An evaluation of the change in land use/land cover and terrain characteristics of Ala River catchment, Akure, Nigeria.

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Abstract

This study evaluates land use change within the upper catchment area of Ala river, Akure, Ondo State over a period of 31 years (1986-2017) using Landsat Thematic Mapper (TM) 5 of 1986, Landsat Enhanced Thematic Mapper Plus (ETM+) 7 of 2002, and Landsat 8 OLI / TIRS of 2017. The normalized difference vegetation index (NDVI), surface runoff and terrain configuration within the study area were analysed using ArcGIS 10.5 software. Three land use types were identified namely; built up, vegetation and bareland/outcrop. The built up covered 29.39 % in 1986 and increased to 43.64% in 2017. Vegetation revealed a reverse trend with a continuous decline from 49.21% in 1986 to 14.16% in 2017 while bareland/outcrop increased from 19.60% in 1986 to 42.20% in 2017. The NDVI values range between -0.03 and 0.4; -0.3 and 0.3; and 0.04 and 0.3 in 1986, 2002, 2017, respectively as an indicator of vegetation degradation. The analysis showed that the study area has been considerably degraded, mainly due to the depletion of vegetation and uncontrolled urbanization process. It is therefore recommended that the government through its physical planning agency, put in place effective control mechanism to guide physical development that will enhance sustainable development in the study area and other parts of the town.

Keywords: *Land degradation, Impervious surface, NDVI, River catchment, Urbanization*

1. Introduction

As cities expand into adjoining rural lands due to urbanization, environmental impacts in terms of land degradation, are becoming apparent particularly in the developing countries (Hugo, 2017; Wang *et al*., 2018) where most physical structures are unsustainably developed (Mohapatra, *et al*., 2014). Urbanization has substantially changed the landscape of the earth surface with various negative effects in terms of physical environmental degradation such as loss of agricultural land, surface and ground water depletion, change in geomorphologic features, flooding, and landslide (Abbas and Fasona, 2012; Mohapatra, *et al.,* 2014). Globally, about 2-3 % of the land area is currently urbanized; this is expected to increase to 4-5% by 2050 (Wallace, *et al.,* 2003). Built-up areas in developing countries, are projected to increase threefold by 2030 and the process is projected to cause the loss of between 1.6 and 3.3 million hectares of prime agricultural land per year in the period between 2000 and 2030 (UNCCD, 2018).

This dynamics in the land use process have given rise to significant negative impacts on ecosystem structure, to the extent that many urban areas, were adjudged to be the most fragile region to the process of land degradation (Mohapatra, *et al.,* 2014). A good example is the increasing amount of riparian lands being developed and utilized for agriculture, human settlements and commercial purposes. Land degradation is a major environmental problem associated with urbanization process all over the world, thus making the land becoming unpleasant and less useful to man (Abubakar, 1993). Consequent upon the negative impacts of land degradation, it has become an important agenda on the international debates as evident in the discussion of the United Nations Conference on Environment (Koohafkan, 2000). As technology advances, so does our ability to change our surroundings, particularly, the surface of the earth are more extensive and occur more rapidly than ever before (Mohapatra, *et al.,* 2014) as more than 20%, 30% and 10% falling within cultivated, forest and grassland areas respectively (Bai *et al.*, 2008).

The rapid and constant change in land use alters the land cover of a region, and this alteration of land cover is found to trigger land degradation (Rahman *et al.,* 2012; Li *et al.*, 2015) as change in land cover contributes greatly to Land degradation in most countries of the world (Onur *et al.,* 2009; Maitima *et al.,* 2009; Ries, 2010). Maitima *et al.* (2009) assessed the inter-linkages between land cover change and land degradation. For instance, forests are cleared and converted to farmland (and later gives way to settlement activities that lead to soil compaction and increased impervious surface which in turn reduces infiltration rate and increases the amount of surface runoff that provokes accelerated soil erosion (Olatunji, 2007; Rahaman, 2012; Adediji *et al.,* 2013; Matano *et al.,* 2015). Mugisha (2002), Misana *et al.,* (2008) and Olson, *et al.,* (2004), to mention but a few, agree that most of the changes observed in land use/cover in many parts of African countries are mainly associated with urban expansion and intensification of agricultural activities to new areas.

