

Implications of Land-Use and Land-Cover Changes for Geomorphic Processes in Selected Parts of Kebbi State, Nigeria

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ABSTRACT

This paper examined the implications of land use and land cover changes for geomorphic processes in selected parts of Kebbi State. Specifically, the objectives of the study entailed a time series analysis of Landsat 5TM of 1991, Landsat 7 ETM of 2003 and 2020 Landsat 8 Operational land Imager (OLI) imageries of the study area to assess the rate and magnitude of LULC changes, identify the LULC change patterns and establish a relationship between changing land use/cover and geomorphic processes in the study area. Major land use classes used to determine changes in land use/ cover are built-up areas, water body, plantation, farmlands, scrubland and Badlands land uses. These were classified in the ArcGIS 10.5 environment. Descriptive statistics were used to summarize data obtained while the chi-square analysis was used to test for significant changes recorded over the examined period. The results showed that the land uses which recorded major changes are the built-up land use (increased from 18km² to 334.73km²), scrubland (decreased from 2330.13 km² to 1581.32km²) and water body (declined from 45 to 17.07) between 1991 and 2020. Chi-square analysis carried out to determine the level of significant changes in the land use and land cover categories for the periods studied shows statistical significance at $p < 0.05$. This result shows that significant changes occurred in the respective land use/land cover types over the examined period. Similarly, dominant geomorphic processes identified in the study area are erosion and flooding, triggered by land use and land cover changes. The study recommends improved technology in mapping and land suitability assessments, maintaining an up-to-date geo-information system and linking geomorphological information to infrastructural planning and development.

Keywords: Geomorphic processes, LULC changes, Satellite imageries,

1. INTRODUCTION

Land is the most important natural resource on which all activities are based (Abubakar and Sawa, 2016). Land use is the human activity that takes place on, or makes use of that land such as residential, commercial, industrial land uses

(Abubakar and Sawa, 2016; Bello *et al.*, 2014), while land-cover is the biophysical state of the earth's surface (Bello *et al.*, 2014).

Land use and land cover change is a prominent issue in urban geomorphology, with

consequences for land degradation and urban planning (Fashae *et al.*, 2022) and has been recognized as one of the main influencing factors of soil erosion, flooding and desertification processes (Abubakar and Sawa, 2016; Mohammadi *et al.*, 2021). Although such geomorphic processes can occur without human interference, studies have shown that accelerated rates of deforestation, loss of agricultural lands, excessive groundwater withdrawal and urban expansion into marginal lands are some of the ways through which humans interfere with natural environmental processes (Abubakar and Sawa, 2016; Yousaf *et al.*, 2021).

Land use practices which result in land cover changes represent a major source of global environmental degradation (Yousaf *et al.*, 2021). Various studies have found that major implications of land cover and land use changes are disruptions in the hydrological response of a watershed, soil erosion and loss of soil fertility (Yousaf *et al.*, 2021), conversions of natural vegetation resulting in vegetation changes and decline in biodiversity (Seki *et al.*, 2018), loss of agricultural lands due to urban expansion and the growth of uncontrolled human settlements. Inappropriate land use practices manifest in land use and land cover changes and increasing vulnerability of land surfaces to flooding and erosion processes (Bashir *et al.*, 2020; Yousaf *et al.*, 2021). Similarly, increasing desertification and aridity in northern Nigeria, exacerbated by deforestation have severe implications for climate, soils and food security.

Emerging from researches in the last few decades is an attempt to develop different methods and techniques for effective assessments and monitoring of land use and land cover changes (Abubakar and Sawa, 2016; Eswaran *et al.*, 1997; Bashir *et al.*, 2020; Zhang *et al.*, 2020). Satellite Remote Sensing (RS) and Geographic Information Systems (GIS) are widely used tools in various fields including land cover assessment and land use change (Eswaran, *et al.*, 1997). The use of remote sensing provides timely and reasonably reliable information for large area monitoring supported by sufficient ground data (Eswaran *et al.*, 1997). Large scale monitoring needs considerable amount of human resources

and time if generated through field studies only. Remote sensing can facilitate studying the factors which influence land/soil degradation processes such as soil type, slope gradient, geology and land cover changes. Satellite imageries can also be used for studying erosional features such as gullies and vegetation cover.

