Magnitude of Land Use and Land Cover changes in Igabi

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Abstract: **Soil erosion and degradation, water pollution and biodiversity loss, cause by intensive crop farming, have resulted in degradation of 1/4 of the global farmland, while almost 1/2 have moderately or slightly degraded. Land Use and Land Cover Change Analysis was conducted to determine the level of farmland degradation in Igabi Local Government Area of Kaduna State, Nigeria. The study area was delineated into 9 zones (A to I) for the assessments. Classified Objects Change Detection which involved comparing vector map and satellite imagery was adopted. The data used were Land-use and Land-cover map in vector format, produced in 1995 and a NigeriaSat-X satellite imagery with 20 meter spatial resolution captured in 2015. The satellite imagery was converted to vector format. The extracted land features were categorized into seven classes, namely; settlements, farmland, barren surfaces, forest plantation, natural vegetation, distorted vegetation and waterbodies. Rural Land Consumption Rate (RLCR) and Absorption Coefficient were computed. The change analysis revealed that 83.3% of the total farmland were rendered barren, 8.5% became distorted vegetation, while 8.2% were consumed by the growing settlement. The locations of the losses to the barren surfaces were mostly in zone E accounting for 76.5% of the total loss. Those converted to distorted vegetation are mostly in zone B (39.1%) where farmland became grasses of very low height. Human settlement in the area had increased between 1995 and 2015 by 31%. The RLCR revealed that the consumption rate was higher in 1995 than 2015 in all the 9 zones, instead of being higher in 2015 since the population has increased significantly. The rapid depreciation of the green vegetation to barren surfaces pose alarming threat to the environment.**

Keywords: **Vegetation, Farmland, barren surfaces, degradation, Change Detection,**

I. INTRODUCTION

Land degradation is a contemporary issue of concern. Significant manifestations of the degradation are evident in several parts of the world. Gao and Liu (2010) found instances of degradation in Tongyu County, Northeast China and attributed the situation to excessive reclamation of grassland for farming, over cultivation, overgrazing, and deforestation. Evidence of land degradation processes exists in western Nile delta of Egypt (Al-Kawy et al, 2011). Due to soil erosion and degradation, water pollution and biodiversity loss, about 1/4 of the global farmland has completely degraded, while almost 1/2 has moderately or slightly degraded (Smit et al., 2013). Smit et al. (2013) further observed that highly intensive farming has led to pollution of soil and water bodies in Europe which results to loss of biodiversity. He added that land has been abandoned in rice-based food systems of Eastern and South-East Asia due to degradation.

The farming systems that led to rapid farming productivity is the productivists farming concept. Generally, some practices in conventional farming systems such as the use of inorganic fertilizer, is detrimental to the environment (Ponisio, et al. 2015), and cause the scarcity of natural resources (Altieri et al., 2012; Kremen and Miles, 2012), water in particular (Hoekstra et al., 2012). Reductions in groundwater account for about 60% as a result of drought, evaporation from lakes and reservoirs (Goldenberg, 2014). He added that farmers in the Middle East and some parts of Asia resorted to drilling underground water sometimes at large scale.

Geographic Information Systems (GIS) Land Use and Land Cover Change (LULC) Analysis was conducted in this study to determine the level of farmland degradation in Igabi Local Government Area of Kaduna State, Nigeria. The significant aspect of land change analysis is to assess various alterations in land uses and land covers, so as to determine what replace what and the magnitude of this replacement (Amin and Fazal, 2012). The land cover is the natural biophysical features covering the surface of the earth, while the land uses are the human activities being carried out on a particular part of the earth. The human activities considered are the conversion of natural environment to farmland use and places of occupation (i.e. settlement).

