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Research Article

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The Dynamics of Agricultural Land use Using Multi-Spectral Imageries in Southern Part of Nigeria

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Abstract

The study examined the factors influencing spatial agricultural land use change and modeled the factors for detecting change in agricultural land use in the Southern part of Nigeria. This was with a view to assessing the dynamics of agricultural land use using multi-spectral imageries in the study area. The study integrated fieldwork and satellites imageries from Land sat Thematic Mapper (TM) 1987, Landsat Enhance Mapper (ETM+) 2002 and NigeriaSat-1 2007 coupled with socio-economic survey. Digital image processing was carried out for satellite imageries. Spatial analysis was achieved using the Arc View (3.2), ArcGIS (9.2) and ILWIS 3.3 software packages. Spatial change in agricultural land use from 1987 to 2007 was tracked from the classified imageries by digitization, overlay operations (by subtraction) and graphical displays. The trend of the change of each identified agricultural land use type between the study periods was determined using cross operation of the ILWIS 3.3 software. The population for the study consisted of farmers in the 28 settlements in the study area, out of which ten settlements were randomly selected using the table of random numbers. Data collected were analyzed using descriptive and inferential statistics. The results showed the trend of changes in the study area, as arable farmland/shrub increased by 0.27% between 1987 and 2002 and decreased by 2.63% between 2002 and 2007, bare land decreased by 1.23% and 6.69% between 1987 and 2002, and between 2002 and 2007 respectively. Moreover, built-up area experienced increase by 3.8% and 9.39% between 1987 and 2002, and between 2002 and 2007 respectively. The forest region also experienced increase by 4.49% between 1987 and 2002 and 0.70% between 2002 and 2007. The plantation cover reduced by 3.15% between 1987 and 2002 and experienced an increase of 2.26% between 2002 and 2007. The results also showed that the factors responsible for the land use changes were population increase (38.7%), rate of development (14.3%), fertility of the soil (19%), availability of roads (7.7%), encroachment into plantation and conversion of forest into farmland and settlement (3.0%) and expansion of crop land (17.3%). The study concluded that human activities were significant drivers that determined environmental degradation in the study area.

Keywords

Multispectral imageries; Agricultural land use; Environmental degradation; Spatial change

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Introduction

Land use can be defined as the human activities that are directly related to land, making use of its resources or having an impact on it through interference in ecological processes that determine the functioning of land cover [1]. An extensive description of land use includes the sequence of operations, their timing, the applied inputs, the implements and traction sources used, and the type of output [2]. According to [3] the most important factor in land cover modification and conversion is human use, rather than natural change. And these changes in land cover cannot be understood without a better knowledge of the land use changes that drive them and their links to human causes [4]. While much land use takes place at the scale of small individual units of production, its impact is global and cumulative [5].

Srivastava et al. [6] opined that land use/land cover (LULC) change have emerged on the global stage due to the realization that changes occurring on the land surface also influence climate, ecosystem and its services. Therefore, the importance of accurate mapping of LULC and its changes over time is very paramount to environmental sustainability. As a matter of facts, the present study was conceived as a result of state creation of Delta State in 1991 giving new status to the study area. Consequently, most of the farmlands, forests and plantations have transformed into human settlement. The growing human population exerts increasing pressure on the landscape as demands multiply for resources such as food, water, shelter and fuel. The study area has experienced moderate population growth, substantial increases in agricultural production, land use and land cover are changing in the study area. Gone are those days when the present study area was covered with large and extensive plantations of rubber and oil palms. Most of these plantations have become mosaics of secondary re-growths. There are increased changes of agricultural land use as there has been encroachment into the primary forest, and expansion of settlement due to the rapid increase in population. It is believed that these changes in agricultural land use in tropical area are not well documented for healthy and sustainable environment due to lack of spatial data. Jones [7] study give credence to this by revealing that up-to-date land use / land cover information can be used for many purposes where knowledge of change and trend is critical. This study therefore developed capabilities in the use of multi-spectral satellite data for capturing changes in the agricultural land use dynamics in the rural area of Ika North East LGA.