A major advantage of remote sensing over other systems is its cost effectiveness for large area monitoring, geo-referencing and near real-time monitoring of land degradation (Eswaran *et al.*, 1997; Bashir *et al.*, 2020; Zhang *et al.*, 2020). Geographic Information System (GIS) has emerged as a powerful tool for handling spatial and non-spatial geo-referenced data for preparation and visualization of input and output and for interaction with models. There is considerable potential for the use of GIS technology as an aid to soil erosion inventory with reference to soil erosion modeling and risk assessment. Shortcomings of the Remote Sensing and GIS technique include temporal resolution of most of the high-resolution sensors which may not be efficient in capturing critical greening of vegetation, selection of appropriate analytical technique, timely data availability and delivery while using the remotely sensed data for land degradation studies (Eswaran *et al.*, 1997). It is argued too, that GIS and Remote Sensing techniques may not detect sheet erosion and nutrient depletion which are also very serious forms of soil degradation (Stringer and Reed, 2006).

Various studies have been carried out in Kebbi State to assess land use and land cover changes. For example, Aleiro *et al.*, (2018) evaluated soil physical properties and their impact on vegetation status in Kebbi State, using geo-spatial techniques. Bello *et al.*, (2014) in assessing land use and land cover changes in Zuru, Kebbi State, found that the changing land use and land cover process has led to the elimination of vegetated land with rapid decline in water bodies. Similarly, Abubakar and Sawa (2016) in an analysis of land use land cover in Birnin Kebbi found that built up areas increased at a rate of 29.87% between 1986 and 2009 while agricultural lands decreased at the rate of 48.4% within the study period. Although literature exists, there is very limited data on the

implications of land use and land cover changes juxtaposed with geomorphic processes in the study area. Thus, while several studies on land use and land cover assessments have been carried out in the study area, there is need for studies which integrate land use change assessments with geomorphologic processes for effective planning and sustainable environment. Specifically, this study aims at an assessment of the implications of land use/land cover changes for geomorphic processes in selected parts of Kebbi State, Nigeria. The objectives include assessing the magnitude and rate of land use and land cover changes from the multi-temporal LULC data (1991, 2003 and 2020), identifying the land use and land cover change patterns and establishing a relationship between changing land use/cover and dominant geomorphic processes in the study area.

2. MATERIALS AND METHODS

2.1 Study area

Kebbi State is located on latitude $12^{\circ}10'.90''\text{N}$ to $12^{\circ}40'.00''\text{N}$ and longitude $3^{\circ}50'.00''\text{E}$ and $4^{\circ}50'.00''\text{E}$ (Fig.1). The climate is dominated by two air masses, Tropical Maritime and Tropical Continental which determine the two dominant seasons of wet and dry. The wet season lasts from April to October in the south and May to September in the north; while the dry season lasts for the remaining period of the year. Rainfall is highly seasonal and varies from over 1000mm in the southern parts to less than 500mm in the northern part (Aleiro *et al.*, 2018). Average temperatures range from 21°C to 40°C between April and June. Relative humidity is generally low (40%) for most of the year except during the wet season when it reaches an average of eighty percent.

