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ANALYSIS OF THE MORPHOMETRIC CHANGES IN ARMATAI RIVER CHANNEL KANO SOUTH, NIGERIA

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Abstract
The study investigated morphometric changes in Armatai River channel of Kano State, Nigeria. It aimed at analysing the morphometric changes at the river channel between 1986 and 2016. Purposive and systematic sampling techniques were adopted for establishing sampling points at the interval of 4kms apart. Geo spatial data was generated and used in the analysis of Landsat MSS of 2016 and Landsat ETM+ of 1986 all of 30m resolution. Arc GIS 10.3 software was used and ENV 5.1. Digital Elevation Model (DEM) of the study area was produced. Measurements of morphometic variables were carried out using instruments. Results showed relationships among channel width, slope and depth. It also shows that the river channel variables vary between the two study years in such a way that the channel width narrowed at the upper course but widened at lower course while channel depth changed both spatially and temporally and slope changed more temporally. Generally, the mean width changes from about 78m in 1986 to 59m (GIS analysis) and 56m (field measurement) in 2016. For slope from about 8^{o} in 1986 to 3^{o} in both GIS and field measurement while average depth of the river changes from 0.18m in 1986 to 0.04 (GIS analysis) due to sedimentation at the lower course in 2016, but increased to 1.03m (field measurement) in 2016 due to excessive deepening at the upper course as a result of sand mining. It can be seen that the width of the river decreases and depth increases, this is a clear indication of sand mining implications on the river channel over the years which may reduce both surface and groundwater recharge. It is recommended that findings of this study should be used for sound planning of water harvesting and groundwater recharge related projects and programmes in the area for development.

Keywords: River, morphometry, water management

Introduction

The watershed management planning highlights the management techniques to control some problems in the catchment/watershed area such as erosion. Due to an increasing population and need for food security, it is therefore, realized that the water and the land resources need to be properly developed using effective management, integrative and comprehensive approaches (Gajbhiye, 2015).

Fresh water is the finite and precious natural resources that are directly related to population of living being. A watershed is a hydrological unit which generates runoff as a result of precipitation, the runoff water generation depends upon morphology of the watershed. Therefore, morphometric analysis of streams is an important aspect for characterization of watershed for proper planning and management for water resource sustainability (Chandniha, and Kansal, 2017).

Morphometric parameters mainly depend upon lithology, bed rock and geological structures. Hence, the information geomorphology, hydrology, geology and land use pattern is highly important for reliable study of drainage pattern of the watershed (Chandniha and Kansal, 2017). Therefore, morphometric analysis is the scientific approach of measurement and mathematical estimation of the earth's, shape, size, surface, and dimension of its landforms (Clarke, 1966; Agarwal, 1998; Obi, Reddy, Maji and Gajbhiye, 2002, Mangan, Anul Haq and Baral, 2019).

Morphometry, among other aspects of morphometric analyses, is of great importance especially to hydrologists and geomorphologists to address serious environmental problems such as soil erosion, slope instability, flood, landslides, and extreme surface runoff beside that, basin morphometric analyses require preparation of drainage map; stream ordering; delineating and measuring the catchment area, perimeter, and length of drainage channels; observing the drainage density and frequency; calculating bifurcation ratio, texture ratio, and circulatory ratio; and analyzing constant channel maintenance to understand the nature of drainage basins (Aspinall and Pearson, 2000; Conforti, Aucelli, Robustelli, and Scarciglia, 2011, and Mangan, Anul Haq and Baral, 2019).

The analysis and evaluation of a drainage system and its characteristics can only be understood through the morphometric analysis of the river basin and the hydrogeological information generated is an important ingredient for watershed modeling and water resource management (Saha1 and Singh, 2017). The recent trend in drainage morphometric assessment through the use of space borne satellite images for extraction of streams and their associated features are one of the important advancements in geospatial technology for drainage system mapping and their periodic monitoring in GIS environment (Singh, Thakur and Singh, 2013; Singh, Gupta and Singh, 2014).

Therefore, spatial remotely sensed data coupled with topographical data analysis procedures are effective tool to understand and manage the natural resources properly. It provides real time and accurate information related to distinct geological formation, landforms and helps in identification of drainage channel formations which are altered by natural forces or anthropogenic activities (Gajbhiye, 2015).