II. METHODOLOGY

GIS LULC change analysis adopted in this study was the Classified Objects Change Detection (COCD). It involved comparing vector map and satellite imagery of the study area. The data used were the Land-use and Land-cover (vector) map of the area produced in 1995 and a NigeriaSat-X satellite imagery with 20 meter spatial resolution captured in 2015. In carrying out the COCD, the two temporal data were used as the basis for the comparison (i.e. changes between 1995 and 2015 were identified). These data were processed and geometrically corrected (geo-referenced). The NigeriaSat-X imagery was classified, interpreted and land features were extracted. The features were verified through Ground truthing and error matrix was calculated. The classified imagery was vectorized and polygonised i.e. converted to polygon shapefile in vector format. The output is a vector map for land-use and land-covers of 2015. This made it the same format with the Land-use/landcover map of 1995. The two vector-maps i.e. land-use and land-cover maps of 1995 and that of 2015, were registered to the same coordinate to enable overlay analysis. They were compared and changes in them were calculated by overlay exercise and the areal extent of each feature was calculated as well.

The extracted land features were categorized into seven classes. These are settlements, farmland, barren surfaces, forest plantation, natural vegetation, distorted vegetation and waterbodies. The term settlement was used in the study to represent towns, villages and other built up areas, such as area of intensive use with much of the land covered by structures or impervious surfaces i.e., residential, commercial, industrial, educational, governmental, hospital, civil and cultural places. Farmland was used to refer to the area that was put to farming activities. These include intensive and extensive grazing, row crops, rain-fed and floodplain agriculture. All these types of agriculture were grouped under the same class. The barren class was the areas of less vegetation that have less ability for cultivation. These areas include bare rock surfaces, gullies and bare soil cover.

In response to climate change which has been leading to desert encroachment in the arid zone on northern Nigeria, the government had carried out afforestation project in some parts of the country. This afforestation project is referred to as forest plantation in this study. The categories of land cover being referred to as the natural vegetation were grown vegetation that were not planted by the inhabitants. The vegetation types in this class include minor tree, woodlands, shrubs, dense grasses, sedge, graminoid, freshwater marsh and swamp. The waterbodies category includes the rivers, reservoirs and ponds. The changes in the settlement and the farmland obtained from the land use change analysis were further analyzed with regard to changes in population of the area referred to as Land Consumption Rate and Absorption Coefficient.

Land Consumption Rate and Absorption Coefficient

Naturally, it is expected that when there is population growth, the land consumption will also increase. In fact this was the practice in the past until the issue of sustainability comes up, which brought the ethics of smart growth in urban areas, while in the rural area, sustainable agriculture is being preached. Emphasis has been laid on the sustainable usage and transformation of the environment. That is to say, even if the population keeps increasing, the land consumption should be reasonable, among others. Hence, in urban transformation studies, Land Consumption Rate and Land Absorption Coefficient are being used to determine rate of transformation and quantitative assessment changes (Amin and Fazal, 2012; Sharma et al., 2012). They are used to assess the sustainability of consumption of the land resource in the urban areas. Conversely, the unsustainable uses of land in the rural areas are either pollution, degradation as a result of intensification or distortion of the natural environment by converting them to farmland. Since this study was carried out on rural area, the Land Consumption Rate and Land Absorption Coefficient were adapted and modified as Rural Land Consumption Rate (RLCR) and Rural Land Absorption Coefficient (RLAC). They were used to determine the sustainability rate. Although part of an urban fringe (i.e. Kaduna metropolis) falls within the study area, the core area for this study is rural. Therefore the urban fringes were categorized under settlements class. The RLCR and the RLAC were used to determine the proportion of the land consumption with regard to the population increase. This determined whether the increase in the land consumption is within a reasonable extent with the population growth, so as to ascertain the level of sustainability of the land consumption.