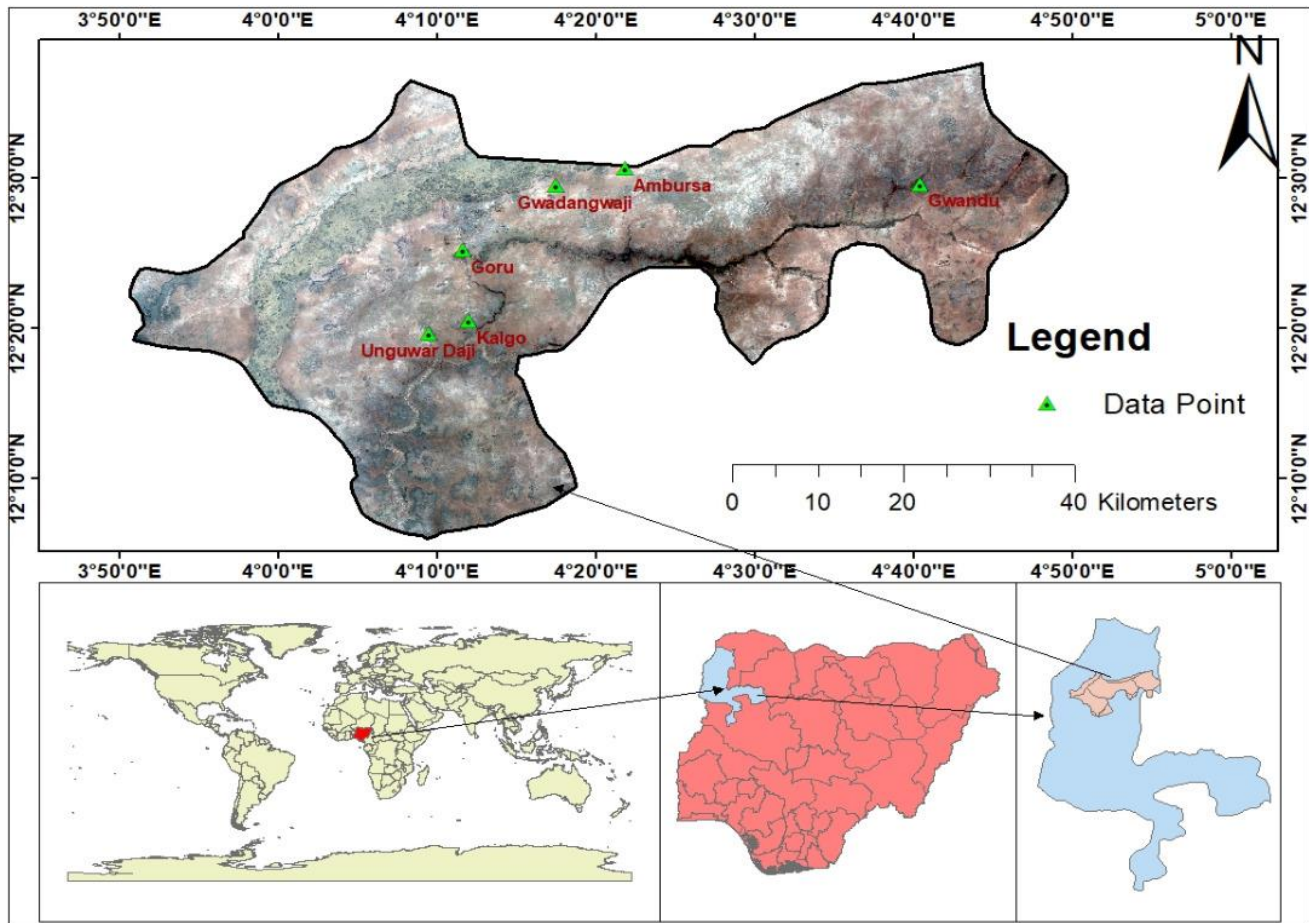


Figure 1: Geographical Location of the Study Area
Source: Laboratory Analysis

The river Rima flows through the sedimentary area into the River Niger in the south west, creating extensive flood plains. Kebbi State can be divided into three relief regions, namely the high plains in the south and south east, the plain landscape in the north and the riverine lowland of the Niger and lower Rima valleys (Mailumo *et al*, 2011). The high plains are characterized by dissected crystalline rocks with hill ranges and domical rises (inselbergs). The plain landscape, where the study area is situated, is monotonous lowland and forms part of the vast Sokoto plains. It is sedimentary in origin, with an average height of about 300m above sea level. The plain surface is interrupted by isolated flat topped lateritic capped hills and ridges. The riverine lowlands are

dominant economic activities in the study area (Usman, 2016; Aleiro *et al*, 2018).

2.2. Landuse and land cover analysis

For the estimation of land use and land cover (LULC) changes, images for three time periods (1991, 2003 and 2020) were used for the study; Landsat 5TM of 1991, Landsat 7 ETM of 2003 and 2020 Landsat 8 OLI (Operational land Imager), with spatial resolutions of 30 meters. Two scenes each, from the satellite imageries were downloaded for the study area using 191/051 and 191/052 paths and rows. The images acquired were then mosaic to adequately cover the study area. Fig. 2 shows a methodology workflow used in the study. The satellite images obtained from the Landsat images were enhanced