Thus, this study is set to analyze some of morphometric properties of Armatai river channel in the southern part of Kano State along its channel due to the growing human water-based activities such as farming, irrigation on small scale, fishing and possibly small scale gardening. Despite these significant roles of the river, it is in constant change every year in terms of depth, width and sediments generation which may affect its general morphology.

Prioritization of morphometric analysis using remote sensing and GIS techniques have been attempted by a number of researchers (i.e Srivastava and Maitra, 1995; Nag, 1998; Agarwal,1998; Biswas, Sudhakar and Desai,1999;Singh and Singh,1997; Reddy, Gangalakunta, Obi, Maji, Amal and Gajbhiye, 2004; Gajbhiye, Mishra and Pandey, 2013a ; Gajbhiye, Mishra and Pandey, 2013,c; Gajbhiye, Sharma and Meshram, 2014d; Sharma, Yadav and Gajbhiye, 2014) all they have concluded that remote sensing and GIS are powerful tools for studying basin morphometry and continuous monitoring and evaluation, remote sensing and GIS technology gives avenue to study basin/river morphometric characteristics for various parameters.

It is well established that drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics of the river basin (Rai, Mohan, Mishra, Ahmad and Mishra, 2017). Likewise, from the literature it can be seen that the last time when studies were conducted in the study area was about twenty-nine years back there might have been significant changes in the Armatai channel's morphology. The channel could have widened and undergoes changes that could consequently have affected its discharge. For that it is important to undertake this study of which the aim was to identify the morphometric changes of the river channel between 1986 and 2016 and compare satellite image date with ground-thruthing measurements (1986 and 2016) for effective management and utilisation of the river catchment.

Materials and Methods

The Study Area

Armatai River channel is located between latitude $11^{\circ}25'$N, $11^{\circ}45'$ N and longitude 08° $44'$E, $11^{\circ}47'$E respectively (Garko, 1987) (see Figure 1). It is a seasonal river originating from the hilly areas of Kibiya through Bunkure. It is a fourth order stream (based on Strahler's Stream Ordering) with low density of tributaries (Garko, 1987) which makes it flows in a short lag time than other rivers in the basin. It drains its water into River Wudil at Dawakin Kudu Local Government of Kano State.

The area constituted the outcrops of younger granites rise more than 1100m above mean sea level. The elevation of their bases ranges between 700 and 800m (Olofin, 1987). The geology of the area consists of Pre-Cambrian rocks of the Basement Complex origin which comprises of gneises, amphibolites, marbles and the older granites which underlie large part of Nigeria including 80% of the Kano region (Mustapha, 2014). The Basement

Complex consists of granite rocks extending up to Yadai towards the North and Gabasawa towards the East. The aeolian sand derived from wind deposits cover most part of the area with thickness of about 5meters in the upland and 10meters along the lowland plains (Olofin, 1987 in Mustapha, 2014).

The climate of the study area is tropical wet and dry type, designated as Aw according to Koppen's classification. The area is within the Sudan Savannah vegetation belt which have more than six month of dry season. In a normal year however, the mean annual rainfall in the area is less than 1000mm. (Olofin, 1987). The mean monthly temperature is between 21^0 to 30^0C with diurnal range of $12\text{-}14^0$C (Olofin, *et al* 2008). But, evapotranspiration is very high in the basin area. Potential evapotranspiration regarded to be 1772mm per annum (Olofin, 1987).