The RLCR measures compactness that indicates a progressive spatial expansion or otherwise of a settlement. It is calculated by dividing the areal extent of land being used by the inhabitants (i.e. settlements and farmland), by their population. It is calculated as; $RLCR = A/P$. Where, A = areal extent of settlements and farmland in Hectares, P = population

The RLAC measures changes in consumption of new settlement land by unit increase in population. This is calculated by dividing the difference of the multi-temporal areal extent (i.e. areal extent of land that was used by the inhabitants in 1995 to be subtracted from same areal extent of 2015) by the difference between the two population figures (i.e. 1995 and 2015 population projections figures) as; $RLAC = (A2 - A1) / (P2 - P1)$, where, A1 and A2 are the areal extents of settlements and farmland (in Km2) for the early and later years, while P1 and P2 are population figure for the early and later years respectively.

The first task was to estimate the population figures using the geometric population projection, since censuses were not conducted in 1995 and 2015. The census figure of 1991 was projected to 1995, being the closest to that date, and the 2006 census figure, which is the latest, was projected to 2015. The following population projection formula was used; $Pp = Pt (1 + r/100)n$, Where; Pp stands for projected population, Pt refers to the base population, r refers to the growth rate, n stands for number of projecting period.

Trend, Rate and Magnitude of changes

The total area that was 3,623 Km2 (262,300 hectares) in 1995, has been found to be 3,621 Km2 (362,100 hectares) from the processed satellite imagery of 2015. Therefore, there is deficiency of 2 Km2 (0.06%) in the later analysis. This is due to conversion from raster data to vector format. Since the difference in the conversion exercise is less than 0.1%, it is therefore considered as negligible. From the image classification result, the overall Kappa Statistics is 0.8487 and the overall Classification Accuracy is 87.5%.

Within the study time frame i.e. 20 years, there was significant swap of the land features among various land use and cover, and some of these features have expanded from their initial sizes. The changes covered the total area of 1003.7 Km2 (100,370 hectares) which is about 27.7% of the total area. Table 1 presents the trend, rate and magnitude of the changes in 1995 and in 2015, while Figure 1 presents the areal extents.

Table 1: Trend and Changes Magnitude

	1995		2015		Change in	Percentage	Annual Rate
	Hectares	%	Hectares	%	Hectares	change	of Change
Farmland	242,700	67	198,300	55	-44,400	18	0.9
Barren Surfaces	39,800	11	79,300	22	39,500	99	4.95
Natural Vegetation	54,700	15	0	0	-54,700	100	5
Distorted Vegetation	0	0	56,900	16	56,900		0
Forest Plantation	9,300	3	8,400	2	-900	10	0.5
Waterbodies	3,700	1	3,400	1	-300	8	0.4
Settlement	12,100	3	15,800	4	3,700	31	1.55
Total	362,300	100	362,100	100			

All the LULC features in the area were affected by the changes as presented in the Table. The significant land transformation was witnessed among natural vegetation, farming, barren lands and settlements. Barren lands and settlements (i.e. built-up area) increased capturing land mainly from farming. The magnitude of the changes among the features varies. Among the features, farmland and forest plantation decreased in sizes by changing to other LULC features while settlement and barren surfaces increased by capturing some of the features. The natural vegetation had completely been converted to other features while a new group of land cover feature referred to as distorted vegetation emanated.

Details of the changes are presented in Table 2. However, changes that are less than 1Km2 (100 hectares), are considered insignificant because they cannot be shown conspicuously in the adopted map scale. Hence, such insignificant changes are not presented. The diagonal figures highlighted in yellow in Table 2, are areal extent of the corresponding land use or land cover feature in 1995, while the figures in the same row are increases in the areal extent of the LULC feature, captured from other LULCs. Similarly, figures in the same column represent the conversion in areal extent of the feature to other LULCs. In order to indicate precise locations of the changes, the study area is subdivided into nine (9) zones using the rivers in the area as the boundaries. The changes in the LULCs at zonal levels are shown in Figures 2 and 3.

