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EFFECTS OF HUMAN ACTIVITIES ON MORPHOLOGY OF THE LOWER COURSE OF RIVER MAYO-INNE, YOLA SOUTH, NIGERIA

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Abstract

The study examined the effects of human activities on channel morphology of the lower course of River Mayo-Inne, Yola South, Nigeria using an integrated approach of remote sensing, geographic information system and field survey. Data on channel characteristics (width, depth, sinuosity, bed elevation, slope, and gradient) and land use/land cover spanning a period of thirty five years (1980-2015) were analysed using descriptive and inferential analysis. Results obtained shows that the mean channel width of the study river increased by 154.57 percent over the study period while sinuosity index which earlier rose from 1.53 in 1980 to 1.57 in 1990 dropped to 1.4 in 2015. Correlation analysis between both channel width and land uses revealed a negative relationships ($n=-0.62$) with vegetation and positive relationship ($n=0.66$) with cropland. The relationship between channel width and built up area exhibits perfect positive relationship ($r=1$). Reasons for the observed patterns were discussed and a number of recommendations were put forwards reducing the effects of human activities on channel morphology.

Keywords: *Morphology, Meandering, Land use/land cover, Sinuosity, Watershed.*

INTRODUCTION

Rivers are dynamic in nature and respond to anthropogenic perturbation on a spatio-temporal scale, leading to changes in fluvial landscape. Disturbances due to human activities have been classified into direct and indirect modification (Knighton, 1984). While the direct modification includes dam construction, diversion of water for irrigation, bank stabilization, channel straightening and sand mining, the indirect modification comes in form of land use/land cover changes resulting from deforestation, urbanization, and change in agricultural practices among others. Most of these activities take place within the confined of river corridor, thus modifying its sediment loads and discharge relationship, inducing dormant instability which ultimately result in stream channel response (Ibiate et al., 2011; Ortega et al., 2014).

The morphology of a river channel is the shape or form of a river along its

length and across its width (Kusimi, 2008; Singh, 2014). This evolves from the interaction between fluid dynamics, channel characteristics, sediment load, and bed and bank materials (Alan *et al.*, 2007). Empirical investigations revealed that human activities, especially those resulting to changes in riparian cover have significant effect on the supply of sediment and discharge to the river channel (Ezekiel 2007; Mubi *et al.*, 2013). Depletion of riparian vegetation due to anthropogenic activities such as farming, have both hydro-geomorphic implications of flooding, erosion and siltation on river channel (Kusimi, 2008). According to Singh (2014), such changes in hydro-geomorphic event can create complicated sedimentary structures leading to the evolution of channel planform over time. The riparian areas of the downstream segment of River Mayo-Inne, the study area in this investigation is witnessing an increase, both in number and intensity of human activities. These activities which are being encouraged by the rapid urbanization process in the region is no doubt affecting the rate of sediment production and delivery unto the river channel; hence the need for this study which seeks to investigate changes in the river channel characteristics and those activities that might be responsible for such changes.

Study Area

The study area is located between latitudes $9^{\circ} 16'$ and $9^{\circ} 26'$ north of the Equator and between longitudes $12^{\circ} 12'$ and $12^{\circ} 20'$ east of the Greenwich Meridian (Figure 1). River Mayo-Inne which is the data collection point is a third order tributary channel within the Benue catchment and it takes its source from Jangali hills in Toungo L.G.A.

The climate of the region is savanna type with rainy season between the months of May and October and the dry season between the months of November and April. The annual rainfall ranges between 800 and 1100mm. The vegetation of the study area can be classified as the Sudan Savannah type that covers most parts of the northern states (Ileje, 2001; Zemba, *et al.*, 2010).

The soil types found in the study area include luvisols, combisols, and alluvial soil (Adebayo and Tukur, 1999) and the relief falls within the plains of the Benue trough that range in height between 140m and 311.1m above sea level. The dominant drainage pattern in the region is dendritic in nature while the study river meanders in the downstream segment to join River Benue which serves as local base level.