Methods and Materials

Study area

The study area is Ika North-East Local Government Area in Delta State (Figure 1). It lies between latitude $6^{0}05^{1}$ and $6^{0}25^{1}$ North and longitude $6^{0}05^{1}$ and $6^{0}25^{1}$ East. It has an area of 463 km^{2} and a population of 183,657 as at the 2006 census. The surface geology of Ika North East LGA includes sedimentary formation of the Benin formation. The study area landscape is predominantly a subdued low-lying deltaic plain. Though the highest elevation of the dissected uplands is only 276 meters above sea level, it is classified as upland relative to more than 80% of the state that lies below 110 meters. The study area experienced tropical climate marked by two distinctive

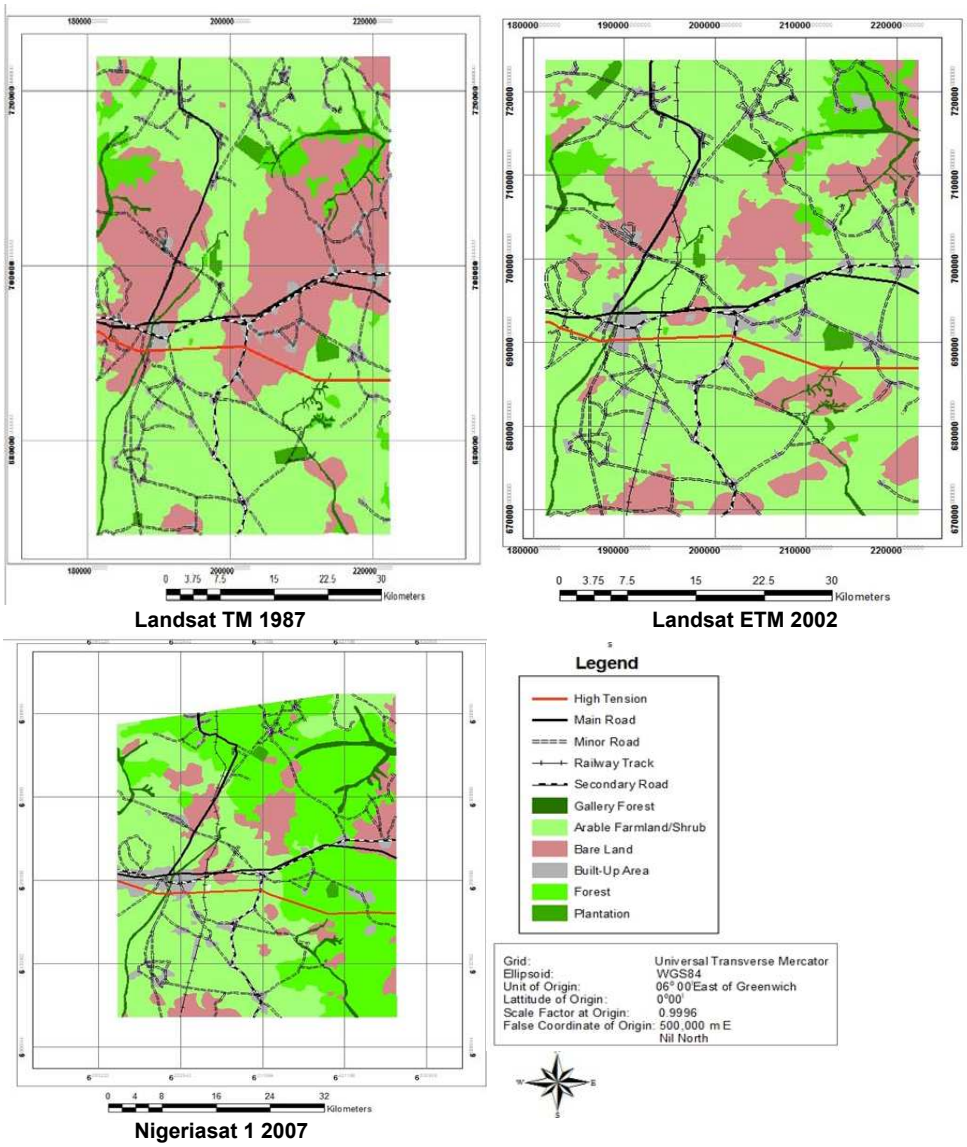

Figure 1: Serial Satellite Images of the study area showing land cover dynamics.