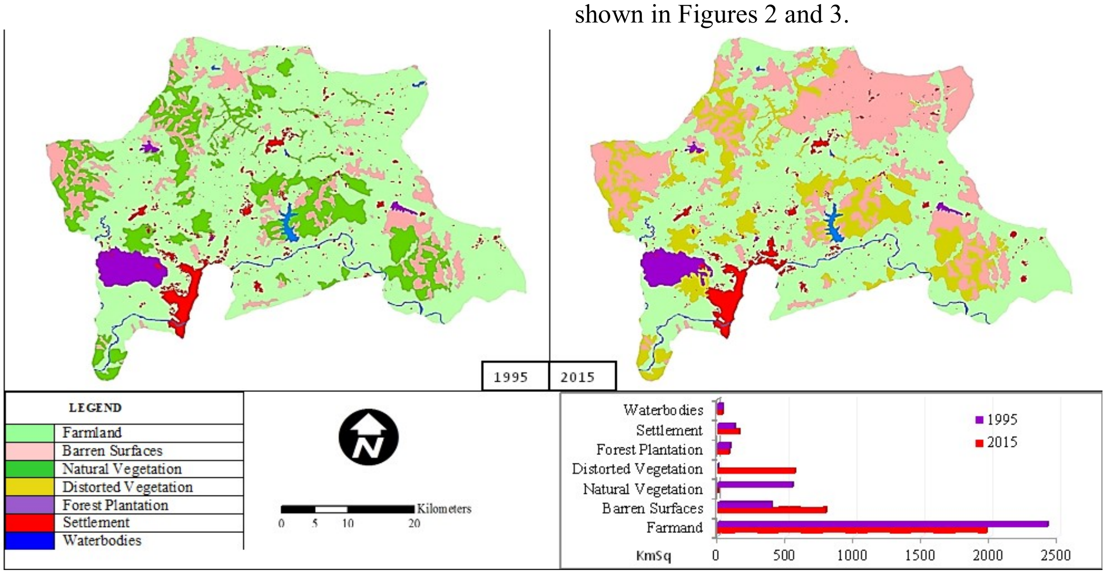
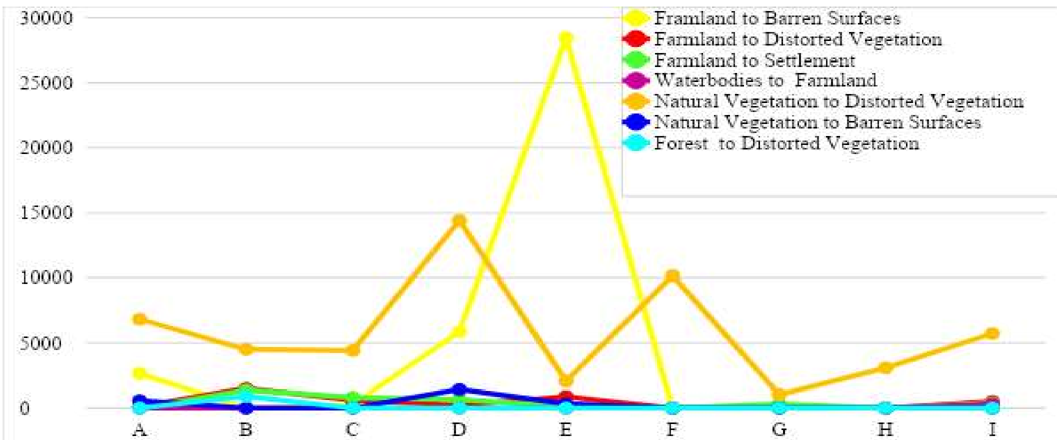


Figure 1: Areal extent of LULC in 1995 and 2015

Table 2: Changes from One Land Use to another (Hectares)

	Farmland Land	Barren Surfaces	Natural Vegetation	Distorted Vegetation	Forest Plantation	Water bodies	Settlement	Total Gain
Farmland	242,700					300		300
Barren Surfaces	37,200	39,800	2,300					39,500
Natural Vegetation			54,700					
Distorted Vegetation	3,810		52200	0	900			56,910
Forest Plantation					9,300			
Waterbodies						3,700		
Settlement	3,660						12,100	3,660
Total Loss	44,670		54,500		900	300		100,370