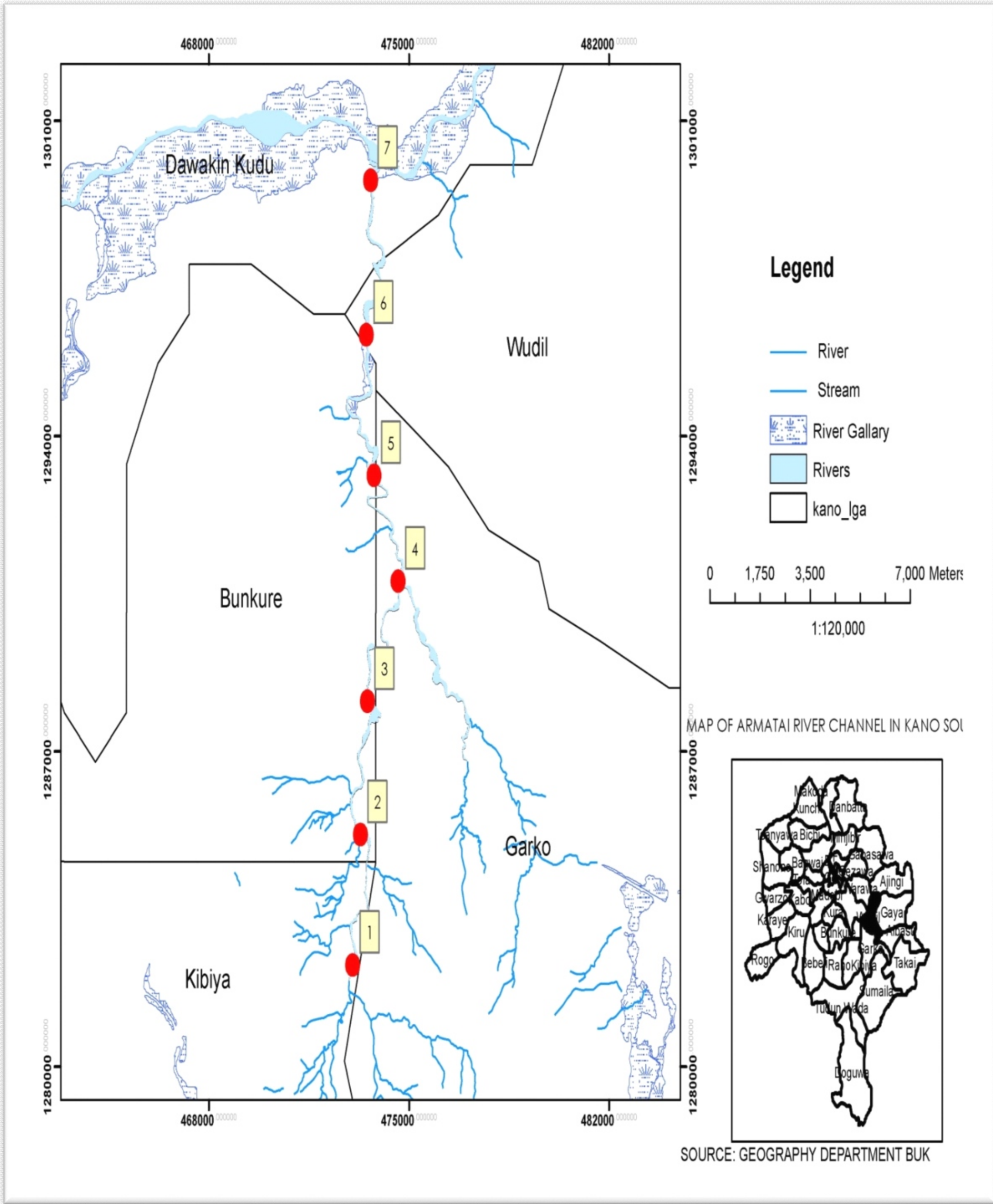

Figure 1: Study Area with seven Sample Points
Digitised map provided from Geography Department BUK.

The hydrogeology of the area is to a large extent controlled by geologic settings, climatic condition and human activities. The river is in the zone of high-water discharge and retention which coincides with the zone of Basement Complex structure (Mustapha, 2014, Rilwanu, Iguisi and Mallam, 2016). Groundwater occurrence within the Basement Complex areas is limited to fissures and weathered overburden (Rilwanu, 2014 and Rilwanu, 2017). Some of river tributaries to the river are lifidi and karanga to mention a few (Olofin, 1987 and Yakudima, 2009).

The soils in the area are highly leached, acidic, high in silt-clay and very low in organic matter which is usually less than 0.5%. Vegetation is of Sudan Savanna, composed of varieties of trees scattered with less grasses. The trees are characterized by broad canopies and are hardly taller than 20 meters. The dominant species are *baobab,* varieties of *acacias* such as *albida, seyal* and *nilotica* (Olofin, 1987). Some of these grasses as well as tree species are regarded as cultural vegetation (Dakata and Yelwa, 2012).