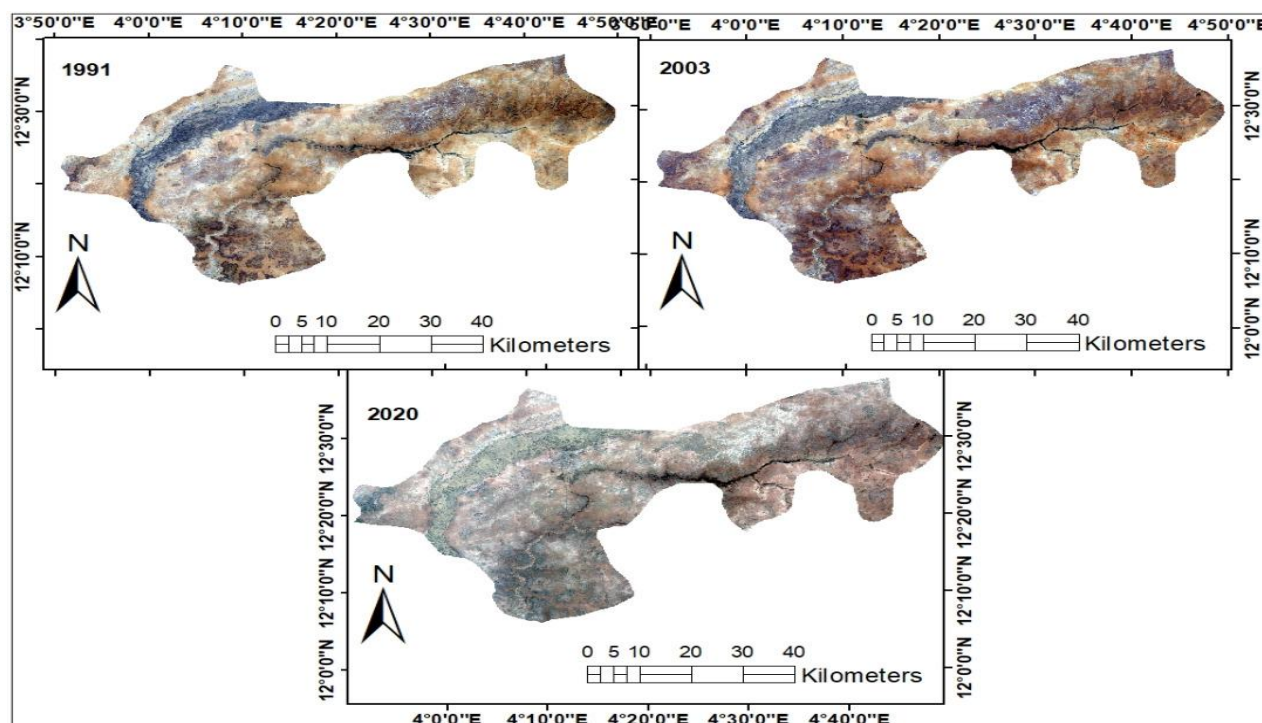


Figure 2: Composite Imageries of the Study Area

Source: Laboratory Analysis

mainly the flood plains of the major rivers (Aleiro *et al*, 2018). The natural vegetation of the study area is the Sudan Savannah and consists mainly of shrubs and bushes with few trees of economic value such as *acacia aibida* (gawo) and drum palms (goriba). Dominant soil types are the upland and fadama soils while rain-fed agriculture and wetlands (*fadamas*) are the

using filtering techniques to improve visibility in ERDAS Imagine V16. Sequel to the image enhancement, a true color composite (TCC) of band 543 was maintained in the selection of training samples for the various LULC groups. The images were subjected to geometric corrections and preprocessing due to radiometric and geometric distortions. A uniform date of data

access which can eliminate the influence of seasonal variations was difficult to maintain due to a lack of consistency in dates from data source. The composite images were classified into six different LULC groups as badlands, water body, scrublands, farm lands, built-up-lands and plantation for 1991, 2003 and 2020 respectively. The accuracy of the classified LULC classes for different images was estimated using Google Earth images, Kappa statistics and confusion matrix.

Post-classification was done to quantitatively evaluate changes in each of the classified images. This approach provides an accurate and reliable method through which spatiotemporal changes can be assessed over geographical points. To this end, all classified maps were imported into ArcGIS 10.5 environment and the six LULC classes (built-up areas, water body, plantation, farmlands, scrubland and badlands) were determined. This was followed by change detection analysis (ERDAS field guide, 1997; Lillesand *et al.*, 2006). The overall change detection matrix was then calculated. It involves a measure of user's accuracy, producer accuracy and the Kappa coefficient. Table 1 shows the confusion matrix generated for the study.

correctly classified as a land cover divided by the total number of sites classified in that category (Congalton, 1991; Lillesand *et al.*, 2006). The user's accuracy calculated is 0.76 or 76%. The Kappa statistics is a measure of overall agreement between image data and the reference (ground truth) data. It is on a scale of 0 and 1, where the later indicates complete agreement. Kappa Coefficient is given as;

$$K = \frac{N \sum_{i=1}^r X_{ii} - \sum_{i=1}^r (X_{i+} \times X_{+i})}{N^2 - \sum_{i=1}^r (X_{i+} \times X_{+i})} \dots(1)$$

Where:

r = number of rows in the error matrix

X_{ii} = number of observations in row i column i (along the major diagonal)

X_{i+} = marginal total of row

X_{+i} = marginal total of column

N = total number of observations included in the matrix

The Kappa coefficient for the classification is 0.64 while the overall accuracy of the