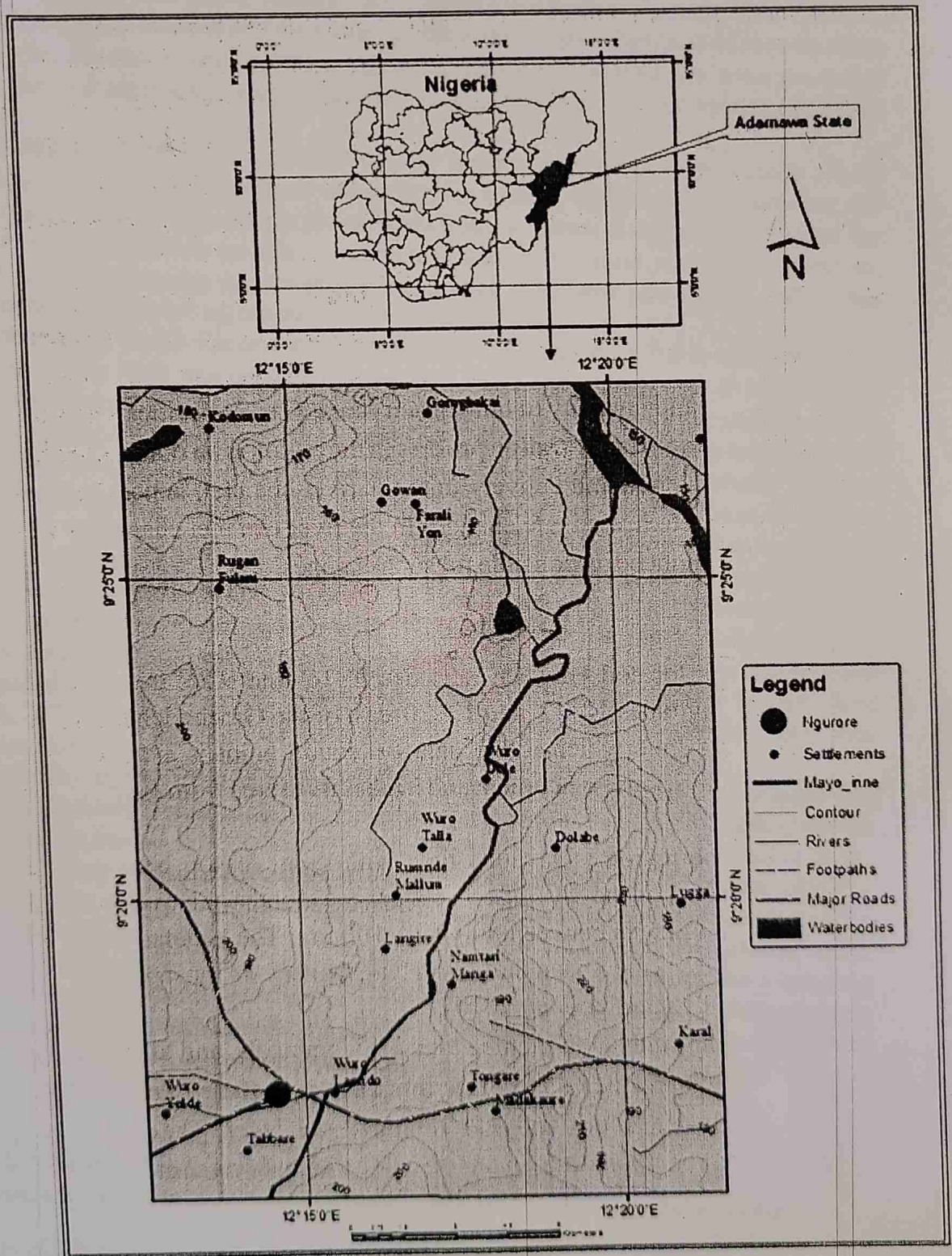


Figure 1: Map of the Study Area

Source: Adapted from Federal Ministry of Land and Survey (1970)

Research Methods

Data used in this study include information on channel characteristics such as bankfull width, depth, channel bed elevation, gradient and slope. Other sets of data are those on land use/land cover and other anthropogenic activities. These data sets were generated using an integrated approach of remote sensing, geographical information system (GIS) and field survey.