Methods

The materials used for this study include Landsat MSS and ETM+ Images (path 188, row 52) from Global Land Cover Facilities and United State Geology Survey (USGS). The Landsat ETM+ image of 2016 was provided by a commercial data provider, while the Landsat MSS image of 1986 was downloaded on February 2016 from USGS, ArcGIS 10.3 and ENVI 5.1. Field equipments include ranging poles, 30-metre measuring tape, theodolite, leveling staff and GPS machine model (Gamin eTrex 10).

Sampling Frame

The total length of the river channel from its source to where it discharges its water is 28 km (Garko, 1987). Based on this, the whole length of the river was purposively selected and systematic sampling technique was adopted at an interval of 4 km in selecting sampling points by which seven sample points emerged (Figure 1).

Data Collection

Field measurements

Field measurements were conducted using ranging poles, tapes, levelling staff, theodolite and GPS machine model (Gamin eTrex 10) among others to obtain the required data. The data obtained are on slope, length, depth, width, cross sectional area and wetted perimeter of the channel. To this end, the tape was used in measuring the width of the river at each seven points selected, staff level was placed at the river bank to measure the river depth and slope measurement was determined using theodolite.

The 1986 LANDSAT ETM+ and 2016 LANDSAT MSS images of the river were subjected to Remote Sensing and GIS analysis which involved geo-referencing and digitizing techniques, using ArcGIS 10.3 version and ENVI 5.1. Digital Elevation Model (DEM) was generated and used in determining the slope and depth of the Armatai River channel from the images, where the three bands image of the study area were used for further analysis and 2016 Shuttle Rader Thematic Mapper (SRTM) was used to generate and extract a contoured map of the study area at 5m interval for both the two images i.e 1986 and 2016. Depth on image was determined by difference of two contours divided by distance apart as adopted from Shri, *et al* (2015).

Shuttle Radar Thematic Mapper (SRTM) was used. The images of the study area after geo-referenced and reclassify were imported in to Arcmap then load Rader Thematic Mapper (SRTM) and selected the desired interval of 5m. Contoured map was generated and using formulae slope values were generated.

Data Analysis

Data on morphometric properties (e.g.width, slope, depth, length, cross sectional area and wetted perimeter) of the river were analysed using GIS and RS techniques in which Digital Elevation Model (DEM) of all the seven sample points selected gave the slopes and the depth while measuring tools (GIS ruler) used in GIS environment gave widths of each of the seven sample points. The 2016 Shuttle Radar Thematic Mapper (SRTM) was used to generate and extract a contoured map of the study area at 5m interval through the following procedure: - Lunch Arcmap then load SRTM image, Arctool box click on Spatial Analysis tool and then dialog box was appeared, Use surface contour tool and input the layer, contour interval and destination folder, A contour map was generated.

The procedure followed in measuring length and width of a river in GIS environment is digitization of the image. Immediately, the length automatically generated from attribute table. Measuring tool from standard tools appeared and was used to measure each point. The formulae used to obtained slope in degree is

tan Q= height/distance between two points ......(i)

Therefore Q= $\tan^{-1}$height/distance............... (ii)

And the equation used in the determination of depth in 1986 and 2016 is

Depth on image= difference of two contours/ distance apart .... (iii)

In the determination of river wetted perimeter is

Wetted Perimeter (wp) = 2*Depth + Width ... (iv)

The formulae used in the river cross sectional area is

Cross Sectional Area (csa) = Depth * Width ...... (v)

Results and Discussion

Changes in river width between 1986 and 2016

The result shows that width of the river widened from approximately 28.0m at the upper course to 180m in the lower course with an overall average of 77.57m in 1986. However, in 2016 the width widened in the upper part to 40m (GIS analysis) and 28m (field measurement) widened to 66m (GIS analysis) and 62m (field measurement). The overall average width of 77.61m in 1986 compared with the overall average width in 2016 of 59.0m and 56.14m by GIS analysis and field measurement respectively indicate an overall narrowing of the river channel over the years which can be explained by sedimentation between the two periods (Table 1 and See Figures 2, 3 and 4 as a sample for example). Indeed, greater narrowing of the width occurs at some sample points. For example, at sample point 6, the river width was 106m in 1986, but in 2016 it reduced to 75m and 73m, based on GIS analysis and field measurement respectively (See Figure 2, 3 and 4 as a sample for example). The coefficient of variation show no much internal variation between the three periods, in 1986 it is 67%, in 2016 24% and 24% in flied measurement (Table 1).

