Gombe Journal of Geography and Environmental Studies (GOJGES)

Vol. 1 N0.2 Jun. 2020

e-ISSN: 2714-321X

p-ISSN: 2714-3201

http://www.gojgesjournal.com

Gombe Journal of Geography and Environmental Studies (GOJGES) Vol. 1 N0.2 Jun. 2020, e-ISSN: 2714-321X; p-ISSN: 2714-3201

CHARACTERIZATION OF CHANNEL CROSS SECTIONS OF BAGADAZA RIVER IN AKKO LOCAL GOVERNMENT AREA OF GOMBE STATE, NIGERIA

Bala Bello Wanah
Department of Geography,
Faculty of Science,
Gombe State University,
Gombe, Nigeria.

bwanah28@gmail.com

Abstract

Studies of cross sections of rivers and streams are areas in geomorphology that need to be addressed. This research aimed at characterizing channel cross sections of Bagadaza River in Akko Local Government Area of Gombe State, Nigeria. The method employed was the production of cross sections of the river at intervals of 300 m along the channel. Tools used for generating data included Global Positioning System (GPS), 30 m tape and 3 ranging poles. A total of 19 cross profiles were drawn. Results showed that the theoretical V-shaped cross sections of rivers at their upper courses were lacking in Bagadaza drainage basin. The cross profiles produced revealed that the riverbed was flat and the channel U-shaped. Some of the cross-sections were 12m deep thereby created narrow gorges. Subjecting the values of the width and depth of the 19 cross sections to Spearman's Rank Correlation analysis, calculated value of coefficient was 0.87 while the critical value at 1% level of significance is 0.575. Since the calculated value is greater than the critical value at DF = 17, H_0 was rejected and accepted H_1 and therefore concluded that there was geomorphological correlation between the width of floor of Bagadaza River and depth of its channel. This implied that geomorphic processes operating in the segments of the river was uniform in spite of the differences of the geological material over which it was flowing. This research did not determine the longitudinal profile of the river. The study recommends that researches should be carried out on the longitudinal profile of the river. It is also recommended that human activities such as cultivation and constructions should comply with international best practices that minimize geomorphological processes that could aggravate deepening and widening the river's channel.

Keywords: *Bagadaza, Channel, Characterization, Cross sections, and Profile*

1. Introduction

River cross section is a representation of the surface of the river that would be exposed if the relief feature or landform were cut through vertically at a point across the river's channel and valley (Nimako, 2004; Mejia and Reed, 2011). Cross sections or profiles of rivers change in shape from the upper to the lower course which Mejia and Reed (2011) described as parabolic or triangular as a result of changes in the river's energy in performing work and the processes that the river carries out (Jackson, 2015 and Wanah, 2017). Alabyan and Chalov (1998) looked at river channel patterns and their natural controls and evolved a morphological continuum, which they indicated was two-dimensional defined by plan features, which there were three: straight, meandering and branching. Their result also indicated that there were three structural levels of fluvial relief namely floodplain, flood channel and low-water channel. Their work was more qualitative than quantitative. Lack of measurement of stream channel parameters such as width and depth along the stream channel created a wide gap, which has to be addressed in order to make a statement on channel pattern. Observations of morphological plan on the surface may not be sufficient to permit making inferences on channel pattern. This study dwelt on measurement of depth and width of Bagadaza River in order to define and characterize the morphological characteristics of the stream bank.

In studying river form and velocity, Waugh (1990) considered cross profiles of narrow and wide river channels and noted their influence on flow velocities. His work dwelled much on the hydraulics of stream flow and the volume of water the river discharges at a point, which he called hydraulic cross section of the river. His study did not considered situations in which rivers' channel bed change in elevation, forming terraces on either side of the bank. At times, even the bed vary in depth, which, if not taken into account, may not give accurate volume of water being discharged at the point where quantification is being taken. Furthermore, resulting features such as channel depth, width, forms of bed and Bagadaza River is located south of Gombe Metropolis where major human activities include farming, construction of residential dwellings and roads. The catchment, being close to Gombe, the capital of Gombe State, is subjected to high human traffic in search of basic raw material such as fuel-wood

channel walls associated with the activity of rivers, and their implications on infrastructural development were not treated. The need for such studies cannot be overemphasized particularly when the rivers pass through or close to urban centers.