Over two decades ago, particularly few years after Akure became capital city of Ondo State in 1976, Ala river catchment has undergone tremendous changes in both land use and land cover. Forests were intentionally cleared for farming activity but taken over by built up use as a result of increasing demand for residential building for the accommodation of the increasing population of Akure. There is growing evidence of land degradation in the area due to improper land use practices, coupled with relief cutting for roads and buildings development and high rainfall. The severity of the degradation has attracted research interest as recorded by the works of Olatunji (2007), Ayeni *et al.* (2011) Olatona *et al.* (2018), Eke *et al.* (2014) among others. Though, these authors explored geospatial techniques (remote sensing and GIS) in their works but Ayeni *et al.* (2011) and Olatona *et al.* (2018) focused on physico-chemical concentration of pollution and flood risk mapping of Ala river, respectively while Olatunji (2007), worked on the quantitative assessment of soil erosion in the study area. Eke *et al.* (2014) observed how urban expansion extended spatially north west of Akure which incidentally corresponding with area under this study. Apart from the work of Olatunji (2007) on aspect of physical soil degradation, there is no known documentation on physical soil degradation in the study area. Knowing the importance to strike balance between economic development and environmental conservation (Krishan *et al.,* 2009; Li, *et al.,* 2015), there is need for up to date information on the spatial and level of severity of the degraded soil in the study area for effective planning and formulation of land use policies. It is on this note that the research is leveraging on the technology offered through the use of remotely sensed data and geographical information system (GIS) to assess the land use/land cover and the terrain configuration of the study catchment.

2. Study Area

The study area is the upper region of river Ala catchment in Akure Ondo State, Nigeria. The catchment lies between Latitudes 7° 14' N, and 7° 17'N, and Longitudes 5° 8' E and 5^0 16' E covering a total area of $55km^2$. The River Ala and its tributaries is one of the main tributaries of River Ogbese in Southwestern, Nigeria. River Ala has a total length of about 57km of which 14.8 km traverses the thickly populated built up area of Akure township. The river takes its source from northwestern part of Akure town and flow southeastern direction of the town (Figure 1). The greater portion of the study area was consisting of built up land use, most of which were haphazardly arranged in space.

The study area is characterized by humid tropic climate (*Am* of Koppen's classification). It has predominantly two seasons, wet and dry. The wet season with averaged rainfall of 2378mm is generally being experienced between April and early November, though, with a short period of dry season in August popularly referred to as 'August break' while dry season is usually from late November to March of every year. The average annual temperature of the study area is $26.7^{O}C$ with daily temperature ranging from $22^{O}C$ during harmattan (December-February) to 32°C in March (Udo, 1981). As evident from hilly and uplands where anthropogenic activities have not been seriously felt, the vegetation type of the study area is the tropical rainforest (Barbour *et al.,* 1982), but the greater parts of the study area have been degraded to secondary vegetation and fallow land (Iloeje, 1981).

The soil of the study area is of Ijare series which is Ferralsol and extensively underlain by the Nigerian basement complex rock of the old-suite, pre-Cambrian origin of the southwestern Nigeria (Anifowose, 1989; Olatunji, 2007). Major rocks are granites, magmatites, quartzite complexes, coarse biotite granites (Olatunji, 2007) amongst others. The relief of the area ranges from gentle surface to high elevation up to 400m above sea level in the northwest and northeast of the study area. The study area slopes southeastwards in the direction of flow of river Ala and it is currently dominated with built up followed by farmland and fallow land uses.