Landsat 1980MSS, 1990 ETM, and 2015 ETM+ images were used for this study. These images do not have global coordinate and projection system, and contain radiometric and geometric error. Various procedures were carried out, to clean and spatially aligned the image data. Such procedures include: coordinate system verification, image spatial extent, geo-referencing, resampling and re-projection, image filter and sub-setting and colour composite development among others.

Considering the profile of the river channel, a total length of 30km which form the lower course of the river was digitized in Arc GIS 10.1 environment and divided into 14 sampling reaches at approximately 2km equidistance positions from where measurements on morphological parameters were taken. The splitting of the river into sampling reaches at regular interval was done using segmentation approach based on spatial similarity in slope, discharge and land use. Ezekiel, (2007), Sarkar, (2012) and Bashir (2014) have earlier use this method to study changes in channel morphology. The channel width was measured in each of the cross-sectional reaches from the satellite imageries. Channel depth and bed elevation were measured during field survey. The coordinate of each of the sample reaches were extracted from georeferenced satellite image and uploaded in Garmin 76S handheld GPS, which was used to track the exact sample point along the channel. The channel bed gradient was computed using the formula: $\text{Gradient} = \text{VI}/\text{HE}$. Where VI= Vertical Interval (bed elevation), HE= Horizontal equivalent. Results obtained from gradients were then converted to slope.

Sinuosity Index which is the degree of meandering or winding of river channel was computed from satellite images, based on Leopold and Wolman (1957) formula given as: $\text{Sinuosity index} = \text{Stream length} / \text{Valley length}$. To analyze the land use/ land cover in the study area, both supervised and unsupervised classification were conducted in Arc GIS 10.1 environment. The supervised classification was employed to establish training sets for proper dictation of land use/land cover and morphological changes over the period of study; this was done using 2015 land sat image. The unsupervised classification was conducted with the 1980 and 1990 land sat satellite imageries. Information on other anthropogenic activities such as sand and gravel mining, grazing and local bricks industries were obtained using interview and personal observation. Both descriptive and inferential statistics were used in analyzing the data from the field.

Results and Discussion

Changes in Channel Width and Depth

Data on channel width and depth and their respective changes are as presented on Table 1.

Table 1: Changes in Channel Width of River Mayo-Inne

Sampling Reaches	Distance (km)	Channel Width 1980 (m)	Channel Width 1990 (m)	Channel Width 2015 (m)	Width Change 1980-1990	Width Change 1990-2015	Channel Depth 2015 (m)
i	2	134.95	97.32	154.58	-36.68	+57.26	2.37
ii	4	122.88	175.85	305.78	+52.97	+129.93	1.84
iii	6	134.94	125.26	212.62	-9.68	+87.36	2.12
iv	8	160.13	231.79	243.44	+71.66	+11.65	2.12
v	10	202.95	219.18	301.91	+16.23	+82.73	2.16
vi	12	105.67	154.58	241.65	+48.91	+87.07	2.30
vii	14	89.56	115.58	185.43	+26.02	+69.85	2.30
viii	16	86.52	88.27	134.94	+1.75	+46.67	2.20
ix	18	69.83	91.87	262.84	+22.04	+170.97	2.40
x	20	241.47	97.32	183.59	-144.15	+86.27	2.12
xi	22	116.47	123.06	187.04	+6.59	+63.98	2.80
xii	24	139.61	139.33	141.94	-0.28	+2.61	2.10
xiii	26	139.61	167.45	205.13	+27.84	+37.68	1.80
xiv	28	147.66	167.68	177.71	+20.02	+10.03	1.50
Mean		135.80	142.47	209.90			2.15
S.D		41.88	44.25	52.63			0.33
CV		30.84%	31.06%	25.07%			15.35%

+ indicate increase in channel width and – indicate decrease in channel width
Source: Satellite Image Analysis and Field Survey (2016)

