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Application of Remote Sensing and GIS Techniques in Mapping Areas Favourable For Fadama Farming in Gwagwalada, Abuja, Nigeria

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ABSTRACT

Because of the important and scarcity of fadama land as well as needs for sustainable development, mapping of areas favourable for fadama farming is likely to be reliable step towards effective fadama farming and rural development in Gwagwalada area. In this study Remote Sensing and GIS techniques were utilized to map out areas that can be favourable for fadama farming. Four steps were followed in mapping areas that are favourable for fadama farming (i) the vector maps were first scanned into Microsoft word software from where it was transferred into the ILWIS GIS software and were digitized on-screen to generate digital contour lines of the area. The digitized contours were then interpolated in the ILWIS GIS software to generate the DTM of the study area, (ii) areas of different elevations that were identifiable on the created DTM were digitized to produce a segment map showing areas of different elevation characteristics, (iii) three bands (band 1 Red, band 2 Green, and band 3 Infrared) data of the Landsat TM image of the area was transformed into a true colour composite image which was digitally classified using ILWIS 3.2 GIS software, (iv) the segment map produced showing area favourable for fadama farming was overlaid on the DTM, Unclassified and Classified Landsat TM image in order to show areas that are favourable to fadama farming. The results obtained shows that, (i) areas lying below 181m above sea level along the banks of River Usuma and other rivers are considered favourable for fadama farming, (ii) the result shows that areas favourable to fadama farming decreases towards the northern part. The potential fadama land in the study area covers 21.8% of the entire study. This study demonstrated that validated remote Sensing and GIS techniques are efficient and adequate tools for mapping areas favourable for fadama farming.

Key words: Fadama, Irrigation, Remote Sensing, GIS, ILWIS 3.2 Academic, Digital Terrain Model (DTM), Gwagwalada, Favourable.

Introduction

Inappropriate land uses and land management practices contribute to land quality problems such as increase rates of wind and water erosion, accelerate rates of soil acidification, nutrient decline, and carbon losses (Smaling *et al.,* 1997; UNEP, 1999; FAO, 2000; Bridges *et al.,* 2001). The population of the Country is now quoted at 127 million people. The irrigated landscape remains very dynamic. There remain considerable uncertainty about the exact extent, area and cropping intensity of irrigation in different parts of the world, due to the dynamics and systematic problems of under reporting and over reporting of irrigation in different contexts and country (FAO, 2000; World Bank, 2003).

In the past in Nigeria, no serious attention was paid to environmental resources considerations in planning and implementation of developmental projects, resulting in environmental damage. Hydrology downstream from dams and major diversions and pumping stations has been modified, especially in the northern part of Nigeria. Extensive areas of fadama, fisheries and wildlife habitats were wiped out (IFAD, 2001).

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According to FAO (2000) Nigeria is among those nations that are at the moment technically unable to meet their food needs from rain fed production at a low level of inputs and appear likely to remain so even at intermediate levels of inputs at some point in time between 2000 and 2025. In Nigeria farming systems are still mainly smallholder-based and agricultural landholdings are scattered and simple, low-input technology is employed, resulting in low-output labour productivity. Generally in the country farmers farm sizes range from 0.5 ha in the densely populated high-rainfall south to 4 ha in the dry northern part of the country (FAO, 2000; IFAD, 2001).

The low-lying areas which are usually flooded during the wet season, popularly known as fadama areas, are scattered across the ecological zones of Guinea Savanna, Sudan Savanna, and the Sahel and the area vary from 1.5 to million ha out of the 33 million ha of land put into cultivation (FAO 1997 and IFAD, 2001). The fadama/wetlands have been used for dry season farming in Nigeria and it has contributed greatly to food crop production in the country more pronounce in the semi arid and arid regions of the country (FAO, 2000; Enplan Group, 2004). Over the years many farmers in the study area cultivates small areas in fadamas during the dry season, using water directly obtained from streams and rivers manually or using electrical power generators to pump water into their lands.

There are actually fadama areas in the FCT, but they have been observed not to be common or not developed, just as in other part of the Niger-Benue trough of the middle belt of the country (Balogun, 2001). The major fadama areas are located along the flood plains of the major rivers that drain the FCT. Fadama farming in the FCT has traditionally depended on rainfall in the wet season as well as residual moisture after flood recession during the dry season. The wet season recession crops are mostly rice and maize. Dry season farming is gaining popularity within the FCT among indigenes and non indigenes mostly especially among the Hausa migrants. Over the years in the FCT farmers are encouraged to engage in fadama farming by FCT Agricultural Development Programme (ADP) with strong financial push coming from World Bank (Balogun, 2001).