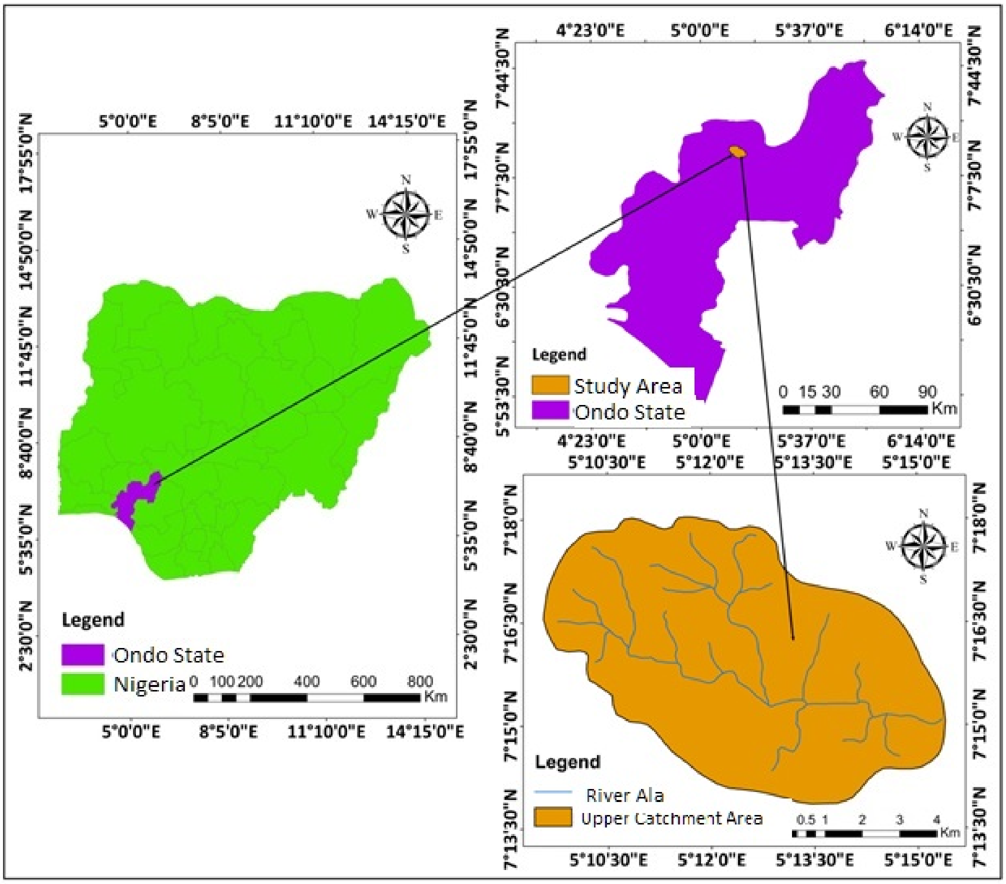

Figure 1: The study area, Ala River Catchment in Akure, Ondo State, Nigeria

3. Materials and Methods

3.1. Data

The data used for the study were Landsat Thematic Mapper (TM) 5 of 1986, Landsat Enhanced Thematic Mapper Plus (ETM) 7 of 2002, and Landsat 8 OLI / TIRS of 2017 acquired from United States Geological Survey (USGS) website. Details of the Landsat image types and band characteristics are well documented elsewhere (Barsi *et al.,* 2014; USGS, 2018). The images were downloaded for path/row 168/061 and projected through georeferencing method to UTM (zone 31) WGS84 datum using coordinates of some points obtained from the study area with hand held Global Positioning System (GPS), GERMIN 72S (accuracy ± 3m). The x,y,z of these points are necessary to bring the geometric value of points on the images to more reliable real world values. The choice of these images for the study was as a result of their high to medium resolution coupled with sharper spectral separation, improved geometric fidelity and greater radiometric accuracy. In addition, the data are free and have open access status (Eludoyin and Iyanda, 2018), thus, encourages users from less developed country like Nigeria with poor economic status (Wulder *et al.,* 2012). Other data used were 1:100,000 topographic map of Akure of 1966, and Google earth imageries of 2007 and 2018. Though, the age of the topographical map is old, but reliable for the delineation of drainage pattern and extraction of contours for the study as the map was produced from aerial photography mission of 1962 (Adewole and Eludoyin, 2019).

3.2. Data processing and analysis

The images were first georeferenced in ArcGIS 10.5 with the coordinates (x,y,z) obtained during the field work. The essence of performing a georeferencing task on the imageries is to improve their quality and provide enough localization of the imageries as advised in remote sensing literature (Eludoyin, and Adewole, 2019). The images were thereafter corrected for radiometric and geometric distortion errors. In addition, image masking (clipping) and image enhancement were performed using ArcGIS 10.5 software. Through clipping, the spatial extent of the area of interest was extracted and image enhancement was carried out on color and contrast level of the image to improve the quality and consequently aid a better interpretation.

3.2.1. Land use/land cover classification

The land use/land cover (LULC) classification for the study area in 1986, 2002 and 2017 were carried out using a supervised image classification technique based on maximum decision likelihood rule (Abrams, et al 1996, Jain, et al, 2014) on the Landsat images for the 3 years. Three major land use classes were identified namely, built-up, vegetation and bareland/outcrop. The total area cover by each land use class for all the years were generated using the field calculator of ArcGIS 10.5. The accuracy assessment of the classified images in terms of producer, user and kappa were also determined using formulae proposed by Bogoliubova and Tymków, (2014).