The table revealed significant variation in channel width within the study period. Out of the 14 sampling reaches monitored between 1980 and 1990, reduction in channel width took place in 4 sampling points, while the remaining reaches showed significant increase in width dimension. Between 1990 and 2015 the table revealed that width change exhibits a positive value at all the 14 sampled points. The mean value of width parameter increases from 135.80m in 1980, to 142.25 in 1990 and to 209.90m in 2015 this represents 64.7% increase in mean width value within a period of 35 years. The channel depth also shows slight variations, it ranges between 1.50 and 2.80m; this parameter however decreases in downstream direction of the river channel. The deepest point along the river channel measures 2.80m while shallowest point is 1.50m. The mean depth of the study river is 2.15m.

The changes in channel width and depth observed in this study, can be attributed to changes in bankfull discharge and sediment deposition this is in line with earlier observations by Ezekiel (2007) and Bashir (2014). Knighton (1984),

revealed that increase in discharge and sediment in a river channel ultimately lead to increase in width and variation in channel depth. However, where river discharge decreases and sediment increase, the channel will respond by increasing or decreasing its width and on the other hand by decrease in depth.

Table 2 presents data on channel profile characteristics (bed elevation, gradient and slope) collected during field survey.

Reach Number	Distance (km)	Bed Elevation (m)	Gradient	Slope (Degree)
i	2	174	0.087	5.22
ii	4	174	0.087	5.22
iii	6	176	0.088	5.28
iv	8	170	0.085	5.10
v	10	171	0.086	5.13
vi	12	168	0.084	5.04
vii	14	166	0.083	4.98
viii	16	166	0.083	4.98
ix	18	167	0.084	5.01
x	20	162	0.081	4.86
xi	22	164	0.082	4.92
xii	24	163	0.082	4.89
xiii	26	161	0.081	4.83
xiv	28	159	0.080	4.77
Total		2341	1.17	70.23 ⁰
Mean		167.21	0.084	5.02 ⁰
S.D		5.05	0.0025	0.15
CV		3.02%	2.98%	2.99%

Source: Field Survey (2016)

The result indicates that bed level elevation of the study river ranged between 159 and 176m, with a mean of 167.21m. It has a standard deviation of 5.05 and a coefficient of variation of 3.02%. The channel gradient also varies along the river course, ranging between 0.080 and 0.088, with an average slope of 5.02⁰. Both the slope and channel gradient decreases downstream of the river channel.

The variations in bed elevation as presented on Table 2 depict the influence of anthropogenic activities along the channel profile. For instance, the channel bed elevation at reach I and II are both 174m, while at reach III the bed level elevation is 176m. The observation is in contrary to normal downstream decrease in bed elevation of a river channel. This anomaly may not be unconnected with heavy anthropogenic activities taking place within the two cross-sectional reaches. Such activities include sand and gravel mining and local brick making as can be seen on plate 1 and 2.

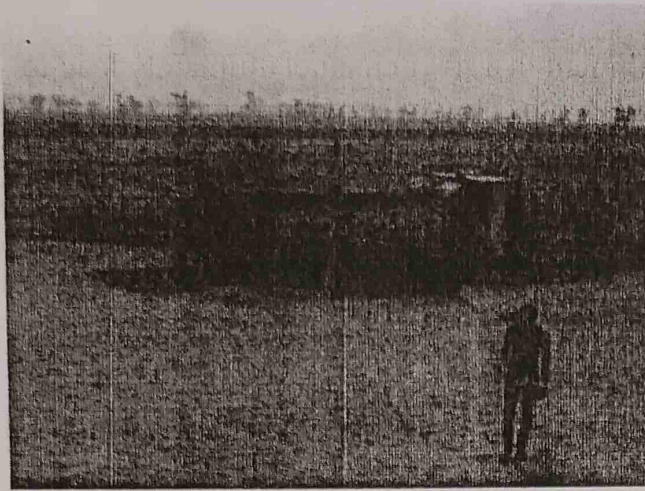


Plate 1: Dry Season In-channel Sand Mining in River Mayo-Inne, Nguroro
Source: Authors Field Work (2016)