However, temporally the river width has changed. In sample point 1 for 1986 and 2016, the difference is +12m field measurement and 1986 is +10m but 2016 field measurement is -2m. At sample point 7 in 1986 and 2016 the difference is -114m, between 2016 and flied measurement is (-4m) respectively. Therefore, these differences were now covered by materials being deposited by the moving water (Table 2). This is similar with findings of Abubakar and Suleyman (2011) at River Gboko Niger where the study revealed that morphometric variables of the river are subjected to variation spatially and temporaly. Hence, deposition takes place in small velocity and low gradient; it causes the river bed to be up and sometimes changing the course or reduces river width (Melekhu, 2016).

Based on Kruskal -Wallis test, the result showed that no significance difference among the Armatai river width values for the three periods (P-value 0.777 at 0.05 significance level) (See Table 6)

Table 1: River width Difference for three periods

S/Point	1986 Width in (M)	2016 Width in (M)	Diff B/W 1986 & 2016	Flied Measumnt (M)	Diffr B/W Flied & 1986	Diffr B/W Flied & 2016
1	28	40	12	38	10	-2
2	35	74	39	69	34	-5
3	56	45	11	42	14	-3
4	73	66	-7	63	-10	-3
5	65	47	-18	46	-19	-1
6	106	75	-31	73	-33	-2
7	180	66	-114	62	-118	-4
SUM TOTAL	543	413	130	393	150	263
MEAN (X)	77.5	59	18.5	56.14	21.36	2.86
S.D	51.98	14.6	37.38	13.92	38.06	0.68
CV (%)	67%	24%	43%	24%	43%	0%

Source: Authors' Fieldwork 2016.

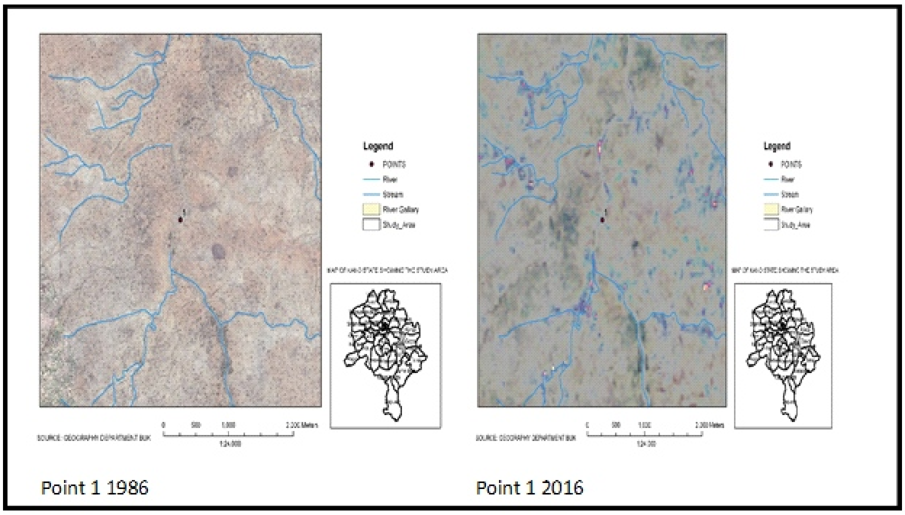

Figure 2: 1986 and 2016 Landsat image of sample point 1 on Armatai.
Source: Data Analysis, 2016.