	A	B	C	D	E	F	G	H	I	Total
Farmland to Barren Surfaces	2,640		250	5,860	28,450					37,200
Farmland to Distorted Veg.	100	1,490	610	230	870				510	3,810
Farmland to Settlement	0	1,370	800	650	140		300		400	3,660
Waterbodies to Farmland										300
Natural Veg.to Distorted Veg.	6,820	4,500	4,410	14,420	2,060	10,170	1,020	3,070	5,720	52,200
Natural Veg. to Barren Surfaces	560			1,410	330					2,300
Forest to Distorted Veg.		900								900
Total Changes per zone	10,120	8,260	6,070	22,570	31,850	10,170	1,320	3,070	6630	100,370

Figure 2: Changes from one LULC to another at zonal levels

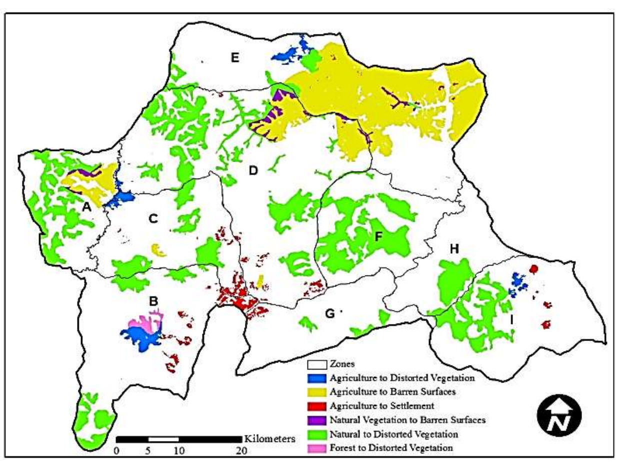


Figure 3: Location of changes in each zone

Farmland

In 1995, the total area under this class was 242,700 hectares i.e. 2,427 Km2 (67% of the study area), but in 2015, the areal extent decreased to 197,730 hectares i.e. 1,977.3 Km2 (55% of the study area). This means that an area covering 44,670 hectares i.e. 446.7 Km2 (18.4%) that were used for farming activities in 1995, have been lost to other land uses even though it gained an increase of 300 hectares (3 Km2) from the bank of the waterbodies. From the total farmland that were loss to other LULCs, 37,200 hectares i.e. 372 Km2 (83.3% of the loss) were rendered barren, 3,810 hectares, i.e. 38.1 Km2 (8.5%) became distorted vegetation, while 3,660 hectares i.e. 36.6 Km2 (8.2%) of the farmland were consumed by the growing settlement. The location of the losses in farmland to barren surfaces were found to be in four zones, mostly in zone E accounting for 76.5% (28,450 hectares) of the total loss.

Others are 2,640 hectares in zone A, 250 hectares in zone C and 5,860 hectares in zone D. The locations of the farmland that converted to distorted vegetation are in six zones. These are mostly in zone B where about 1,490 hectares (39.1%) farmland became grasses of very low height. Others are 100 hectares in zone A, 610 hectares in zone C, 230 hectares in zone D, 870 hectares in zone E, while 510 hectares is in zone I. The loss of farmland to distorted vegetation and barren surface can be attributed to abandoning of farming due to loss of fertility, since the main farming method is the bush fallow system.

It was discovered during the field verification exercise that maize is the dominant crop among farmland uses. Other crops largely cultivated in the area include rice, sorghum, cowpea, pepper and sugarcane. The farmland that was lost to Settlement are mostly in zone B, accounting for 37.4% (1370 hectares). Others are 800 hectares in zone C, 650 hectares in zone D, 140 hectares in zone E, 300 hectares in zone G and 400 hectares in zone I. New institutional structures and residential buildings were found during the field verification exercise in the area.