(i) Overall Accuracy (%) = $\frac{\sum D_{ii}}{\mathrm{N}} \times 100$ [1]

(ii) User Accuracy (%) = $\frac{D_{ii}}{\mathrm{C}_j} \times 100$ [2]

(iii) Producer Accuracy (%) = $\frac{\mathrm{D}_{ij}}{\mathrm{R}_i} \times 100$ [3]

(iv) Kappa Coefficient (Kc) = $\frac{\mathrm{N}\sum \mathrm{D}_{ii} - \sum \mathrm{R}_i \mathrm{C}_j}{\mathrm{N}^2 - \sum \mathrm{R}_i \mathrm{C}_j}$ [4]

where:

$\sum \mathrm{D}_{ii}$ – the total number of correctly classified pixels
N – total number of pixels in the error matrix.
Dij – number of correctly classified pixels in row *i* (in the diagonal cell)
$\sum \mathrm{D}_{ij}$ – the sum of correctly classified pixels in all images (total diagonal elements of an error matrix)
R_i – total number of pixels in row *i*.
C_j – total number of pixels in column *j*.

3.2.2. Extraction of normalized difference vegetation index (NDVI

The normalized difference vegetation index (NDVI) was used to extract and analyze the healthy nature of the vegetation cover in the study area. NDVI is calculated as a ratio difference between measured canopy reflectance in the red and near infra red bands respectively (Nageswara, *et al.,* 2005; Gandhi, *et al.,* 2015). The equation is as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED}, \text{ where } (-1 \text{ NDVI } +1)$$

Where RED is visible red reflectance, and NIR is near infrared reflectance. The wavelength range of NIR band is (750-1300 nm), RED band is (600-700 nm). The NDVI value varies between -1.0 and +1.0. A very low value (0- 0.1) of NDVI represents bare land or/and rock. Moderate value (0.2 to 0. 3), represent shrub and grassland, 0.4-0.5 represents bushland/woodland while high value (0.6 and above) indicates dense vegetation e.g temperate and rainforest. The negative NDVI values, represent water bodies (Gandhi *et al.,* 2015, Singh, *et al.,* 2015).

3.2.3. Extraction of digital elevation models and drainage network

The Digital Elevation Model (DEM) of the study area was generated from the digitized contour values from a topographical map of the study area as at 1966 on a scale 1:100,000. The slope map was generated using surface analysis tool of the ArcGIS 10.5. Also generated from the topographical map was the drainage network of the study area.

3.2.4. Calculation of flow direction

Based on the approach presented by Jenson and Domingue (1988), the flow direction of runoff in the study area was calculated using eight-direction (D8) flow model in the ArcGIS environment. The eight –directional way has value expressing the way in which water flows. The values are 1, 2, 4, 8, 16, 32, 64 and 128. When water flows in the direction of east, it has value 1, when flow west, it has value 16. If water flows northward or southward, the value is 64 and 4 respectively (Jenson & Domingue, 1988).

4. Results and Discussions

4.1. Land Use and Land Cover Temporal Analysis

Land use and land cover (LULC) were classified into 3 categories; built-up, vegetation and bare land/outcrop (Table 1 and Figure 2). The accuracy assessment of the image classification is shown in Table 2 with overall accuracy of 93.3%, 90.0% and 86.7% respectively for 1986, 2002 and 2017, respectively. The kappa values for the 3 years indicates a very strong agreement between the images and ground truthing as the values (0.8 - 0.90) tends towards 1 (Bogoliubova and Tymków, 2014).

From Table 1, built-up area covers about 16.04 km^2 (29.39%) in 1986 and increased to 23.83 km^2 (43.64%) of the study area in 2017, with an annual increase of 1.65% (1986-2017). Vegetation covers about 26.87 km^2 (49.21%) of the study area in 1986 and decreased to 7.73 km^2 (14.16%) in 2017, with an annual decline of 2.30% between 1986 and 2017. Bare-land/outcrops covers about 11.68 (19.60%) in 1986 and increased to 23.04 km^2 (42.20%) in 2017, with an annual increase of 3.13% (1986-2017). From Table 1, a large scale decline (0.885 km^2) was observed in vegetation during 2002 to 2017 and this may have been partly responsible for the increase experienced in the same period under bareland/outcrop land use (0.586 km^2). However, the changes experienced in the study area was not unexpected as a result of increase in the demand for residential purpose and agricultural land to take care of increased population in Akure during this period in terms of accommodation and food provision. Hassan, *et al.* (2015) observed a similar trend between 1992 and 2012 in Islamabad, Pakistan where an astronomical increase was observed in built-up land use at the expense of other land uses such as bareland and forest that were on continuous decrease. A similar trend was observed by Rahaman *et al.* (2012) in North-West District of Delhi where built up land use increased from 3% in 1972 to 28% in 2003. Figure 2 clearly show the transformation in the Land Use (LU) changes between 1986 and 2017 with built up expanding into bare/outcrop and vegetation land uses which was mostly prominent around the wetland along Ala rivers and towards the North-eastern direction in the study area. Consequentially, the changes in the LULC has some detrimental effects on the environment in form of loss of prime agricultural/arable lands, induces surface run-off, erosion, transporting sediments downstream and waste materials into Ala River (Ibitoye, *et al*., 2019).