Table 1: Confusion Matrix for Landsat 8 2020 Classified LULC Map

LULC	Built-Up Area	Water Body	Plantation	Farm Lands	Scrub Land	Badland	Total	User's Accuracy %
Built-Up Area	15	0	0	0	1	1	17	88.24
Water Body	0	13	0	1	0	0	14	92.86
Plantation	0	0	8	0	0	0	8	100.00
Farm Lands	0	2	5	12	3	3	25	48.00
Scrub Land	0	0	2	2	11	7	22	50.00
Badland	0	0	0	0	0	4	4	100.00
Total	15	15	15	15	15	15	90	
Producer's Accuracy %	100.00	86.67	53.33	80.00	73.33	26.67		
Overall Class Accuracy%	70.00							
Kappa Coefficient	0.64							

The producer's accuracy for this study is 0.70 or 70%. User's accuracy, on the other hand, indicates reliability or the probability that a site classified on the image is really that land cover type on the ground. It is the number of sites

classification is 70%. The overall accuracy is represented by the ratio of the number of correctly classified pixels by the total number of pixels sampled. A total of 90 sample points were used in this study. Descriptive statistics in the

form of mean and percentages were used to summarize the data generated while chi-square analysis was used to test for significant changes in land use and land cover changes over a period of nineteen (19) years.

3. RESULTS AND DISCUSSION

3.1 Land use and land cover changes (1991-2020)

Figures 3a-c show the classified land use/land cover maps of the study area for the periods between 1991 and 2020, while Table 2 shows the

associated statistics. The results of classifications show six classes of land use/land cover types and indicate that the built-up areas increased from 18km² (0.65%) in 1991 to 86.6km² (3.1%) in 2003 and 334.6km² (12%) in 2020. Water body occupied 45km² (1.6%) in 1991 but shrank to 29.9km² (1.1%) in 2003 and 17.07 km² (0.61%) in 2020. Plantation land use declined from 9km² (0.32%) in 1991 to 3.86km² (0.14%) in 2003 and increased again to 9.81 km² (0.35%) in 2020. Farmlands increased from 175km² (6.3%) in 1991 to 260km² (9.35%) in 2003 and 476.93km²

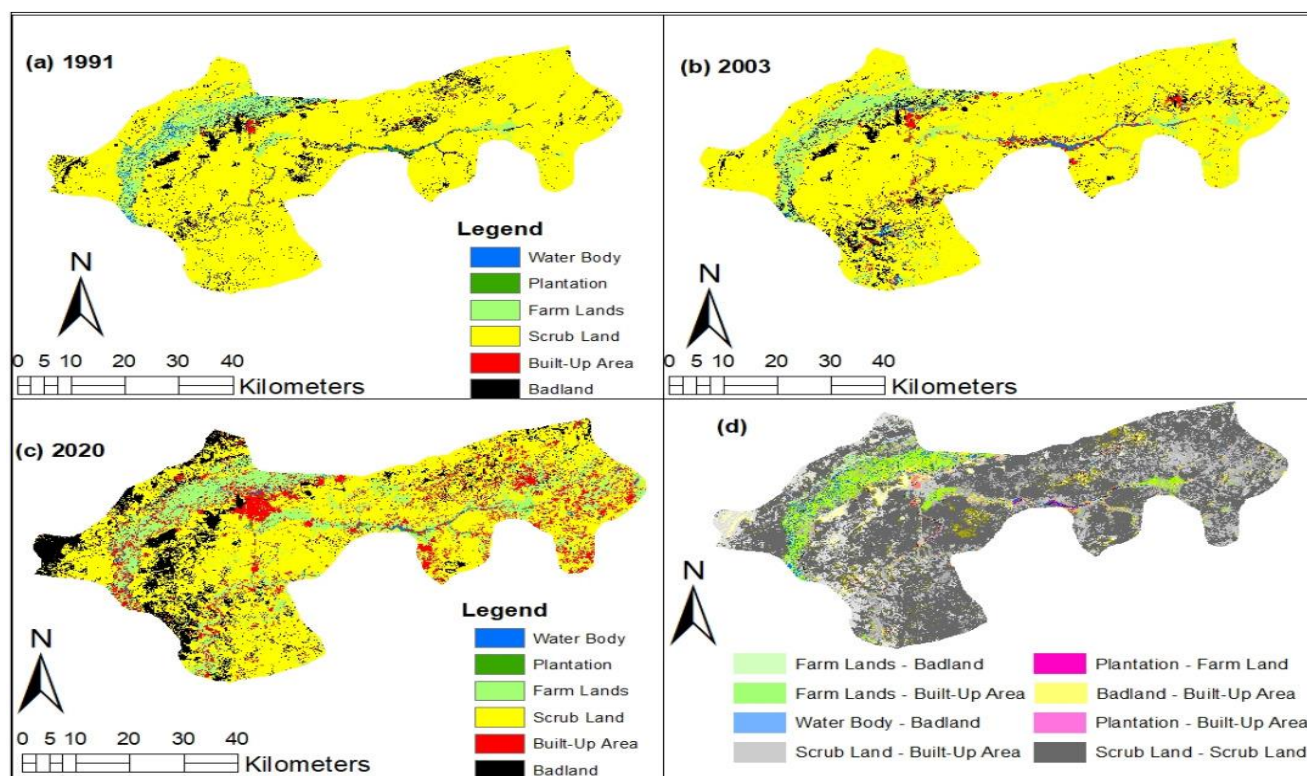


Figure 3a-d: Classified Land use/Land Cover Maps of the Study Area

Sources: Laboratory Analysis, 2021.