Oyegoke and Ifeadi (2007) applied Strahler's system of stream ordering and investigated the relationship between drainage basin area and stream length to River Gongola. Having concentrated on drainage basin area and stream length, their work ignored the characteristics of the channel of river and thus their implications on structural developments such as agricultural, residential and transportation along and across the river in the light of the fact that river banks in Nigeria are inhabited by rapidly growing populations.

In a study, Wanah and Abdullahi (2018) worked on the longitudinal profile of Bagadaza River, reported observations on the profile of the river, and ignored cross sections of the channel and the associated channel width and depth, which have direct implications on human endeavours. Geologically, much of River Bagadaza lies on the unconsolidated Kerri-Kerri, Gombe Sandstone and Pindiga Formations. Being susceptible to fluvial erosional processes, the Bagadaza River and its tributaries have curved out channels that are unique in many respects and differ from the theoretical channel features of rivers particularly in its upper course.

extraction, farmlands and pasture for cattle as well as carrying out other socio-economic activities. The entire Bagadaza drainage basin is targeted for residential, commercial and educational facilities, which are attracting more people into the basin thereby intensifying activities that are threatening the basin as a natural environment, and on the width and depth of the channel of the river. Although aspects of the basin have appeared on topographical maps and town planning charts, considerations of cross profiles along the river for studying landforms of the channel and their implications on development have not been treated before. The study of the long profile of the Bagadaza River by Wanah and Abdullahi (2018), have ignored the cross sectional areas of the channel. Knowledge on the dimensions of width and depth, and other physical attributes at the points where the cross sections were made at regular distances along the length of the channel is lacking and it is a necessary information in the light of the intensity of human trafficking and constructions of facilities being put in place astride the river. Therefore gap exist for satisfying aspirations of the rapidly growing population in the basin and for researchers, students and land administrators for the characteristics of cross sections along Bagadaza River. A study of this nature cannot be overemphasized as many advantages can be derived from its results. In addition, such studies may inform formulation of mitigating strategies to overcome the difficulties that features along the channel could pose to human endeavours. The question posed for this research, therefore, is what are the characteristics of cross sections of the river channel? Wanah and Abdullahi (2018) worked on the longitudinal profile of Bagadaza River, reported observations on the profile of the river, and ignored cross sections of the channel and the associated channel width and depth, which have direct implications on infrastructural development.

This study aimed at characterizing cross sectional profiles along Bagadaza River in Akko Local Government Area of Gombe State, Nigeria. The objectives are to:

i. determine the length of Bagadaza River and its basin area;
ii. produce cross profiles along Bagadaza River;
iii. characterize channel cross profiles of the river;
iv. examine the effect of channel's cross profiles on structural development.

2.The Study Area

The Bagadaza River is located south of Government Reserved Area (GRA) in Gombe metropolis and occupies a basin that is bounded by latitudes 10° 15' 13" N and 10° 17' 33" N and longitudes 11° 06' 25" E and 11° 10' 42" E as shown in Fig. 1. The upper part of the basin is on the unconsolidated Kerri-Kerri Formation whereas the Gombe Sandstone and Pindiga Formations underlie the middle.