Table 1: Land use/Land cover change in the study area between 1986 and 2017

LAND USE AND LAND COVER	Area (Km^2) / %			Annual rate of change (Km^2) / %		
CLASSES	1986	2002	2017	1986 - 2002	2002 - 2017	1986-2017
BUILT UP	16.044 (29.39)	19.346 (35.44)	23.826 (43.64)	0.206 (1.28)	0.299 (1.55)	0.251 (1.56)
VEGETATION	26.869 (49.21)	21.004 (38.47)	7.733 (14.16)	-0.366 (1.36)	-0.885 (4.21)	- 0.617 (2.30)
BARELAND/OUTCROP	11.683 (21.40)	14.246 (26.09)	23.037 (42.20)	0.160 (1.37)	0.586 (4.11)	0.366 (3.13)
TOTAL	54.596 (100.00)	54.596 (100.00)	54.596 (100.00)			

Note: Figures in bracket are the percentage of land cover in each land use category.

Table 2: Accuracy assessment of images used for land use/land cover classification in the study area

	Accuracy assessment					
Land use/land cover	1986		2002		2017	
	Producer	User	Producer	User	Producer	User
Vegetation	100	83.3	90	81.8	80	88.9
Built-up	100	100	100	90.9	100	90.9
Bare ground/outcrop	80	100	80	100	80	80.0
Overall accuracy	93.3		90		86.7	
Kappa	0.90		0.85		0.80	