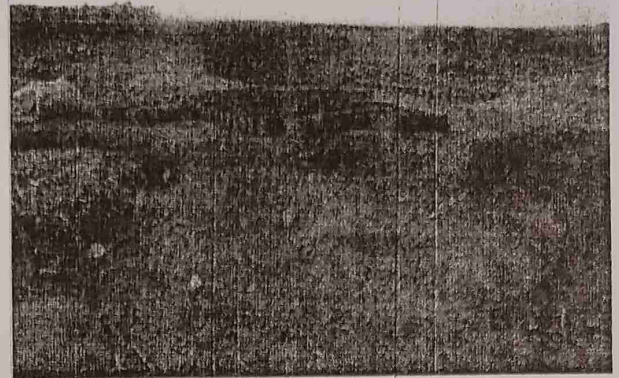


Plate 2: Local Brick Production and its Impact on Channel Bank
Source: Authors Field Work (2016)

The sinuosity index (SI) computed for the study river show distinctive variation within the study period (Table 3).

Table 3: Sinuosity Index for River Mayo-Inne

S/N	Year	Sinuosity	Channel Pattern
1	1980	1.53	Meandering
2	1990	1.57	Meandering
3	2015	1.46	Straight

Source: Satellite Image Analysis (2016)

The table reveals that the 1.53 sinuosity index for 1980 is increased to 1.57 within a period of 10 years; this result thus classifies the study river as a meandering river based on Leopold and Wolman (1957). However, the 1.57 SI value drastically reduced to 1.46 in 2015, changing the channel into a straight pattern. This sudden change in channel pattern from meandering nature to straight pattern could be linked to problems of decreased channel discharge and increased sediment deposition. In order to confirm this assertion, a correlation analysis was carried out between sinuosity index and mean annual discharge of the study river. The analysis shows a positive relationship ($r=+1$) between the two variables. This is in accordance with the process response model of channel adjustment in fluvial systems as developed by Schumm (1969) and Knighton (1984). Both authors proposed that a decrease in channel discharge, with a substantial increase in channel bed sedimentation of any river, will result in a decrease of sinuosity value of such a river.

In order to explain the factors influencing morphological changes in the study area, satellite imageries of the study area for 1980, 1990 and 2015 as presented in Figures 2, 3 and 4 were analyzed. From these imageries, change dictation analysis shows that significant changes have taken place in the six land use/ land cover generated in the study area within the study period (Figure 4).

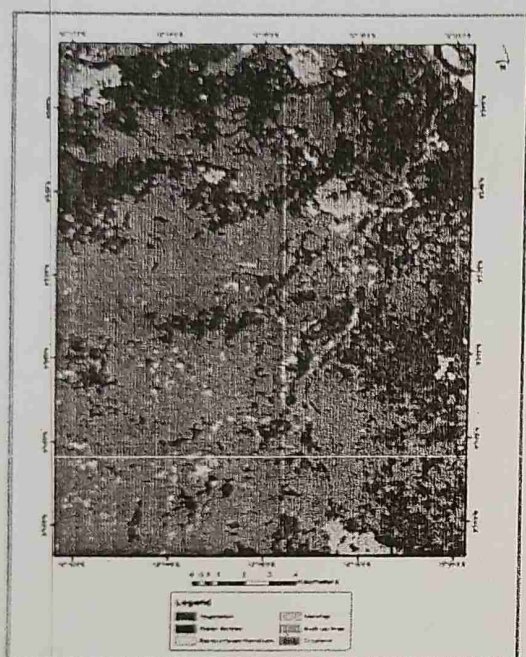


Figure 2 Satellite Image of River Mayo-Inne 1980
Source: United State Geological Survey.