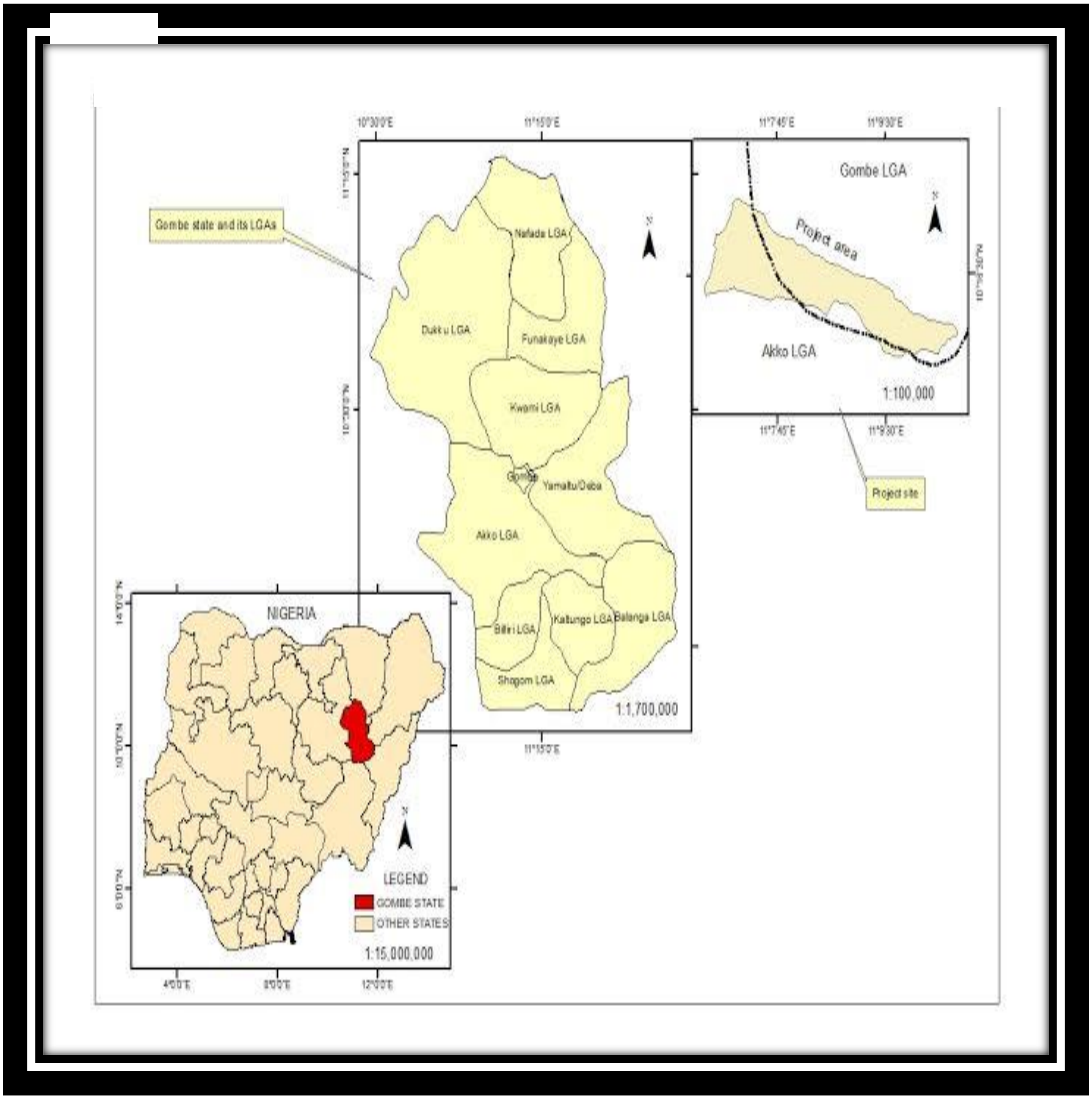

Fig. 1: Inset of Nigeria showing Bagadaza Drainage Basin
Source: Federal Ministry of Land and Survey, 2020

3.Methodology

A total of 19 points (Appendix I) were taken at intervals of 300 m along the length of the river channel for the production of cross sections. Where the channel was straight, the interval between two adjacent profiles was adjusted to more than 300 m. On the other hand, where the stream channel meanders and therefore short stretches were encountered, the distance between two adjacent cross profiles was adjusted to less than 300 m. The procedure of producing cross sections involved determining a central point (Centroid = ℂ) on the bed of the river channel. The coordinates of the ℂ was taken with the aid of hand-held Global Positioning System (GPS). The width of the channel bed was determined starting with the left (L) side of the ℂ and the distance from the ℂ to the base of the bank channel was measured in meters (m). The GPS point at the foot of the bank was taken. The height (h) up the bank to the point where the bank leveled was also measured. Horizontal distance above the first point at the foot of the bank was determined and measured to the point where there was another vertical rise. The procedure was repeated until the researcher was on the top of the bank. Recording of GPS points were repeated at the points where the elevation changes. The procedure was repeated on the right (R) side of the ℂ. Adding up the distance on the left side of the ℂ with that on the right gives the width of the bed of the channel, and thus of the profile.

