results.

Table 1: Characteristics of datasets for the study

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<th>S/no</th>
<th>TYPE</th>
<th>FORMAT</th>
<th>PATH/ROW</th>
<th>NAME/ SHEET NUMBER</th>
<th>SPECTRAL BANDS</th>
<th>SCALE/ RESOLUTION</th>
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<td>Digital</td>
<td>189/55</td>
<td>3 (RGB)</td>
<td>10m</td>
<td>2007, Private Individual</td>
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Results and Discussion
Area Extent of Wetlands

Wetlands in the study area reveal evidence of reduction as shown in Table 2. In 1986, wetlands occupied 4487.28 hectares, which decreased to 3894.09 hectares, giving a decrease of 593.18 hectares over the period of 15 years. This implies that 39.55 hectares of wetland sites were being removed yearly. The rate of decrease continued between 2001 and 2005 when 329.55 hectares of wetland sites were removed. This shows that 8.46% of wetlands were removed between that time frame that is, 2001 to 2005. Between 2005 and 2007, about 162 hectares of wetland sites were removed. It is therefore, obvious from Table 2 that over the period of 21 years (1986–2007), 2,549.78 hectares of the ecosystems have been removed.

The results of the field survey corroborate the findings of the image data. The respondents whose compositions were males (83%) and females (17%) declared that wetlands in the study area were reducing in size. While 60.6% affirmed that the wetlands are decreasing 39.4% were not sure, as their response was neither yes nor no. Among the respondents, 47.9% attributed the decrease in size of wetlands to urban expansion, resulting from increase in human population while10.6% traced the disappearance to the conversion of the ecosystem to dump sites. However, 38.3% were of the opinion that yearly fadama cropping especially during the dry season was responsible for the decrease in size of the wetlands.
It is instructive to note that the study area became the capital city of Kogi State in 1991, which led to the influx of people and consequently the expansion of the settlement. Places that were used for urban agriculture were converted to residential area. The wetland areas that were zone of flora and fauna ecosystems were subsequently converted to fadama cropping, mechanic workshops and commercial centres.

Plates 5, 6, 7, 8 and 9 show various human activities on wetland sites as captured during the field survey. Some of these activities have tendencies of degrading and depleting the ecosystem. For instance, Plate 5 is a wetland site within Lokoja converted to a dump site, with a complete loss of flora and fauna species in the ecosystem. Plate 6 reveals a portion of wetland area in which road passes through, which has now attracted people for building of houses. This implies that a land use on wetland can trigger other land uses, which can consequently undermine the ecosystem. Plates 7 and 8 are wetland locations at Sarkin Noma and Owara respectively both in the study area already converted for cropping. Plate 9 depicts a motorcyclist washing the motorcycle by a wetland and water vendors around the wetland in Lokoja.

<table>
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<th>YEARS</th>
<th>Wetland Area (m²)</th>
<th>Areas (hectares)</th>
<th>Change Per Interval Year</th>
<th>% change per Interval year</th>
<th>Change per Year</th>
<th>% Change per Year year</th>
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<td>-0.23</td>
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</table>

Source: Fieldwork, 2010
Spatial pattern of Wetland Areas

Figures 3, 4, 5 and 6 depict the spatial patterns of wetlands in the study area between 1986 and 2007. In 1986, wetlands were found all over the area except in southwestern part of the area. However, the ecosystem was more concentrated in Okomoba and Sarkin Noma area, both found west of river Niger and Kpatakpoti and Nyamkpo, south of river Benue (Figure 3). The ecosystem shows evidence of reduction in 2001 as some wetland sites reduced in size and in areas. Examples were found in Okomoba, Sarkin Noma, Gbargada, among others where they were mostly found in 1986 (Figure 4). The trend continued in 2005 and by 2007, the ecosystem had drastically reduced in the area. (Figures 5 and 6). This continuous decrease could have serious implication on man and biodiversity and there is a need for careful use of the ecosystem.

The findings of this present study substantiate the claim of United States Environmental Protection Agency (1997) that the Federal Aid Highway Program (FAHP) brought substantial loss to wetlands. The agency analyzed readily available data on the extent of Federal Aid road construction and wetland loss over the life of the program with certain assumptions to derive a rough national estimate of the potential magnitude of wetland loss resulting from the FAHP. It also used the results of the few empirical studies identified in the literature to calculate rough estimates of FAHP related wetland losses for specific regions which are used to augment and provide perspective for the evaluation of the national estimates. It was attested that the federal aid road construction induced a loss of high magnitude to wetlands nationally.

Other scientific studies revealed that wetlands were being threatened, owing mainly to continued drainage, urbanization, pollution, over-exploitation or other unsustainable uses of their resources (Kusler, and Montanari, 1978; Kusler, and Riexinger, 1986; National Audubon Society; 1993; Scodari, 1994). Report also shows that in Canada, up to 70 per cent of the wetlands have been lost in settled areas, and more are lost every day. Finlayson and Spiers, (1999) however, recommended the use of multi-scalar temporal earth observation data sets to monitor the status of change/loss in wetlands. Collaborative projects for monitoring change in wetland use were initiated for the coastal wetland in Sri Lanka and the inland wetland in India. These were based on the application of the LCM (Land change modeler) module in IDRISI-Andes and included a focus on capacity building and regional knowledge exchange. Presently, there is no adequate support, management and monitoring of wetland areas in Nigeria, which led to frequent conversion of the ecosystem for residential and industrial development; an inventory of wetlands is therefore essential.

Conclusion

It is evident in the study that wetland resources are being threatened mostly by human activities such as urban farming, construction of roads and buildings, landfill resulting from dump site, among others. The protection of the ecosystem by urban planners and policy makers is necessary. The results of questionnaire survey corroborated image data findings as 60.6% of the respondents supported the fact that wetlands in the study area were reducing in size. The decrease was attributed to the influx of people into the area, which put more pressure on the limited resources including the wetlands. The implication is that if nothing is done to protect this ecosystem, there may be an increase in urban disasters such as flooding, which wetlands can mitigate. The study therefore, recommends restricting access to the large portion of wetland areas, as well as educating the public on the misconception that wetlands are wastelands. Besides, there should be periodic inventory of wetland sites so as to monitor changes that take place on them and more research should be geared towards wetland study to know the state of wetlands at any point in time.
References