Barren Surfaces, Forest Plantation, Natural /Distorted Vegetation and Waterbodies

The natural vegetation that include minor tree, woodlands, shrubs, dense grasses, sedge, graminoid, freshwater marsh and swamp, have suffered serious anthropogenic distortion. In 1995, this class of land features covered areal extent of about 54,500 hectares (15% of the study area).

Due to the anthropogenic activities, 52,200 hectares i.e. 95.8% of this class have completely converted to what is being referred to as distorted vegetation. These are found in all the zones but the greater portions are 14,420 hectares (27.6%) in zone D and 10,170 hectares (19.5%) in zone F. 4.2% (2,300 hectares) of the natural vegetation are adversely degraded which rendered them barren, indicating that they have been cultivated for some time but later abandoned due to lost in fertility. The greater portion of this is found in zone D covering an area of 1,410 hectares (61.3%). Others are 560 hectares in zone A and 330 hectares in zone E. The barren class, identified as areas of less vegetation that have less ability for cultivation, that include bare rock surfaces, gullies and bare soil cover, was found to have rapidly increased. In 1995, this category of land cover was 39,800 hectares (11% of the study area), but increased to 79,300 hectares (22% of the area) by 2015. This change is about twice its size of 1995 (99% i.e. 39,500 hectares). Some of the barren surfaces are degraded farmlands that have not been cultivated for a very long time, as observed while discussing changes from farmland use to barren surfaces.

The degraded farmland that became barren surfaces covers about 37,200 hectares and are found in four zones; A, C, D and E. Most of it; about 76.5% (28,450 hectares) were found in zone E, 15.8% (5,860 hectares) in zone D and 7.1% (2,640 hectares) in zone A. Only a small portion (less than 1%) is in zone C. Apart from conversion from farmland, there are places that were classified under natural vegetation category in 1995, but now similarly became barren surfaces. The natural vegetation that became barren surfaces covers about 2,300 hectares, mostly (1,410 hectares) found in zone D. 560 hectares are in zone A and 330 hectares in zone E. Although these places were natural vegetation in 1995, there is maximum likelihood that they have been subjected to intensive farming within the 20 year-change period. The conversions of the farms to barren surfaces are mostly due to loss in fertility of these farms and the inability of the farmers to improve their fertility.

The afforestation project carried out by the Nigeria government has been referred to as forest plantation as mentioned. In 1995, areal extent of this vegetation covered about 9,300 hectares (3% of the study area). Due to anthropogenic activities, the areal extent was in 2015, reduced to 8,400 hectares (2% of the study area). This change is decrease by about 10%. Distorted vegetation class replaced the 900 hectares of the forest plantation. This is found in zone B. The undisturbed forest plantation is dominantly tree-plantation. However, when it is encroached, depending on the kind of encroachment, it turns to grassland with few trees or grassland completely. Distorted Vegetation were previously under the natural vegetation category, farmland or forest plantation and therefore were not found in the 1995 land cover classes, but they now cover 56,910 hectares (1.3% of the study area), capturing 52,200 hectares i.e. 91.7% of its area, from natural vegetation, 3,810 hectares (6.7%) from previous farmland and 900 hectares (1.6%) from forest plantation. The portion of the distorted vegetation that was formerly under the natural vegetation is found in all the zones. The portions that were formerly farmland are located in zones A, B, C, D, E and I, while the encroached forest is found in zone B. In the distorted vegetation class, the vegetation grew after the natural vegetation of the area has almost been destroyed completely. Depending on the intensity of the activities carried out on a particular land cover, some land covers turned to grassland of less than 50 cm in height, while some land features turned to shrubs.