Arable fadama land mapping and management practices will be major approaches for improving the management of land resources for Fadama farming. In this era, a key developmental agenda for many developing countries is the development of their agricultural base through irrigation.

Data on fadama potential areas in Gwagwalada and environs is not readily available, as neither statistics nor maps of areas are available. In order to propose any short and long term measures to enhance fadama farming in Gwagwalada and immediate environment, it is essential to have reliable maps showing areas favourable for fadama farming. Such maps will also be a prerequisite for land development strategy and action plan towards fadama farming development and agricultural crop production at large. Researches are therefore needed that demonstrates how Remote Sensing and GIS techniques can be useful in mapping areas that are favourable for fadama farming and the need for such studies constitutes the main aim of this study. Thus, implementing a GIS analysis will be part of a larger, long term effort to gain a better understanding of floodplains favourable to fadama farming.

Remote Sensing technology produces an authentic source of information for surveying, identifying, classifying, mapping, monitoring, and planning of natural resources and disasters mitigation, preparedness and management as a whole (Ibrahim *et al.,* 2007 and Graham, 2007). Multiband, multidate and multistage satellite imaging has been extensively used in Asian countries and the developed countries of the world for water resources studies, monitoring and management of agricultural lands (Pramanik *et al.,* 1992; Panagopoulos, 2001).

Geographic Information System (GIS) can integrate Remote Sensing and different data sets to create a broad overview of how potential fadama area is. This approach to fadama farming planning enables communities and concern agencies to potent and increases their productivity. One of the potential approaches of doing this involves the use of Remotely Sensed and Digital Terrain Model (DTM) to map out areas that are favourable for fadama farming. A DTM is a quantitative representation of the topography of the Earth (or sometimes other surfaces) in a digital format (Andreas and Manos, 2002; Ibrahim *et al.,* 2007). The DTM is also a valuable component in analyses involving various terrain characteristics such as profile, cross-section, line of sight, aspect and slope. DTM also encourages, flood mapping, Urban planning, agricultural planning etc. (Natale *et al.,* 2007). While the Remotely sensed image of an area give a true representation of an area based on land use.

Study Area

Gwagwalada town is located about 40 Kilometers away from the Federal Capital City of Abuja and it is centrally located within the Federal Capital City (FCT) and it falls between latitude $8^0 55'$ N and $9^0 00'$N and longitude $7^0 00'$ and $7^0 05'$ (Figure 3.1). The study area has a total landmass of about 6,500 hectares ($65km^2$)

and with the rapid rate of urbanization, developmental processes are now taking places even outside where was earlier considered as the Gwagwalada boundary (Balogun, 2001).

The climate of the study area just like most climate in the tropics have a numbers of climatic elements in common, most especially the wet and dry season's characteristics. Mean temperature in the area ranges from 30^0C - 37.0^0C yearly with the highest temperature in the month of March and mean total annual rainfall of approximately 1,650mm per annum (Balogun, 2001). Rainfall play a vital role with respect to agricultural activities within the study area and most farming activities highly depend on rainfall (Balogun, 2001). About 60% of the annual rains fall during the months of July to September. The study area is drained by River Usuma which is an important tributary of River Gurara and is the largest and major river within the study area. (Balogun, 2001). The town has a population of 23,114 in the year 2000 people and is one of the largest satellite town and the third largest urban centre in the FCT (Balogun, 2001).

The soils in the study area show a high level of variability comprising mainly of sand, silt, clay, and gravel. Alluvial soils are commonly found in the valleys of the various rivers but highly concentrated at the valley of River Usuma, these soils cover very small part of the study area and the water table around the places where this type of soils dominates is usually very high. It has well decomposed organic matter content in the surface layer, and its texture become heavier with depth, as the weathered parent material is approached. The alluvial soil support to a grate extent irrigation/fadama farming due to its various natures (FCDA, 1980; Balogun, 2001). The soils outside the river bank are luvisols. These soils are products of down-wash from the hills and are generally the local soils. (FCDA, 1980; Balogun, 2001).