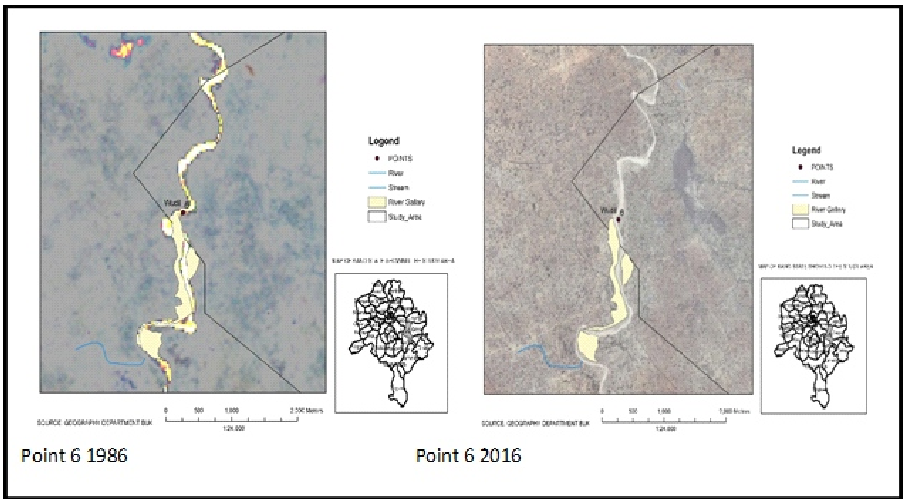

Figure 3: 1986 and 2016 Landsat image of sample point 6 on Armatai.
Source: Data Analysis, 2016.

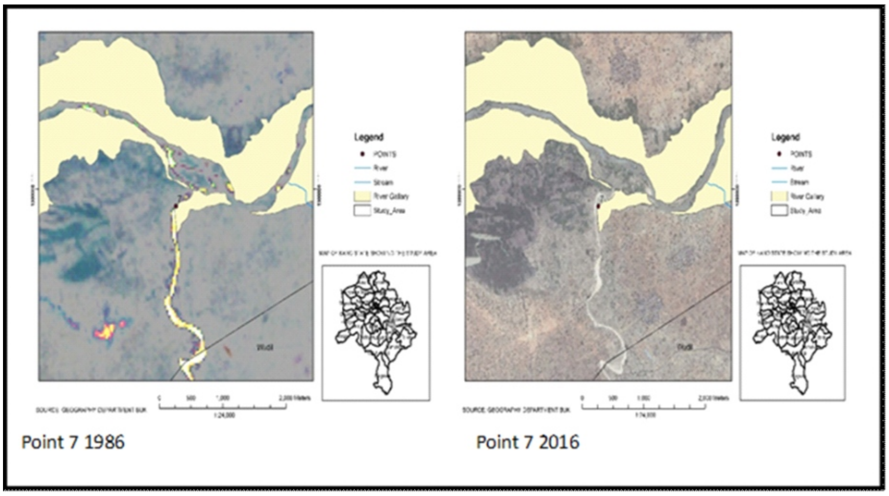

Figure 4: 1986 and 2016 Landsat image of sample point 7 on Armatai channel.
Source: Data Analysis, 2016

Changes in Armatai River depth between 1986 and 2016

The river depth on land satellite of 1986 image shows that sample point1 is 0.18m, in flied measurement is 2.00m. Between the two periods there is the difference of (+1.82m) this indicates the vertical erosion power of Armatai River at its upper course (Figure 1). From sample point 2 in flied measurement to the last sample point (7) the values were increased. But, between 2016 image and flied measurement sample point 1 increased to (+ 1.88m) (Table 2) the coefficient value of 1986 indicates 155% and for flied measurement is 42%. This shows highly significant internal difference among the three periods (Table 2). Point 1 as the deepest sample point is similar to what Olofin (2012) viewed, that the deepest part of the channel is on the outside of bend its where erosive action of a river is directed to the outside bend of the river.

Source: Authors' Fieldwork 2016.For Kruskal Wallis test, the result shows highly significant difference among the river depth values for three periods were the p-value is 0.001 at 0.05 significant level (Table 6). This indicates a strong human activities within the Armatai channel.