seasons: the dry and wet seasons. The dry season occurs between November and March, while the raining season begins in April and lasts till October. The month of July witnesses the heaviest rainfall. The average annual rainfall is 1,905 mm. The temperature is high, ranging between 28°C and 34°C with an average temperature of 30°C. The soil found in the study area is the ferrasols on loose sandy sediments. The ferrasols are deeply weathered red and yellowish brown soils with abundant free iron oxides without a laterite iron layer. The vegetation of the area is the tropical lowland rainforest which is divided into undisturbed rainforest and the secondary forest. The secondary forest is as a result of the destructive activities of man leading to large-scale deforestation of the typical lowland rainforest which is distinguished from the high forest by its smaller height, smaller biomass volume and reduced diversity of species. However, the native species in the area are *Triplochiton scleroxylon, Melicia excelsa, Khaya ssp, Mansonia postulata, Piptadeniastrum africanum, Scottelia curiacea, Ricinodendron heudelotii, Pausinystalia jolimbe* and *Erythrophyleum spp*. The major land uses are agriculture and residential with a negligible amount of institutional land use [8].

Methods of study

Both primary and secondary data sources were employed for this study. The primary data was obtained through the administration of questionnaire and the global positioning system (GPS) in acquiring the coordinates of the study area. Random sampling technique was adopted in questionnaires administration using the table of random number. The questionnaires were administered to 300 farmers in 10 settlements in the study area. Out of twenty eight settlements, ten settlements were selected randomly using the table of random numbers. Thirty questionnaires were administered to the identified farmers in each of the ten settlements. The secondary data for the study were based on time series of Landsat Thematic Mapper (TM) 1987 and Landsat Enhanced Thematic Mapper Plus (ETM+) 2002 which were obtained from the National Centre for Remote Sensing,

Jos and NigeriaSat-1 2007 which was acquired from the National Space Research and Development Agency (NASRDA) Abuja, coupled with topographical map of the study area and its environs with a scale of 1:100,000 was used as a base map for this study. Table 1 shows the characteristic of the images used for the study. The processing of the imageries was carried out using the ILWIS 3.3 Patch version (Integrated Land and Water Information System), ArcView 3.2 and the ArcGIS 9.2 software packages. The imageries were processed and classified. After the classification the images were exported as Geo-TIFF and shape files to the ArcView and ArcGIS Environment in order to produce land use maps of the study area using the standard procedure for information extraction. Both supervised and unsupervised methods were adopted for the study. Unsupervised classification was first adopted for the three imageries after which intensive ground truthing was done. This was used as a training site for supervised classification of the imageries. That is, the appropriate training areas was selected based on familiarity with the study site through reconnaissance survey and fieldwork which gives the knowledge about the actual survey cover types present on the images. During the ground truthing different land uses were observed, which were used to classify the images. The imageries were classified using the maximum likelihood classifier algorithm. The classified imageries were digitized using the on-screen digitizing process. This was done in order to create land use maps of the study area from the classified imageries. The confusion matrix was carried out using the ILWIS software. This was necessary in order to access the accuracy of the image classification.

Statistical techniques

A descriptive statistical technique was used to analyze the data using the Statistical Package for Social Scientist (SPSS) version 17. This was used to analyze the socio-economic data and the factors affecting land use change. The analysis of the data collected was also done using the multi-nominal logistic regression model to determine the relationship between the factors responsible for agricultural land use change and the years of experience as a farmer. Thus the formula:

$$Y_o = X_1 + Y_n + E_n + ex_o + Y_1X_n(0.471) + E_o \quad (1)$$

Deputed the relationship between the factor where

X_1= soil fertility; Y_n=Development rate; E_n=Encroachment; E_{xo}=Expansion of cropland;

Y_1X_n= population and availability of road; 0.471= mean of Y_1X_n; E_o= time interval, 0,2,4,6,8……..n Uslaner [9].

Results and Discussion

Accuracy and reliability assessment of the classified image

In this study omission and commission errors were taken into consideration while confusions between classes were also resolved. To achieve a reliable and accurate classification, the training parcels for the supervised classification were carefully selected. The accuracy for Landsat TM image of 1987 was 83.32%, for Landsat ETM+ image of 2002 and NigeriaSat-1 image of 2007 was 71.74% and 78.14% respectively. The average reliabilities for the classified images were 80.06% for 1987 image, 64.87% for 2002 image and 69.35% for 2007 image. The overall accuracies were 84.62% for 1987 image, 70.33% for 2002 image and 75.78% for 2007 image (Table 2).

Land use and land cover between 1987 and 2007

Table 3 shows that in 1987 the study area was extensively covered by arable farmland and shrubs (45.68%). This confirms the observation that the main activity of man in this area is farming coupled with its rurality and fertile soil. 33.96% of the area was covered by bare land followed by forest (8.08%), plantation (7.68%) and built up area (4.60%).