Table 2: Spatial extent and percentage coverage of land use/cover (1991-2020)

LULC	1991 (km ²)	(%)	2003 (km ²)	(%)	2020 (km ²)	Percentage (%)
Built-Up Area	18.00	0.65	86.58	3.11	334.73	12.04
Water Body	45.00	1.63	29.86	1.07	17.07	0.61
Plantation	9.00	0.32	3.86	0.14	9.81	0.35
Farmlands	175.00	6.29	260.09	9.35	476.93	17.15
Scrubland	2330.13	83.81	2223.59	79.97	1581.32	56.88
Badlands	203.00	7.30	176.16	6.35	360.27	12.96
Total	2780.13	100.0	2780.13	100.0	2780.13	100.00

(17%) in 2020. The results also show that scrublands decreased consistently throughout the period of study from 2330.13km² (84%) in 1991 to 2223.59km² (80%) in 2003 and 1581.32km² (57%) in 2020. The area covered by bare surfaces was about 203km² (7.3%) in 1991, decreased to 176.16 km² (6.35%) in 2003 and increased again to 360.27 km² (13%). Overall, the dominant land use/land cover types in the study area within the examined period are scrublands, bare surfaces, farmlands and built-up areas, while water bodies and plantation ranked least in aerial extent.

The results of land use and land cover exchanges between the various land use/land cover types are presented in Fig. 3d and Table 3. There are considerable variations in the net change in land use/ land cover types within the period under study. This may be attributed to seasonal variations (such as rainfall) and the dates of acquisition of the satellite imageries which may result in distortion in the trend of the different land use/cover types. For example, plantation land use declined from 9km² (0.32%) in 1991 to 3.86km² (0.14%) in 2003 and increased again to 9.81 km² (0.35%) in 2020. Irrespective of these climatic variations, there is no doubt that land use/land cover types are changing over time. For example, the decrease in the spatial coverage of badland surfaces in 2003 may be attributed to increasing population and the need for

developing existing lands for private, commercial and industrial purposes.

Similarly, spatial variations in farmlands and water bodies in the period under study are affected by seasonal variations and also by the expansion of the built up areas. The decline in the spatial coverage of cultivated land may be attributed to urban expansion and development. Results from Table 3 show that only 27.9% of the area covered by badland in 1991 remained as badland surfaces in 2020. The rest was converted into scrubland (41%), farmlands (15.8%), built-up areas (13.3%), plantation (0.99%) and water body (0.91%). The area occupied by built-up area which remained as built-up area was 42.2%. About 57% of it was converted to scrublands (24%), farmlands (23%), badlands (6%), plantation (2%) and water body (1.9%). Similarly, about 62% of the area occupied by farmlands remained as farmlands in 2020 while the rest was converted to built-up areas (19%), scrubland (11%), badland (4%), water body (3%) and plantation (0.5%). Only about 9% of plantation land use remained as plantation land use while the rest was converted to farmland (35%), built-up and scrubland (20%), water body (10%) and badland (5.3%). The area occupied by scrubland which remained as scrubland was 1466.94km² (63%). The rest was converted to farmland and badland (about13%), built-up areas

Table 3: Land use and land cover change detection between 1991-2020

LULC Units (Km ²)	LULC Units (Km ²) 2020						
1991	Badland	Built-Up Area	Farm Land	Plantation	Scrub Land	Water Body	Total
	56.62	27.00	32.14	2.00	83.39	1.85	
Badland	(27.9)	(13.3)	(15.8)	(0.99)	(41.1)	(0.91)	203.00
Built-Up Area	1.09	7.59	4.25	0.36	4.38	0.34	
Farm Lands	(6.06)	(42.2)	(23.6)	(2.0)	(24.3)	(1.9)	18.0
	7.44	32.89	109.2	0.90	19.00	5.57	
	(4.25)	(18.8)	(62.4)	(0.51)	(10.86)	(3.18)	175.00
	0.48	1.83	3.17	0.82	1.80	0.90	
Plantation	(5.33)	(20.3)	(35.2)	(9.11)	(20.0)	(10.0)	9.00
	292.78	255.44	304.41	4.68	1466.94	6.0	
Scrubland	(12.6)	(10.96)	(13.1)	(0.20)	(63.0)	(0.26)	2330.13
Water Body	1.86	9.98	23.76	1.05	5.81	2.40	
	(4.13)	(22.2)	(52.8)	(2.33)	(12.9)	(5.33)	45.00
Total	360.27	334.73	476.93	9.81	1581.32	17.07	2780.13