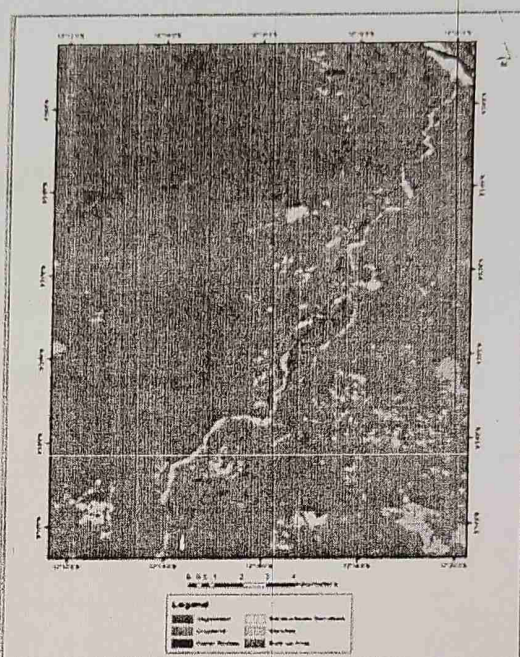


Figure 3 Satellite Image of River Mayo-Inne 1990
Source: United State Geological Survey.

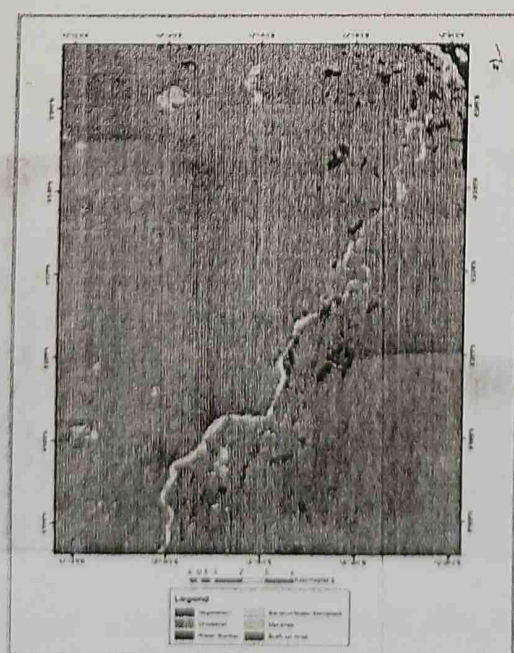


Figure 4 Satellite Image of River Mayo-Inne 2015
Source: United State Geological Survey.

The land use/land cover change detection analysis in Figures 5 to 7 shows that significant changes have taken place within the period of study.