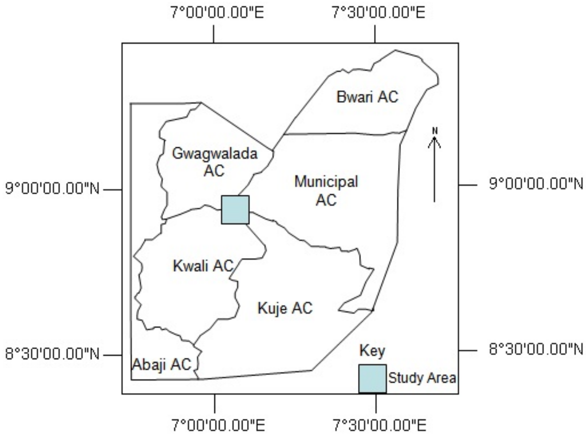


Fig. 1: Map of Abuja Showing the study Area.

The soils that border the alluvial valley bottom most especially of the River Usuma have tick cover of sand-wash materials. The characteristics of the soil shows that they all have palest colours and the textural character of the soil takes common pattern of loamy sand top soil and sand clay B horizon. Due to the nature of the soils they are either loose or they have weak structures. Theses soils are very vulnerable to erosion due to their nature and farming is usually affected by the by this phenomenon (FCDA, 1980; Balogun, 2001).

In Gwagwalada town fadama land along the river Usuma and its tributaries have being contributing greatly to crops production. Large area of the fadama land has been affected due to construction of the lower Usuma Dam and other forms of human activities upstream. It is feared that development projects could divert still more water from source river and stream.

Materials and Methods

Materials Used

The materials, used in this study include the following:

(a) Four large scale maps covering the study area at a scale of 1:10,000 were obtained from Federal Capital Development Authority (FCDA). The topographic maps used include Kuje Sheet 207 NW 1b, Kuje Sheet 207 NW 1c, Kuje Sheet 207NW 1e and Kuje Sheet 207NW 1f. The contours interval on these topographic maps was 2.5m. The topographic sheets' ground coverage is 7000m by 4600m approximately. Grid intervals for these topographic maps are 500m and the sheet sizes are 3'45" N and 2'30'' E.

(b) Landsat TM 2001 image of the study area, which has 30m resolution, was used. The bands used for this study include Band 1 Red (p189r54_4t971221_nn1), Band 2 Green (p189r54_4t971221_nn2) and Band 3 Infrared (p189r54_4t971221_nn3). The image was obtained from NEMA (National Emergency Management Agency) Head office in Abuja.

Software and Hardware Used

The equipments, software and hardware used in this study include the following:

(a) ILWIS 3.2 Academic GIS software was used to import raster maps via GeoGateway, to export segment maps, to digitize raster maps, to create new representation, editing of point, segment, polygon and raster maps, insert coordinate systems of maps, and output possibilities with annotation to glue segments maps, convert raster maps to segment, and finally to create DTM. ILWIS 3.2 Academic Software was also used for the classification of the Landsat TM imagery.

(c) Verification of the manipulated data was carried out through conducting ground truth exercise using handheld GARMIN III GPS which constitute a primary source of data.

(d) Complete GIS hardware used includes Personal Zinox Computer Model No.S96H, HP Deskjet 3740 and HP Deskjet Colour Printer and flat-bed Scanner (20/30).

Methods

Producing DTM: In creating DTM for the study, analytical procedures of ILWIS 3.2 Academic were employed. The four topographic maps were digitized on screen. This process of screen digitizing involves creating and/or editing a segment or point map while an existing raster map is displayed as a background in a map window. The procedures employed in digitizing the topography maps are thus:

b. New segment map was created from the create command of the File menu in ILWIS 3.2 Academic.

a. Computer mouse was used to add points to a point map and add segments to a segment map. It was also used to delete points or segments; rename points or segments, and move points or move intermediate points within a segment.

c. With the computer mouse, segments were added to a segment map, delete segments, rename segments, and move intermediate points within a segment.

d. The digitized contours from value domain were interpolated to obtained rasterized surface of the topography. Subsequently, the DTM of the entire area was produced by interpolating the four glued digitized contour maps that were produced through digitizing in the value domain.