Measurement of the elevation up the right bank, and horizontal distances were repeated as was done for the left bank. The data generated is presented in Appendix I and were used in drawing the 19 cross profiles along the channel of river

.

4. Results and Discussion

The cross profiles and the characteristics of the channel observed at each cross section are presented in this sub-section.

4.1The Length of Bagadaza River and its Basin Area

The land area of Bagadaza drainage basin determined by the application of ArcGIS is 7.879 km^2 while the stream length of the river through its meanders from its farthest point on its longest source tributary to its mouth was 8.826 km. The points at which the 19 cross sections were drawn are shown in Fig. 2. The first cross profile was taken close to the highest point on one of the source tributaries of the river. Although spacing of the profiles from the mouth of the river up to its farthest tributary was guided by 300 m distances, the peculiarity of the channel subjected reduction of the distances to allow studying the characteristics of the channel at those segments of the river (Fig. 2). The distance was arrived at through the summation of the lengths of the longest source tributary and those of the segments of the mainstream channel down to its mouth.

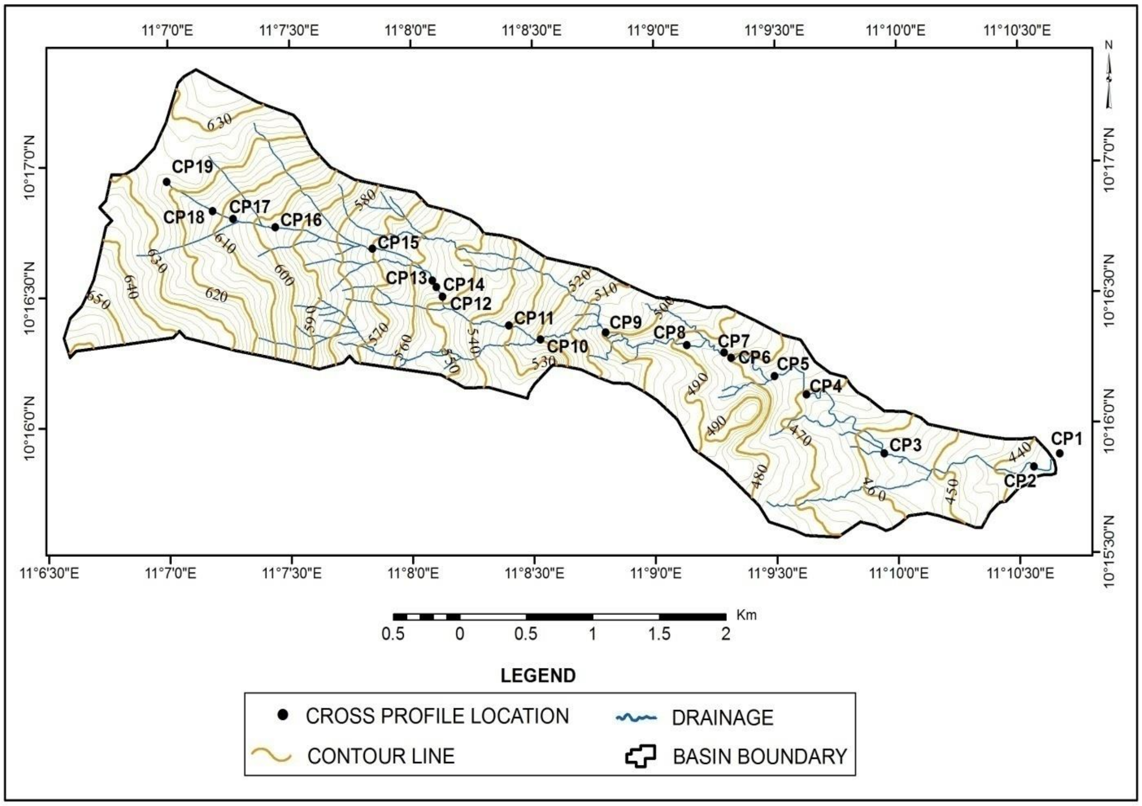

Fig. 2: Location of Cross Sections (CP 1-19) on Bagadaza River
Source: Fieldwork, 2020