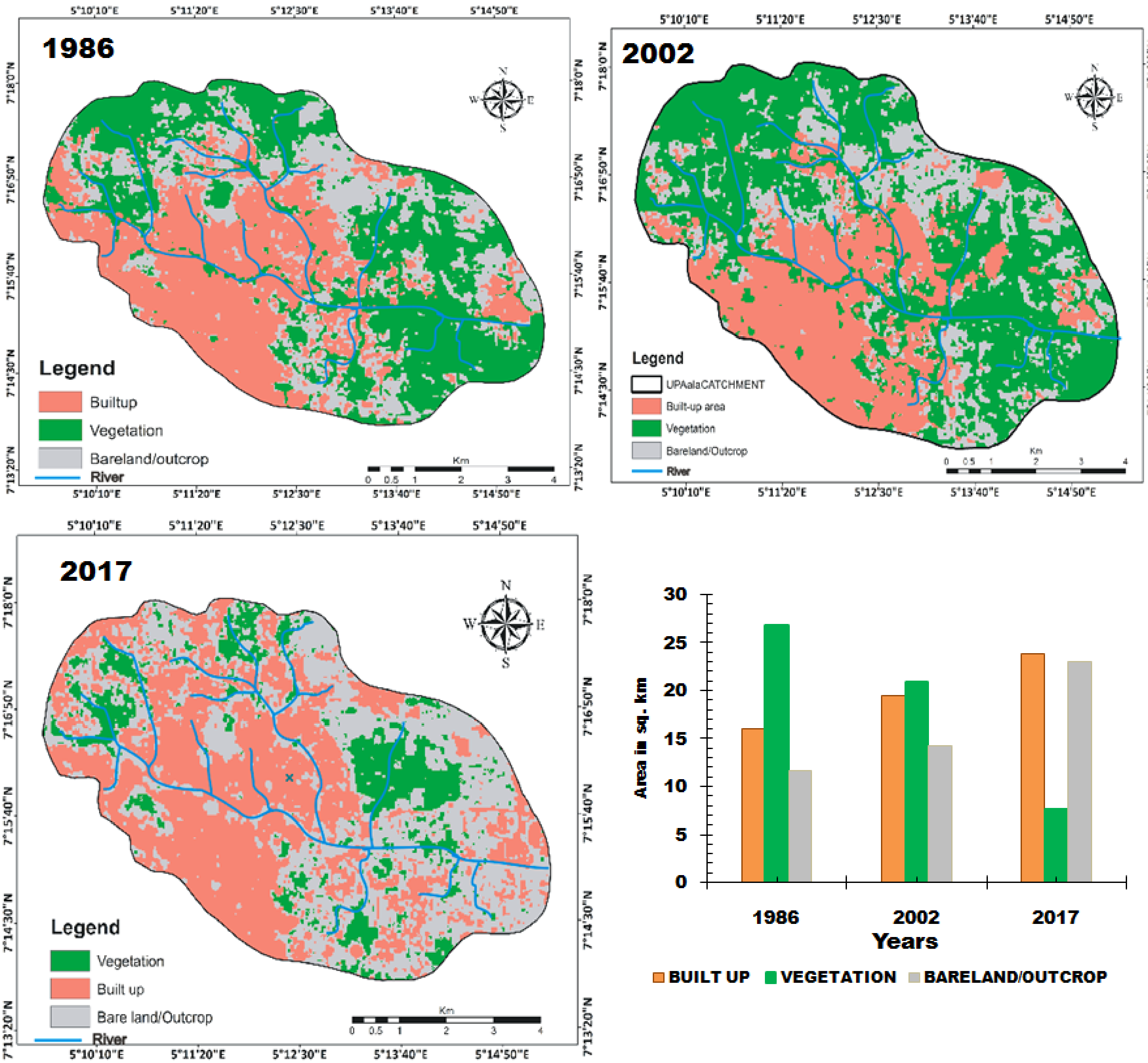

Figure 2: Changes in area occupied by built-up, vegetation and bareland/outcrop around Ala River basin in Akure, Southwest Nigeria.

4.2. Vegetation Analysis

NDVI is an important biophysical indicator of soil erosion and land degradation in general, which can be estimated from imageries using vegetation indices. The values of NDVI obtained for the study area are shown in Figure 3. In 1986, the NDVI values range between -0.034 and 0.364 and by 2002, the values were between -0.328 and 0.331 and by 2017, the values ranged between 0.038 and 0.319 (Figures 3). Generally, the values of NDVI as an indicator for the detection of surface features shows that the study area fall within less than 0 and 0.33 (Gandhi *et al.,* 2015). This indicates that the surface features ranged from bareland/concrete to degraded or poorly vegetated. In a general assessment, the lowest values of NDVI correspond to the portion categorized as built up in the study area which were on continuous increase while the highest value of 0.33 correspond to the portion categorized as vegetation (see Figure 3). It is therefore suffice to say that the rapid change in the vegetation decline is observed to be directly proportional to the increased urbanization rate and process as the increase in the rate of urbanization will deplete the vegetation cover in the study area. This decline in the vegetation and increase rate of urbanization has great influence on land degradation in the study area as the process has a correlation with increase surface runoff that will lead to soil loss through erosion processes. It is worth to note that plant cover protects soil from direct impact of raindrops and also slows down surface runoff and allows excess surface water to infiltrate into the soil. The reverse is the case when the surface is bared and thus encouraging surface runoff as in the case of built up and bare land/outcrop land use categories in the study area.