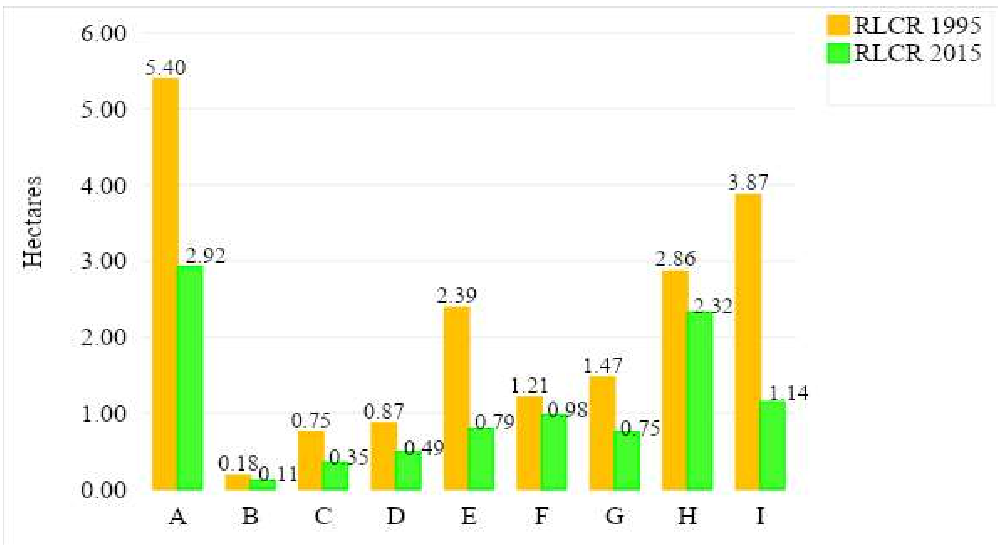
Water-body category, said to include rivers, reservoirs and ponds was in 1995, covering an area of about 3,700 hectares (about 1% of the total area). About 300 hectares of the river bank dried up and is being used for crop cultivation, reducing the total area of the water bodies to about 3400 hectares in 2015. The change within this period is 8% with the annual change rate of 0.4%. It spread along the banks of the water bodies.

Settlements

As stated in the methodology, the term settlement represents towns, villages and other built up areas i.e., residential, commercial, industrial, educational, governmental, hospital, civil and cultural places. The results revealed that this land use has increased from 12,100 hectares (3% of the entire study area) in 1995 to 15,800 hectares (4% of the study area) in 2015. This is to say it has increased by 31% within these periods. The expansion is mostly adjacent to the Kaduna metropolis while in other parts of the area; the growth is along the main roads as seen in Figure 3. This provides evidence that the expansion is mainly caused by increasing land demand due to population growth and the development of public and private institutions. Although the areal extent of the settlement has increased, the land consumption (the land areas presently being used by the inhabitants, i.e. the combination of farmland and the settlement) has reduced. This is further assessed using the Rural Land Consumption Rate (RLCR) and the Rural Land Absorption Coefficient (RLAC), discussed in the next sections.

III. RURAL LAND CONSUMPTION RATE AND RURAL LAND ABSORPTION COEFFICIENT

These sections present the Rural Land Consumption Rate (RLCR) and Rural Land Absorption Coefficient (RLAC) of the change detection. The projected population of Igabi was 344,239 in 1995 and 552,289 in 2015. The annual rate of the population change between the two temporal periods i.e. 1995 and 2015, is 1.9%. Contrary to the human settlements which increased by 30.6%, the population increase according to the projected figure is 60.4%. The RLCR revealed that the consumption rate was higher in 1995 than 2015, in all the 9 zones (Figure 4). This is more pronounced in zones C, E and I, where the decrease in the rate is more than half i.e. 53.2%, 66.9% and 70.5% respectively. Three other zones also witnessed significant changes of about half of their rate of 1995, these are zones A (45.9%), D (43.2%) and G (48.8%). This is further determined by the RLAC shown in Table 3.