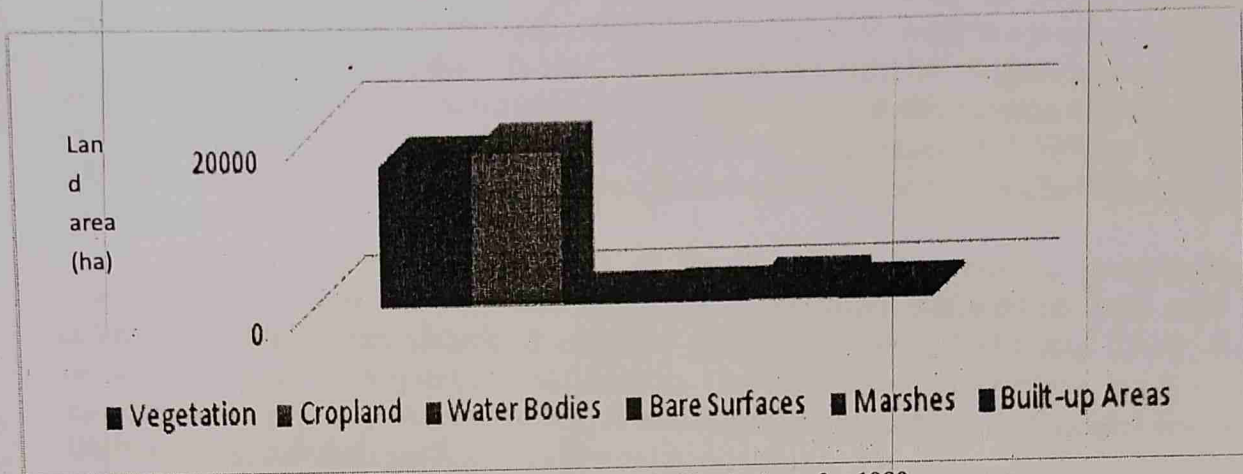


Figure 5 Land use/Land cover Classification of the Study Area for 1980

Source: Satellite Image Analysis (2016) by the Author

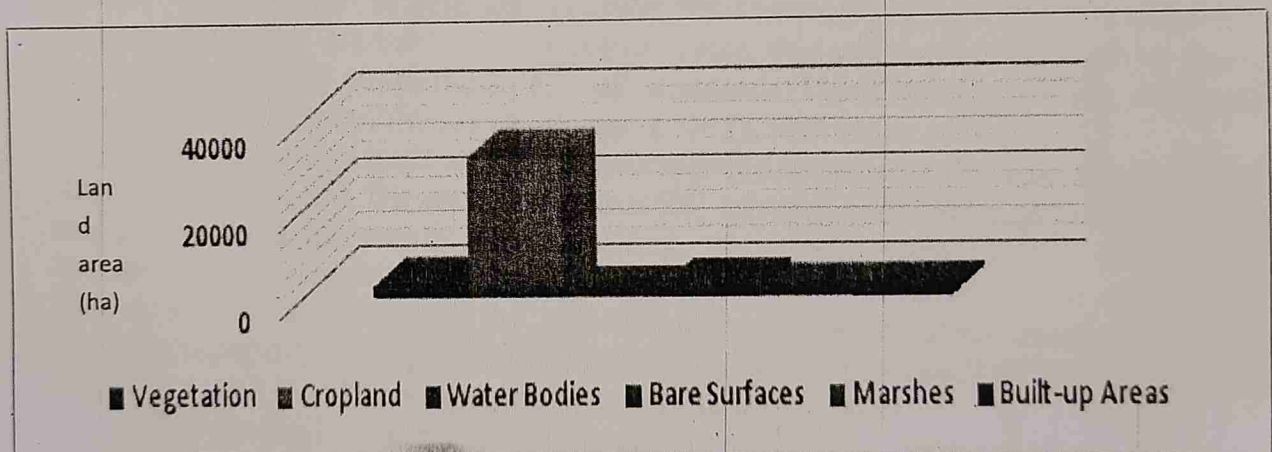


Figure 6 Land use/Land cover Classification of the Study Area for 1990

Source: Satellite Image Analysis (2016) by the Author

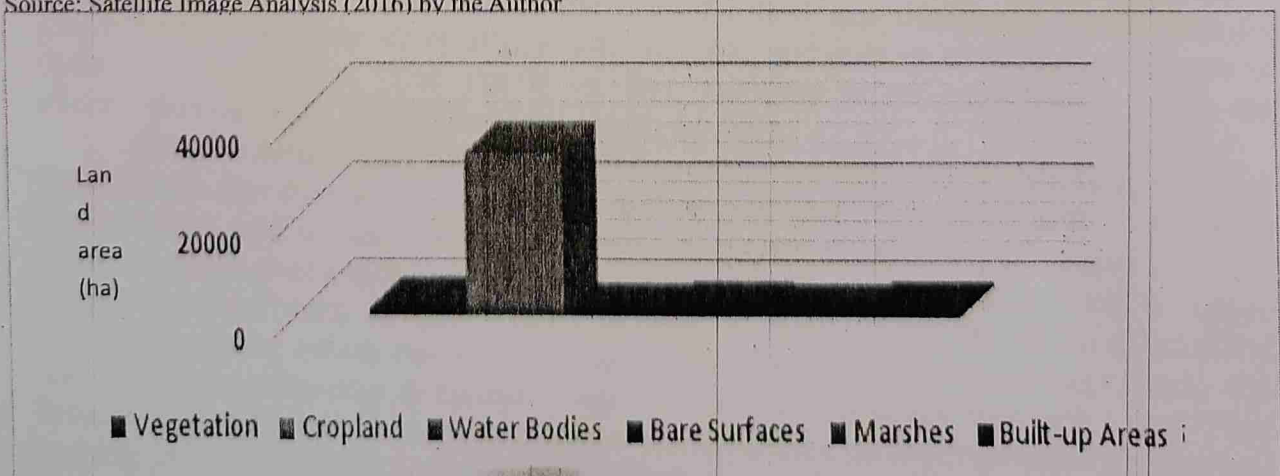


Figure 7 Land use/Land cover Classification of the Study Area for 2015

Source: Satellite Image Analysis (2016) by the Author

From the above figures, it can be seen that area covered by vegetation and cropland experienced much changes and may have been responsible for changes observed in channel morphology of the study river. The percentage area covered by vegetation which was 45.15% in 1980 reduced to 3.62% in 2015; this change represents 92% reduction in area covered by vegetation within a period of 35 years. The implication of this result is that, 2.6% area covered by vegetation is being lost annually to deforestation activities in the study area. On the contrary, area occupied by cropland increased by 88.2% from its initial coverage of 17699ha in 1980 to 33277ha in 2015. This demonstrates an increase in the rate of arable farming in the study area.

In order ascertain the effects of land use/ land cover on morphological changes; correlation analysis was carried out between changes in land use/ land cover types and mean values of channel width for 1980, 1990 and 2015. Result obtained shows a negative relationship ($r=-0.62$) for vegetation and positive relationship ($r=0.66$) for Cropland. The relationship between channel width and built up areas exhibits perfect positive relationship ($r=1$).

The increase in channel width observed in this study may not be unconnected with the decrease in vegetal cover especially the riparian vegetation. This is because reduction in riparian vegetation weakens the shear strength of bank materials and increases the lateral mobility and migration rates; this action thus make river channel more susceptible to widening by fluvial processes. This finding is in line with earlier observations made by Murray and Paola, (2003), Mubi et al., (2013).

The contrary result which shows cropland especially the arabie type helps in loosening the bonds between soil particles, making them susceptible to agent of erosion and transportation. To this effect, the loosed particles are subsequently transported and deposited in river channel, leading to the siltation of channel bed. The deposited silt reduces the effectiveness of the channel cross-section and carrying capacity, causing the river to erode its banks. The result of this analysis is in consonant with the observation made by Alan et al., (2007).