(11%) and water bodies (0.26%). Similarly, the area which remained as water body in 2020 was about 2.40km² (5.33%) while the rest was converted to farmlands (53%), built-up area (22%), scrubland (13%), badland (4%) and plantation (2%).

In general, the analysis of data on land use/land cover changes shows that both spatial and temporal changes in the LULC of the study area over the examined period are significant. Result of chi-square analysis carried out to determine the level of significant changes in the different land use and land cover types for the three periods studied shows statistical significance at $p < 0.05$, with a calculated χ^2 value of 114 and a table value of 18.31. This indicates significant changes in the different land use/cover types over the period studied.

3.2 Magnitude and trend of change in land use and land cover (1991- 2020)

The magnitude and rate of change in land use and land cover between 1991 and 2020 is presented in Table 4.

The results also show positive changes in farmlands, badland and plantation land uses. The upward trend in farmlands may be attributed to increased demand for arable lands and the commercial importance attached to wetland farming associated with rice production in the state (Aminu *et al.*, 2019). Similarly, the observed trend in the plantation land use category may be attributed to the increased reforestation/afforestation efforts by government establishments and academic institutions such as the Federal University Birnin Kebbi. The downward trend observed in scrubland during the period of study may also be attributed to conversion of scrublands to built-up areas due to the rapid urban expansion experienced in the study area following the creation of the state within the period under study. Similarly, the downward trend for water body over the examined period may be due to seasonal variations because many river tributaries in the study area are ephemeral streams and shrink during the dry season. Similarly, increased erosion from upstream and sedimentation may

Table 4: Magnitude of change in land use and land cover (1991- 2020)

Landuse/ land cover types	1991 (area km ²)	2020 (area km ²)	Magnitude of change (1991 -2020)	Annual rate of change (area km ² /Yr)
Built-Up Area	18.00	334.73	316.73	10.92
Water Body	45.00	17.07	-27.93	-0.96
Plantation	9.00	9.81	0.81	0.03
Farmlands	175.00	476.93	301.93	10.41
Scrub Land	2330.13	1581.32	-748.81	-25.82
Badlands	203.00	360.27	157.29	5.42
Total	2780.13	2780.13		

The results from Table 4 indicate that there is a positive change in net coverage for built up area, with consistent gains in spatial coverage from 1991 to 2020. The upward trend in built up area is a reflection of population growth and conversion of other land uses to built-up areas. The upward trend in the built-up areas is in agreement with Rikko and Laka (2013) who observed that increase in built up areas reflects the rapid population increase which converts smaller farming settlements at the fringes of the urban areas into residential land uses.

also result in decline in the aerial extent of the water bodies as observed by Aminu, *et al.*, (2019). The increased trend in badland coverage may be attributed to increased number of degraded lands no longer suitable for agricultural uses, scrubland that have been cleared and left bare for sale and conversion of scrublands at the fringes of the urban area into residential land uses. The overall trend in land use and land cover change is a reduction in scrubland and an increase in built-up areas and badlands.

3.3 Geomorphic implications of land use and land cover characteristics in the study area

Major geomorphic processes triggered by land use and land cover changes in the study area are flooding and erosion. These occur in areas where the soil has been stripped of its natural vegetation cover due to fuel wood extraction, construction (built-up) and cultivation purposes. These geomorphic responses are exacerbated by deforestation, compaction through grazing and tillage practices which are major land use types in the study area. The upward trend in built-up areas and farmlands and a corresponding decrease in shrubland indicates loss of surface vegetation.

Although rainfall characteristics such as intensity, frequency, amount and duration are a major cause of flood occurrences, studies all over the world have identified modification of surface areas due to changing land uses as a major cause of increased flood hazard and watershed vulnerability to rainfall and increased of peak flows (Issaka and Ashraf, 2017; Bashir *et al.*, 2020; Yousaf *et al.*, 2021). When rain falls over surfaces with little or no vegetation, raindrop impact acts to seal off pore spaces resulting in surface compaction, reduced porosity and infiltration. This has implications for increased runoff, sediment detachment and localized flooding (Aminu, 2015).