% Change	45.9%	36.3%	53.2%	43.2%	66.9%	19.0%	48.8%	18.8%	70.5%

Figure 4: Comparison of Rural Land Consumption Rate between 1995 & 2015

Table 3: Rural Land Absorption Coefficient

	Settlement + Farmland			Population			
Zones	1995	2015	Difference	1995	2015	Difference	RLAC (Hectares)
A	8962.5	6211.2	2751.3	1661	2128	467	5.891
B	32292.4	30800.6	1491.8	181208	271447	90239	0.017
C	25057.8	24198.2	859.6	33375	68865	35490	0.024
D	57353.4	51210.6	6142.8	66262	104250	37988	0.162
E	56107.2	26701.8	29405.4	23500	33804	10304	2.854
F	15105.7	15093.7	12.0	12520	15444	2924	0.004
G	21570.7	21524.3	46.4	14708	28641	13933	0.003
H	12155.4	12125.1	30.3	4244	5215	971	0.031
I	26157.0	25592.5	564.5	6761	22421	15660	0.036

The RLCR and the RLAC revealed that the area that was put to human activities, which are the farmland and the settlements, was wider in 1995 than in 2015 even though the population has been increasing. This is an abnormal situation because even if the concept of environmental sustainability, which emphasizes smart growth, is strictly adhered to, the areal extent of the land uses is not supposed to reduce, when the population keeps increasing. To determine if there is relationship between changes in farmland and changes in population at zonal levels, correlation were computed. The results of the correlation is -0.272, indicating a weak negative correlation, and an insignificant relationship was also ascertained, when a level of significance (α = 5% < 0.478), signifying insignificant relationship between them.

IV. CONCLUSION

The findings of the LULC change analysis has revealed that there had been serious distortion of the ecosystem in the study area between 1995 and 2015. The Natural vegetation which was about one-sixth of the area has completely been altered. Being an agrarian society, the farmland which was two-third of the area has been reduced to about half of the area. Conversion of vegetation cover to barren surfaces, which is among the worst types of unsustainable use of environment, has doubled its initial size. This supports some observations such as Smit et al. (2013). Nevertheless the change detection result, which revealed that the category of land, which is put to farming activities maintain the highest share in the total land use in Igabi, the rapid depreciation of the green vegetation to barren surfaces pose alarming threat to the environment. Other LULC changes that include the reduction in forest plantation and water bodies as well as the sprawl of the settlement have all been discovered. Water-body category was seen to have shrunk from 3,700 hectares in 1995 to 3,400 hectares in 2015. The change within this period is 8.1%. However, there is temporal issue regarding the analysis of changes in water bodies. This is because the volume of water increases during rainy seasons and decreases at the dry seasons. Similarly, even if the images being compared were both captured within the rainy seasons, the water volume and coverage of the run-off ways vary within a season, depending on the amount of rainfall in some days. Therefore, the time at which the data was captured influences the areal coverage of the water bodies. This finding on water loss in Igabi, is in line with the existing literature such as Goldenberg (2014).

The RLCR has revealed that the consumption rate was higher in 1995 than 2015 in all the 9 zones, instead of being higher in 2015 since the population has increased significantly. The land consumption, that is the land areas presently being used by the inhabitants, i.e. the combination of farmland and the settlement has reduced. This finding negates the general belief that population increase leads to further consumption of land. RLCR was 0.740 hectares in 1995, while in 2015, it was 0.386 hectares. Although it was seen that the size of the settlements has increased in 2015 by about one-third (31%), the decrease in the farmland size is very high. This makes the RLCR to drop drastically in 2015 by 0.354 hectares. The RLAC between 1995 and 2015 is negative (0.199), which suggests that the natural vegetation has not been encroached by the rural activities within this period. Conversely, the findings of the GIS change analysis showed that the natural vegetation has completely been altered, i.e. consumed by distorted vegetation mostly. This is so because the loss of the natural vegetation is mostly to distorted vegetation rather than farmland. However, very small portion of the vegetation is loss to settlement development. This is not manifested in the RLAC due to high rate of the reduction in farmland. The question that arose as a result of this finding is on the causes of this reduction in farmland. It became imperative to determine the actual causes of these changes. Hence, there is the need for surveys on the socioeconomic characteristics of the inhabitants of the area and their farming practice.

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