Producing Colour Composite Image

Colour composite was created by combining 3 raster images (band 1 Red, band 2 Green, and band 3 infrared). In this study the dynamic method of producing colour composites was used. A dynamic colour composite is usually calculated using the Heckbert Quantization Algorithm. The Heckbert algorithm produces a colour composite on the basis of the amount of variation in pixel values in the three input maps. This algorithm first built a three dimensional histogram, indicating how 'popular' any given value is in the image. The algorithm creates boxes which have approximately equal popularity in the image. Then, colours were assigned to represent each box for proper representation. Using dynamic colour composite the following steps were perform in the ILWIS 3.2 Academic GIS software.

Supervised classification system was used to classify the image. (i) Box classifier was employed to group the various pixels in the dataset into different classes. (ii) Training data generated during the reconnaissance survey was used in training the classifier. (iii) A supervised classification foremost depends on the spectral values of the pixels selected to serve as training pixels from an imagery sample data. (iv) Relevant information on the classes for which training pixels were selected in the sample set were viewed and stored in the Sample Statistics.

Summary of Steps Taken in Mapping of Areas Favourable for Fadama Farming

Four steps were followed in mapping areas that are favourable for fadama farming are:

i. Production of DTM

The digitised contours were interpolated in the ILWIS 3.2 Academic software to generate the DTM of the study area.

ii. Digitising of the DTM Image to Generate Segment a Map

Areas of different elevations that were identifiable on the created DTM were digitised to produce a new segment map showing areas of different elevation characteristics.

iii. Production of Composite Landsat TM Image

The three bands (band 1 Red, band 2 Green, and band 3 Infrared) data of the Landsat TM image of the area was transformed into a true colour composite.

iv. Classification of the Composite Image

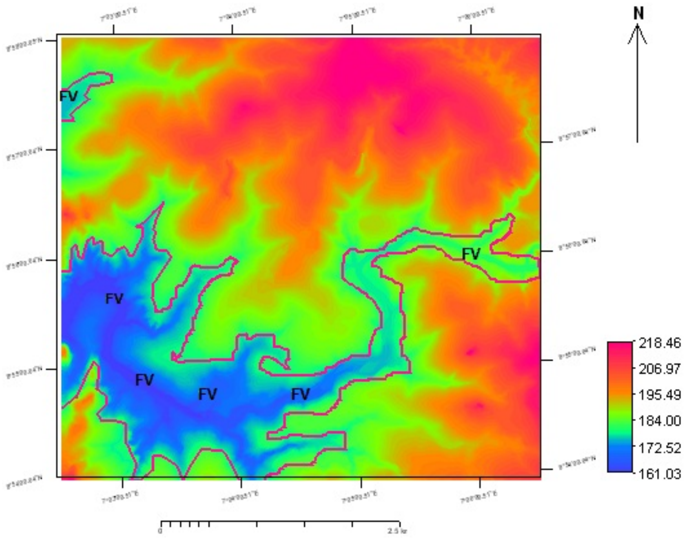
The produced composite image was digitally classified using a supervised classification module of the ILWIS GIS. Training dataset was generated from the sites selected on the image and subsequently surveyed on the ground during the ground truth exercise.

v. Overlaying of the Segment Map on the DTM, Unclassified and Classified Landsat TM.

The segment map produced in (ii) was overlaid on the DTM, classified and unclassified Landsat Images of the area in order to generate new maps that show areas favourable for fadama farming.

Results and discussion

The DTM, Classified and Unclassified Landsat image of the study area shows area favourable for fadama farming (See Figure 2, 3 and 4). Alluvial soils are highly concentrated at the valley of River Usuma in the study area, these soils cover reasonable part of the study area, the water holding capacity is very high and the water table around the places where this type of soils is prominent is usually very high too with well decomposed organic matter content in the surface layer and its texture become heavier with depth, as the weathered parent material the alluvial soil support to a grate extent irrigation/fadama farming (Balogun, 2001).