Soil erosion is a major geomorphic response to land use changes. It may result naturally (due to

topographic, soil and climatic characteristics) but often times; it is caused by human interference in the natural environment. For example, wind action in sediment detachment, transportation and deposition is enhanced by sparse vegetation cover and loose soils in the study area. The destruction of soil structure and texture associated with deforestation, grazing and poor agricultural practices help create conducive conditions for the development of gullies which often begin in the form of sheet or rill erosion and eventually capture the available drainage channels (Bashir *et al.*, 2020). Gullies are dominant geomorphic features dissecting the landscape of the study area and acting as stream channels during the wet season. However, this has implications for drainage density. Drainage density indicates how dissected the landscape is by channels (Aminu, 2015). It reflects the tendency of the drainage basin to generate surface runoff and the erodibility of the surface materials. A high drainage density means more runoff and less infiltration, lower groundwater recharge and more of flash flood events. Similarly, gully development, induced through conversion of forested areas to cultivated lands, results in reduction of the evaporative term in the water balance (Nyssen *et al.*, 2006; Moges and Holden, 2008), increase soil wetness and saturation and destroys the cohesive strength of the soil (Nyssen *et al.*, 2006). Plate 1 shows examples of badland sites in the study area.

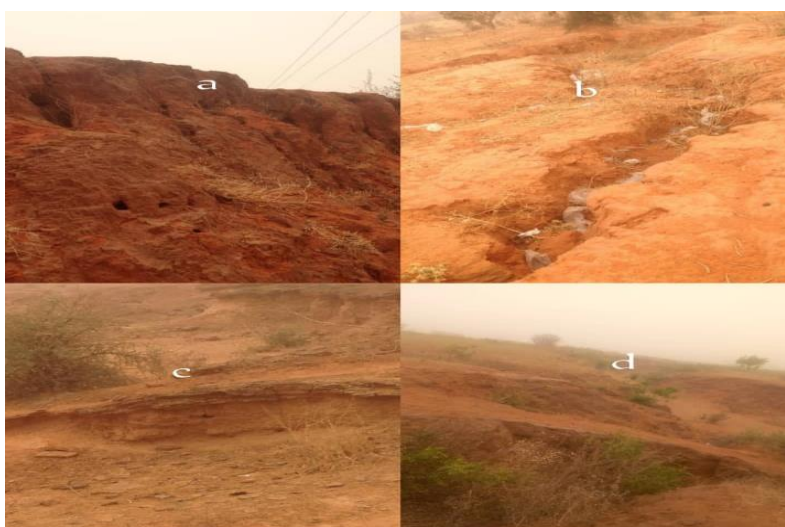


Plate 1: Examples of Badland sites in the study area
 Source: Fieldwork, 2021.

As the basic structural foundation for the built environment, soil plays an important role in the stability of structures (Brady and Weil, 2002; Gardiner and Miller, 2004). For example, the particle size distribution, soil shrinkage limits, plastic and liquid limits determine the quality of roads, houses and drainage facilities (Cameron *et al.*, 1998). In a semi-arid environment such as the study area with sparse or absent vegetation, decline in soil resilience and ecological deterioration are consequences of soil erosion linked to land use and land cover changes (Zhang *et al.*, 2020). Studies have also shown that semi-arid soils are characterized by high sand fractions, high bulk densities and are generally susceptible to degradation (Aminu, 2015; Zhang *et al.*, 2020) just as the microbial assemblage in the soil indicates soil quality due to their sensitivity to changes in the environment (Ayangbenro and Babalola, 2021).

4. CONCLUSION

This paper focused on the impact of land use and land cover changes on geomorphic processes in selected parts of Kebbi State, Nigeria. Dominant land use and land cover types in the study area are scrubland, built-up area, farmlands and badlands. While there was considerable expansion in the built-up land use, the study showed decrease in scrubland and water body. Similarly, major geomorphic processes identified in the study area are erosion and flooding. Although there is an absence of baseline data on geomorphic processes in the study area, findings from the study indicate a strong relationship between land use and land cover changes and the existing geomorphic processes, evidenced by the extensive gully erosion in the study area. Understanding the dynamics and patterns of land use and land cover changes and the spatial distribution of these geomorphic processes is fundamental for proper management of land resources and sustainable development. This study has provided baseline data on the implications of land use and land cover changes on geomorphic processes in the study area. However, future studies may consider a temporal and spatial expansion of the study, while taking into consideration the history of the dominant geomorphic responses in the study area. The study recommends improved technology in

mapping and land suitability assessments, maintaining an up-to-date geo-information system and linking geomorphological information to infrastructural planning and development.

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