Table 3 also shows that in 2002, farming remained the major activity of man in the area as arable farmlands / shrub covered 47.54% of the total classes followed by bareland (27.68%), forest land use / land cover (13.51%) and built up area (7.22%) land cover.

The analysis of NigeriaSat I 2007 shows that arable farmland covers 41.21%; bareland covers 18.42%; built-up covers 10.61% while forest covers 25.17% of the total area. The increase identified in forest land use can be adduced to government policy on afforestation, which was introduced in 2004, while that of built-up area was claimed to be population growth in the area. Plantation covers 4.51% of the areal extent (Figure 1).

Table 1: Imagery Characteristics.

S/N	Data Type	Spatial Resolution	Date of Acquisition	Location on WRS
1	Landsat image TM	28.5m	21/12/1987	P189R056
2	Landsat image ETM+	28.5m	6/1/2002	P189R056
3	NigeriaSat_1	32m	20/01/2007	

Table 2: Confusion Matrix of the Satellite Images.

Mode	Accuracy	Average Reliability	Overall Accuracy
Landsat TM 1987	83.32 %	80.06 %	84.62 %
Landsat ETM+ 2002	71.74 %	64.87 %	70.33 %
Nigeriasat-1 2007	78.14 %	69.35 %	75.78 %

Detection of change

Table 4 shows a negative change in plantation land cover between 1987 and 2002. This may be due to the fact that people were encroaching into the plantation for the purpose of arable crops cultivation and expansion of towns. Built-up land cover has increased by 57% while both forest land and arable farmland/shrub increased by 67% and 4.07% respectively. The classification result of the 2002 imagery was subtracted from the classified 1987 imagery while the classified 2007 imagery was also subtracted from the classified 2002 image. This was done in order to determine the extent of change between the study years.

The period between 2002 and 2007 witnessed a downward trend in the rate of physical expansion of the city as against 1987 and 2002. For instance, the built-up land only increased by 46.96% as against the 57% between 1987 and 2002. Also, there was an upward trend of 86.31% in forest and 11.29% in plantation which is evident between 2002 and 2007; also within the same year there was a downward trend of 13.15% in farm land and 33.44% in bare land. The reason adduced to this was the effort of the government in embarking on afforestation programme.

Socio-economic analysis

Table 5 shows that 41.0% of the respondents' claimed that thick forest land cover was the initial land cover type in the study area while 30% claimed that the area was initially grassland. The remaining

Table 3: Land use / Land cover dynamics between 1987 and 2007.

LULC	1987		2002		2007	
	Area (Ha)	Area (%)	Area (Ha)	Area (%)	Area (Ha)	Area (%)
Arable farmland / shrubs	113713.7	45.68	118342.4	47.54	102777.2	41.29
Bare land	84529.08	33.96	68893.29	27.68	45852.47	18.42
Built-up area	11447.28	4.6	17971.56	7.22	26410.16	10.61
Forest	20104.83	8.08	33632.91	13.51	62662.76	25.17
Plantation	19120.77	7.68	10075.59	4.05	11213.1	4.51
Total	248915.7	100	248915.7	100	248915.7	100

Table 4: Trend and rate of change from 1987-2007.

Landuse /cover	1987-2002		2002-2007		Annual Rate of change			
	Area (ha)	% change	Area (ha)	% change	1987-2002		2002-2007	
					Ha	%	ha	%
Arable Farmland/ Shrub	4628.61	4.07	-15565	-13.15	308.574	0.27	-3113	-2.63
Bareland	-15635.79	-18.5	-23040.8228	-33.44	-1042.386	-1.23	-4608.165	-6.69
Built up Area	6524.28	57	8438.5972	46.96	434.952	3.8	1687.713	9.39
Forest	13528.08	67.3	29029.8484	86.31	901.872	4.49	5805.97	0.70
Plantation	-9045.18	-47.3	1137.5172	11.29	-60301.2	-3.15	227.50	2.26

Source: Fieldwork, 2010.

respondents' 18% and 11% claimed that the area was covered with tree plantation and fallow land respectively.

Table 6 shows how long each of the respondents has been cultivating a particular parcel of land. 51% claimed to have been cultivating the land for above 30 years; 22% for between 11 and 20 years; while 17% and 10% have been cultivating it for between 21 to 30 years and less than 11 years respectively.