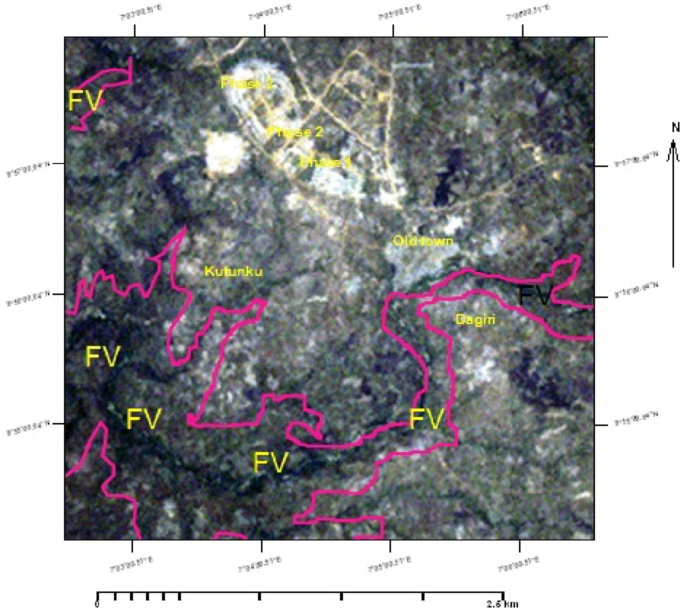


FV = Favourable for Fadama Farming

Fig. 2: DTM Showing Areas Favourable for fadama Farming.

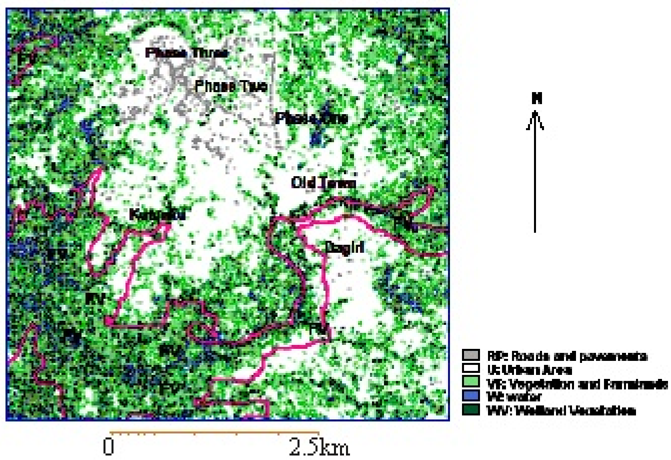
According to (Meridian Energy, 2007) water level changes with discharge point of the shallow aquifers are expected to be less than what is further away from opposite points as water level discharge will be decapitated through charges in discharge rates from the river or spring. Wet land is expected in the lowest lying areas in the surrounding close the river or spring (Meridian Energy, 2007). Areas that have such characteristic on the DTM, classified and unclassified Landsat Image (See Fig. 2, Fig. 3and Fig. 4) falls between elevations less than 181m above sea level and are mapped FV (favourable for fadama farming).
The floodplain of Usuma River within the town, where the river divides the old town from Dagiri is highly dominated by urban structures thereby making it impossible for fadama farming (though mapped favourable for fadama farming). At the fringe of the study area, urban development is less making the area favourable for fadama farming.

Potential fadama land in the study area covers 21.8% of the entire area (area that fall below 181m above sea level). The area considered favourable for fadama farming is dominated by wetland vegetation, normal vegetation and farmlands rather than urban structures except in around the Old town and Dagiri. Areas considered not favourable for fadama farming are highly dominated by urban structures, vegetation and upland farmlands within Gwagwalada town (See Fig. 4).



FV = Favourable for Fadama Farming.

Fig. 3: Teue Colour Composite Showing Areas Favourable for Fadama Farming



FV = Favourable for Fadama Farming.

Fig. 4: Classified Landsat Image Showing Areas Favourable For Fadama Farming.

The table below (Table 1) shows the result of pixels sizes of the various land cover in the study area. Roads and pavement covers 928 pixels (1.39%) also 753768 m^2 of the study area, built-up area cover 29413 pixels (44.04%) also 23890709.3 m^2 of the study area, vegetation and farmlands covers 27614 pixels (41.35%) also 22429471.5 m^2 of the study area, water 3761 pixels (5.63%) also 3054872.3 m^2 of the study area and wetland vegetation covers 5064 pixels (7.58%) also 4113234.0 of the entire study. Built-up has the largest coverage of the study area with (44.104%) of the study area.

The classified Landsat image shows that most of vegetation and farmlands as well as wetland vegetations and water are highly concentrated in the area mapped as favourable for fadama farming. This clearly indicates that this area can be fully put into fadama farming because it is highly void of urban structures and settlement.