Changes in Slope of Armatai River between 1986 and 2016

Slope of Armatai River changed especially between one sample points to another. The slope of the Armatai river channel in the upper course was 10.09° but decreased to 7.12° by GIS analysis with a difference of -2.97° and 3.03°by field measurement in 2016 giving a difference of -4.09° indicating vertical aggrading during the thirty years. The overall average slope in 1986 was 7.92°but this decreased to 2.53°and 2.60°in 2016 from the imagery and field

Table 2: Depth Difference for the Three Periods

S/POINT	1986 Depth in (M)	2016 Depth in (M)	Diff B/W 1986 & 2016	Field Measure-ment in (M)	Diffr B/W Flied & 1986	Diffr B/W Flied & 2016
1	0.18	0.12	-0.06	2.00	+1.82	+1.88
2	0.71	0.00	0.00	1.00	+0.29	0.00
3	0.11	0.11	0.00	0.68	+0.57	+0.57
4	0.13	0.07	-0.57	0.89	+0.76	+0.82
5	0.07	0.00	0.00	0.92	+0.85	0.00
6	0.04	0.00	0.00	1.00	+0.96	0.00
7	0.02	0.00	0.00	0.70	+0.50	0.00
SUM TOTAL	1.20	0.30	0.90	7.19	5.99	6.89
MEAN (X)	0.18	0.04	0.14	1.03	0.85	0.99
S.D	0.24	0.05	0.19	0.44	0.20	0.39
CV (%)	155%	125%	30%	42%	113%	12%

Table 3: Slope Difference for Three Periods

S/POINT	1986 Slope in (degree)	2016 SLOPE in (degree)	Diff B/W1986 & 2016	Flied Measurement in (degree)	Diffr B/W Flied & 1986	Diffr B/W Flied & 2016
1	10.09	7.12	-2.97	3.03	-7.06	-4.09
2	23.17	0	0	0.8	-22.37	0
3	6.33	6.33	0	0.92	-5.41	-5.41
4	7.74	4.28	-3.49	0.8	-6.94	-3.48
5	4.34	0	0	11.3	6.96	0
6	2.69	0	0	0.74	-1.95	0
7	1.14	0	0	0.63	-0.51	0
SUM TOTAL	55.5	17.73	37.77	18.22	37.28	0.49
MEAN (X)	7.92	2.5	5.39	2.6	5.32	0.07
S.D	7.37	3.27	4.1	3.92	3.45	0.65
CV (%)	93%	129%	36%	150%	57%	21%

Source: Authors' Fieldwork 2016.

measurements respectively. Thus, the coefficient of variation in 1986 was 93%, in 2016 image was 129% and field measurement was 150%. Therefore, slope decreased from the upper, through the middle to the lower parts of the river at all the periods, but more so between 1986 and 2016 as a result of pronounced deposition activities showing that the river lost its competence downstream spatially and temporally (Table 3, Figure 2). This finding is in line with the findings of Pramanik (2016) in India where the study revealed that the drainage density of the river is determined by lithology and geological controls of the drainage pattern for the entire basin.

However, the non-parametric analysis of significance for the Armatai River slopes of the three periods. 1986, 2016 and flied measurement, (P-value is 0.055 at 95% level of significance) this indicates that there is no significance difference among Armatai slope for the three periods (Table 6).

Changes in Cross Sectional Area of Armatai River between 1986 and 2016

Armatai cross sectional area result of three periods show difference. Sample point 1 in 1986 and 2016 image analysis show the increment of (+9.84m^2) between the years. Sample 2 of 1986 and flied measurement shows a difference of (+44.15m^2). Between 1986 and flied measurement sample point 6 is the second highest after sample point 1 with the value of (+68.76m^2). (Table 4 Figure 3).

The analysis of non-parametric test of difference for cross sectional area of the river for the three Periods shows highly significance difference due to the fact that p-value is 0.000 at 95% level of significance (Table). This indicates Armatai River channel morphology under goes serious changes between 1986 and 2016 due to the human interaction within the channel, human activities such as sand mining and the impact of changes upstream are more pronounced downstream. This result is similar to the findings of Pande and Moharir (2017) and Fashea and Faniran (2015) Whose studies revealed that downstream morphological characteristics of the river varies distinctively at each cross section with the bed slope being the most significantly varied among all other morphologic parameters.