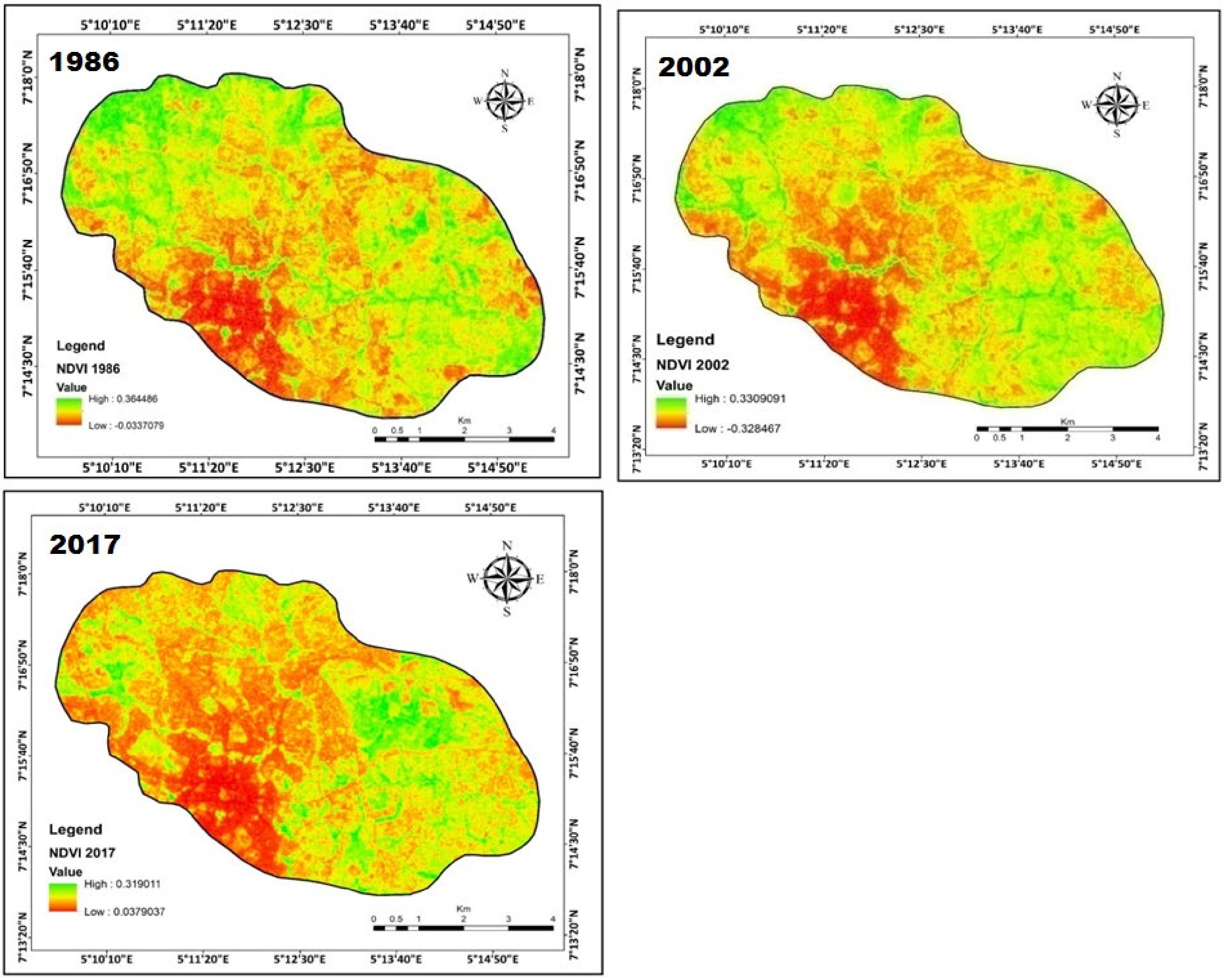

Figure 3 Changes in Normalized Difference Vegetation Index (NDVI) between 1986 and 2017

4.3. Slope, runoff and flow direction.

The slope of the upper catchment area of River Ala varies greatly, with the North part characterized by highlands with a very steep range of slope 6.4 -10.7 and 10.7 - 17.9 (Figure 4). However, some areas are as low as between 0-1.5 and 1.5-3.5 particularly along the river channel. The implication of the slope pattern is that there will be more runoff generation from highland to lowlands as the terrain of the study basin is characterized of steeper and longer slope. This character of the terrain serves as a potential area for soil erosion as runoff will accumulate faster with more energy and consequently causing rill and gully erosion in the study area. The result of analysis of LULC of the studied basin showed that more portion of the basin, particularly the urban and bareland/outcrop were exposed to direct impact of rainfall due to poor infiltration capacity of these surfaces. Increase in urban land use surface is direct related to increase in the impermeable surface (paved and compact bare soil) which resulted to more rainfall ending up as runoff along the slope and constituted to inundation in the flood plan of the drainage basin similar to observation of Ibitoye, *et al.* (2019) at Ala River flood plan of Akure.

The flow direction map (Figure 5) indicated that runoff will flow in all the eight directions with the resultant values ranged from 1, 2, 4, 8, 16, 32, 64, 128 thus, confirming the eight direction pour-point model diagram (Jenson & Domingue, 1988). However, most of the runoffs will flow mainly East, South and South-eastern directions with the greater portion flow towards the South-eastern direction. Eroded materials will be transported from steep slope to moderately flat terrain with gentle slope. Unfortunately, the flat terrain in the study area fall within the highly urbanized area and this section of the basin suffers incessant occurrence of flood, particularly in the rainy peak period (July-Sept) (Ibitoye, *et al*., 2019).