In general note, apart from the floodplain of Usuma River where the river separate the old town from Dagiri were the whole potential fadama farming area is dominated by urban structures, there is less urban development in the areas mapped favourable for fadama farming and this can also be a contributing factor to a large extent to wetlands and soil nature.

Table 1: Showing Data of the Pixels Sizes of the Landcover of the Study Area.

Land Cover	Number of pixels	% of pixels	Area (m^2)
Roads and Pavement	928	1.39 %	753768.0
Built-Up area	29413	44.04%	23890709.3
Vegetation & Farmlands	27614	41.35%	22429471.5
Water	3761	5.63 %	3054872.3
Wetland Vegetation	5064	7.58%	4113234.0
Total	66780	100 %	54242055.1

Source: Classified Landsat Image, October, 2007.

According (Richard, 2006) Fadama lands have great potentials in crop production and of significant importance. Many experts believed that developing fadama lands for crop production is capable enhancing food production in Nigeria (FAO, 2000; Enplan Group). The incidence of poverty in FCT which is widespread and has been a complex challenge can be addressed by exploiting fadama land and fadama projects initiatives to provide a framework for addressing both poverty reduction and the sustainable management of fadama ecosystems, which are vulnerable to bad farming practices and unplanned urban development.

The major potential crops include Rice (*Oryza Sativa*), Maize (*Zea Mays*), Okro (*Hibiscus Esculentus*), Pepper (*Capsicum Annum*), Water Leaf (*Talium Triangulare*), Pumpkin (*Cucurbita Pepo*), Sugar Cane (*Saccharum Officinarum*), Greens (*Amaranthus Spp*), Spinach (*Spinacia Oleracea*), other vegetables such Tomatoes and Ayoyo (Ewedu).

Gwagwalada town has recorded significant increase in built-up area over the years mostly in the fringe of the town mainly due to population growth covering over 44.04% of the total study area (fig. 4 and table 1). The implication of this is that with increase in built up area towards the fadama lands which are concentrated at the fringe of the town will gradually be lost to urban development leading to lost of fadama land which has great tendencies towards increasing the rate of poverty likely among the local people who depend greatly on crop production and onto fadama farming as a medium of improving their livelihood.

Conclusion

This study unraveled the potential of Remote Sensing and Geographic Information Systems (GIS) techniques in the struggle towards achieving sustainable environmental development and food security with a sole interest in mapping areas favourable for fadama farming, to know the extent of the area useful for fadama farming and also identifying the extent of the various land uses within the study.

In this study some the major findings are:

- Areas on the DTM considered favourable for fadama farming falls between elevations less than 181m above sea level.
- At the fringe of the study area, urban development is less dominates the area map favourable for fadama farming making the fringe more favourable for fadama farming.
- Dagiri within the study area is highly dominated by urban structures thereby making it impossible for fadama farming despite the fact that large area falls on fadama favored area due to high level of urbanization.
- Potential fadama land in the study area covers 21.8% of the entire study area on the DTM.
- Area mapped favourable for fadama farming is dominated by wetland vegetation, normal vegetation and farmlands rather than urban structures except in around the Old town and Dagiri.
- Built-up has the largest coverage of the study area with (44.l04%) of the study area, Roads and pavement covers 1.39% of the study area, vegetation and farmlands 41.35% water 5.63% and wetland vegetation covers of the entire study area.
- Crops that can be grown in this area include Rice, Maize, Okra, Pepper, Water Leaf, Pumpkin, Sugar Cane, Greens, Spinach, Vegetables such Tomatoes and Ayoyo (Ewedu).

Despite the fact that fadama potential land covers 21.8% area the study area, the expansion of urban area towards the fadama area need not be overlooked due to the fact the urban expansion cannot be totally stopped, this remain a critical threat to the fadama land but sustainable planning, management will be of significant in the drive towards sustaining and preserving fadama land in the study area which also house wetland vegetation ecosystem that is very important in provision of regulating services and products which generate socio-economic benefits, fadama play a key role in sustaining the livelihoods of communities and the survival of wildlife and biodiversity both in the catchments and downstream. In a general note policy maker in Abuja and a Nigeria as whole need to incorporate fadama lands/wetlands conservation into urban planning and development scheme.

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