Changes in Wetted Perimeter of Armatai River between 1986 and 2016

Wetted perimeter of Armatai River between1986 and 2016 based on GIS analysis, sample point 1 show an increase of +11.88m. Sample point 2 also increases to +37.5m. From sample point 3 to the last sample point wetted areas of the river at 1986 were no longer wetted in 2016. Between 1986 and 2016 sample point 7 was drastically decreased by -114m. Based on flied measurement and 1986 sample point 1 and 2 were increased to +13.64m and +34.58m respectively. In the same period, sample point 3 to last sample point show reduction in the wetted portion of the channel. Sample point 7 is the point with highest value of -116.64m. (Table 5 and Figure 4).

However, Kruskal Wallis test of difference for wetted perimeter among the three periods in River Armatai reveals no significance difference between the years because the p-value is (0.914 at 0.05 level of significance) (See Table 6).

Table 4: Cross Sectional Area Difference for Three Periods

S/POINT	1986 Csa (M^2)	2016 Csa (M^2)	1986 & 2016	Flied Measurement Csa (M^2)	Diffr B/W Flied & 1986	Diffr B/W Flied & 2016
1	5.04	14.88	9.84	76	70.96	61.12
2	24.85	0	0	69	44.15	0
3	6.16	4.95	-1.21	28	21.84	23.05
4	9.49	0	0	56.07	46.58	0
5	4.55	0	0	42.32	37.77	0
6	4.24	0	0	73	68.76	0
7	3.6	0	0	43.4	39.8	0
SUM TOTAL	57.93	2445	33.45	348.35	290.42	323.9
MEAN (X)	8.28	3.49	4.79	49.76	41.48	46.27
S.D	7	5.09	1.91	17.66	10.66	5.57
CV (%)	84%	145%	61%	35%	49%	110%

Source: Authors' Fieldwork 2016.

Table 5: Wetted Perimeter Difference for Three Periods

S/Point	1986 WP in (M)	2016 WP in (M)	Diff B/W 1986 & 2016	Flied Measurement in (M)	Diffr B/W Flied & 1986	Diffr B/W Flied & 2016
1	28.36	40.24	11.88	42	13.64	-2.24
2	36.42	74	37.58	71	34.58	-3
3	56.23	45.22	-11.01	43.36	-12.87	1.86
4	73.26	66.14	-7.12	64.78	-8.82	-1.36
5	65.14	47	-18.14	47.84	-17.3	0.84
6	106.08	75	-31.08	75	-31.08	0
7	180.04	66	-14.04	63.4	-116.64	-2.6
SUM TOTAL	345.53	413.6	131.93	407.38	138.15	6.22
MEAN (X)	77.93	59.08	18.55	58.19	19.74	0.89
S.D	47.89	13.45	34.44	12.57	135.32	0.88
CV (%)	61%	22%	39%	21%	40%	1%

Source: Authors' Fieldwork 2016.

Table 6: Test of difference for the river parameters among the Three periods

S/N	Parameter	p-value	Remark
1	Width	0.777	Not Significant
2	Depth	0.001	Significant
3	Slope	0.055	Not Significant
4	Cross sectional area	0.000	Significant
5	Wetted parameter	0.914	Not Significant

Source Data Analysis, 2016.

Conclusion

It is concluded that width of the river is expected to be narrow at the upper and middle course in both 1986 and in 2016. However, temporally the river width decreases at the middle course and lower course. Hence, deposition takes place in small velocity and low gradient; it causes the river bed to be up and sometimes changing the course or reduces river width. The result showed that no significant difference among the river width values for the three periods. The river depth increases over the years indicating the vertical erosion power of Armatai River at its upper course. It was established also that in terms of depth there is highly significant difference among the three periods.

It was established that the slope of the Armatai River channel decreases from 1986 to 2016 which is as a result of pronounced deposition activities showing that the river lost its competence downstream spatially and temporally. In addition, the result shows no significant difference along Armatai slopes for the three periods. Armatai cross sectional area result of three periods show difference. Sample point 1 in 1986 and 2016 image analysis shows increment in the morphometric variables between the years.

Recommendations

Based on the findings of this study in order to maintain the original channel morphology and wetted perimeter human activities upstream like sand mining should be minimised for effective watershed development in the area. It is recommended that findings of this study should be applied in sound planning of surface and groundwater recharge related projects and programmes in the area for development and future studies of this nature should be supported by high resolution imageries like ones with1or 0.5 metre resolutions for more detailed.

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