Table 7 shows the types of crops planted in the study area. 91.0% of the respondents planted annual crops, 2.3% biennial crops while 6.7% engaged in the planting of perennial crops. Table 8 shows that 70.0% of the farmers practice shifting cultivation while 30.0% practice continuous cultivation. The implication of shifting cultivation is to allow the over-used land to fallow for a period of time for the soil to regain its fertility before using it again.

Table 5: Vegetation types in the study area before first cultivation.

Vegetation	Frequency	Percentage
Thick forest	123	41.0
Fallow land	33	11.0
Tree plantation	54	18.0
Grassland	90	30.0
Total	300	100.0

Source: Fieldwork, 2010

Table 6: Length of cultivation on a particular land.

Length of cultivation	Frequency	Percentage
Less than 11 years	30	10.0
11-20	66	22.0
21-30	51	17.0
Above 30	153	51.0
Total	300	100

Source: Fieldwork, 2010

Table 7: Types of crops planted.

Types of crops	Frequency	Percentage
Annual	273	91.0
Biennial	7	2.3
Perennial	20	6.7
Total	300	100

Source: Fieldwork, 2010

Table 8: Farming systems of the respondents.

Farming system	Frequency	Percent
Continuous cultivation	90	30.0
Shifting cultivation	210	70.0
Total	300	100.0

Source: Fieldwork, 2009

The change in crop types planted on the farmland between 1987 and 2007 was examined. The result of field survey in Table 9 shows that 67.2% of the respondents' farmland was occupied by arable crops in 1987 while those of 32.8% were occupied by tree crops. In 2002, 75.0% of the land was occupied by arable crops while 25.0% was occupied by tree crops. By 2007, 70.5% of the farmland was occupied by arable crops while 29.5% of the farmland was occupied by tree crops.

Table 10 shows that 38.7% of the respondents claimed that population increase were responsible for change in land use in the study area. This assertion was in line with O'Donnell [10] and Orimoogunje and Gadiga [11] study. 14.3% of the respondent claimed that the change was due to the rate of development. This gives credence to the study conducted by Turner et al. [12], Orimoogunje et al. [13] and Orimoogunje and Ekanade [14]. 19.0% of the respondent agreed

that the change in the land use was due to the fertile nature of the soil and 14.3% claimed that it was due to the need for space for further development. 7.7% adduced the change in the area to the availability of roads while 3.0% and 17.0% believed it was encroachment into plantation, conversion of forest into farmland and settlement and soil fertility respectively.

Table 11 shows the nominal regression of the relationship between the factors responsible for agricultural land use change in Ika North East LGA. It was observed that population, development rate, soil fertility, expansion of cropland, encroachment into forest and plantation are the significant factor that brought about the change in the agricultural land use in the study area.

Conclusion

It has been observed that the land use/ land cover of the study area had changed during the period under review. This result is in line with the observations of Osei et al. [15], Omo-Irabor and Oduyemi [16,17]. This result also gives credence to the work of Srivastava et al. [6] that revealed that the change analysis of the multi temporal images indicates an increase in urban areas and a major shift in the agricultural practices. The change was mainly due to the fact that there was an increase in population growth. The study also shows that the landscape of Ika North East LGA has gone through a tremendous change after the creation of the Local Government in September, 1991. On the other hand the study has demonstrated the capabilities of geo-informatics techniques to capture data integrate data and analyse data covering of an area over a long time frame. In order to produce useful information on characteristics of landscape due to impacts of human activities which is a significant driver that determines the wholesomeness or otherwise of the environment. This can only be achieved through the use of time series of remotely sensed data as demonstrated by this study.

Table 9: Change in crop type within the study year.

Year	Tree crop in Percentage	Arable crops in Percentage
1987	32.8	67.2
2002	25.0	75.0
2007	29.5	70.5

Source: Fieldwork, 2010

Table 10: Factors responsible for land use change.

Factors	Frequency	Percentage
Population	116	38.7
Development rate	43	14.3
Soil fertility	57	19.0
Availability of road	23	7.7
Encroachment	9	3.0
Expansion of cropland	52	17.3
Total	300	100.0

Source: Fieldwork, 2009

Table 11: Result of Nominal Regression.

Factors	Std error	Degree of freedom	Significant
Soil fertility	.540	1	0.000
Population	1.038	1	0.13
Availability to road	1.155	1	0.341
Development rate	1.031	1	0.007
Encroachment	1.080	1	0.000
Expansion of cropland	0.430	1	0.000

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