The gradual increase in built up area in relation to the mean channel width, is an indication of increased in paved surfaces in the suburbs. This reduces the rate of infiltration capacity, and increases the rate of runoff and discharge. Such changes cause the river to adjust its width, depth, gradient, and pattern to attain a new state of dynamic equilibrium. The result of this analysis is in conformity with the observation of Iroye, (2008) and Mubiet al., (2013).

Sand mining, local block industries, cattle rearing and abstraction of water for domestic and industrial use are some of the major anthropogenic activities taking place within and around the study river. Interview conducted with some of the residents of the study area found at the sand mining site revealed that over 20 tripper load of sand are being extracted daily in order to meet up with the high demand of sand from nearby urban centres like Jimeta and Yola. This factor is apparently the reason for the reduction in channel bed elevation as observed in reach I and II on Table 2. About six local block industries were identified by the researcher at Ngurore making use of both bank and bed materials in producing concrete and local bricks; such activities help in accelerating channel bank degradation.

Conclusion and Recommendations

Changes in land use/ land cover especially cropland, vegetation, built up areas and other anthropogenic activities have several consequences on the supply of sediments and discharge to the river channel. To this effects, the channel respond by changing its width, depth, sinuosity and other forms of morphological characteristics to attain a new state of dynamic equilibrium. These changes can impact negatively on riparian land uses. It is therefore pertinent for government and other relevant agencies to:

- i. develop a buffer strips of between 10 to 100m along river channel, using the original plant species that existed in the area. This will help to increase the shear strength of bank material and reduce the effect of under cutting by fluvial activities;
- ii. minimize and checkmate adverse anthropogenic activities such as clearing of riparian vegetation, over cultivation, in-channel sand and gravel mining, and grazing along the river channel. Government should also restrict or eliminate livestock access to stream banks or buffer zones. If possible, use off-stream watering sources to provide water to livestock; and
- iii. educate and enlighten the local inhabitant, on the adverse effects of anthropogenic activities on river ecosystem.

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