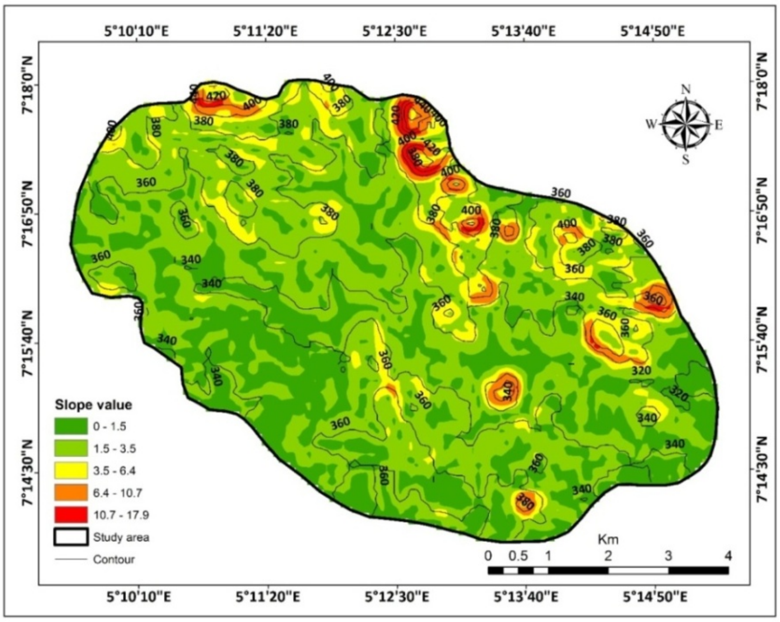

Figure 4: Contour and slope map of the study area.

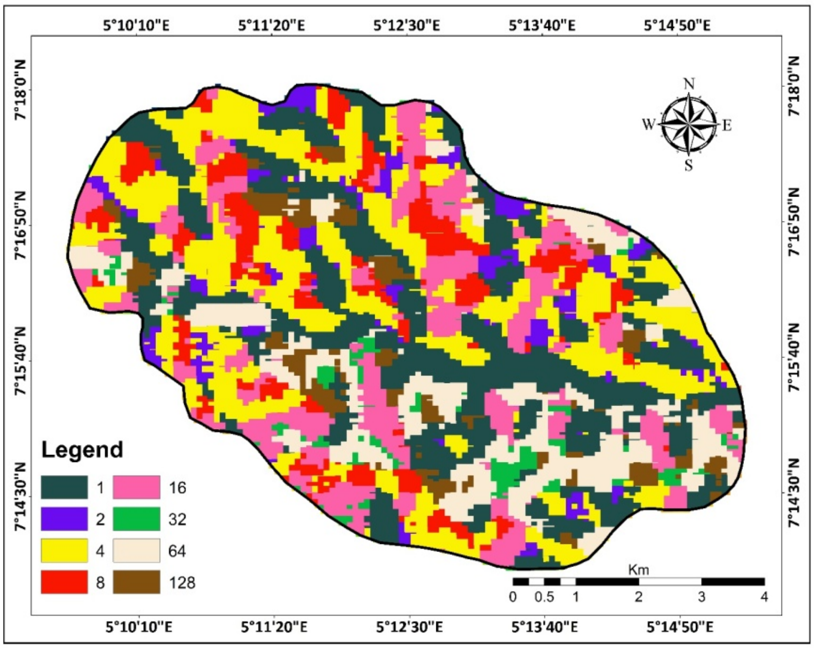

Figure 5: Flow direction map of the study area.

5. Conclusion

The study shows that land use and land cover in the study area has changed significantly over the years and the use of Remote Sensing and GIS techniques in this research has facilitated an easier analysis and interpretation of the changes that has happened in the area. The LULC analysis over the period of study (1986-2017) indicated that built up and bareland/outcrop show continuous increase from 29.39% (built up) and 21.4% (bareland/outcrop) in 1986 to 43.64% (builtup) and 42.2% (bareland/outcrop) in 2017. Expectedly, the study also revealed that vegetation land use was declining at a very alarming rate of 2.3% annually, decreasing from 49.21% in 1986 to 14.16% in 2017. The spatial distribution of the NDVI value (0.038 – 0.319) as revealed in the NDVI maps confirmed that the greater proportion of the study area tends towards zero value which indicates non vegetal surface, such as built up and bareland/outcrop surfaces. Based on the results of analysis in this study, it is evident that there was unsustainable land use pattern in the study area and therefore needs great intervention through proper policy formulation and implementation. Relevant government authorities such as Town Planning Authority and environmental agencies were charged to be alive to their statutory roles in ensuring sustainable urban development which will minimize the rate and severity of land degradation in the study area and in other similar surface characteristics. Such policies should be targeted at regulating human activities that change the land surface such as layout designs, construction of buildings and infrastructure.

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