4.2 Characterization of Cross Profiles along Bagadaza River

Nineteen (19) cross profiles were produced at guided intervals of about 300 m downstream along the main stream channel and are presented in Fig. 3. A river's cross profiles are cross sections of a river's channel and valley at certain points in the course of the river (Jackson, 2015) and it is a representation of the surface that would be exposed if the relief feature or landform were cut through vertically (Nimako, 2004). Cross profiles change in shape from the upper to the lower course as a result of changes in the nature of material over which the river flows, river's energy, and the processes that the river carries out. The cross section of the river at its upper course is wide. The expected deep V-shaped valleys at the upper courses of rivers are lacking in the source tributaries of the Bagadaza River. Measured depths of the first and second stream orders were 0.26 m and 0.74 m as depicted in Figs. 3(a & b) and it implies that the valleys at those orders were relatively flat with shallow depths which were due to deposition of sediments that is due to the friable nature of the Kerri-Kerri Formation which allows rapid infiltration of much of the water of the source tributaries rather than vertical cutting of the channel. Figs. 3 (c & d) are cross sections at meandering points. The section shown in Fig

3(c) is that of a meander at a segment in the middle course of the river. The cross section shows that under cutting at the meander is not pronounced as to obliterate the U-shaped valley often observed where the stream channel tends to be straight. Elevations on both banks were not the same indicating that erosion was cutting into the steeper bank. Undermining the steeper bank may result into the migration of the meander and thus of the river channel, a process that is common in the lower courses of rivers and is described as divagation (Faniran and Jeje, 2002). The landforms shown by the cross profile in Fig. 3(d) are a cliff and a slip-off slope. The cliff is 3.5 m above the bed of the stream while the slip-off slope, a convex feature which is formed by the deposition of sediments on the channel floor (Faniran and Jeje, 2002). The width of the channel bed at Fig. 3(d) was 6 m in contrast with 1.4m of the section in Fig. 3(c).

The bed of the channel of the river in Figs. 3(e & f) is shallow. The depth on the right bank was 1.5 m in Fig. 3(e) and 2 m on the left bank. The shallowness of the channel is explained by the fact that the stream at this segment was on Gombe Sandstone, which slowed vertical erosion that could have deepened the channel bed. The section of the river channel in Fig 3(f) is one taken at a meander. The bank on the right bank is a cliff developed by undercutting and collapsed of bank material and the eventual washing of the material by strong water flow. Repetition of the process is responsible for the accentuation of the meander. The section of the river in Fig. 3(g) presents the river channel as U-shaped with a sixteen meter (16 m) broad floor. The floor is covered by deposits of sediments, which hindered downward cutting into the layers of rocks beneath. Consequently, lateral erosion acted on the banks of the channel, which explains the broad channel bed. The cross section in Fig. 3(h) presents the channel in a not well defined terrace on the left bank. The floor of the bed was narrow (3.5 m) but is 5.5 m deep on the right bank. The section in Fig 3(i) is similar with that in Fig 3(g) while Fig. 3(j) is similar with that in Fig 3(f) and same explanations also hold. Whereas Fig. 3(k) presents the river channel with relatively well defined terraces, Fig. 3(l) is a swing of the meander to the left bank with slip-off slope on the right bank. Fig 3(m) and Fig. 3(n) were sections taken along the river channel where gorges have developed. Whereas the gorge in Fig. 3(m) was 5.5 m deep, there were sections along the stream channel where depths of gorges were 12m. The cross profiles at Fig 3(o) shows the channel as being straight with indications of development of slip-off slope in its past history. The cross section in Fig. 3(p) was taken at that part of the stream where the channel had swung its meander to the right bank. The bed of the channel at the section was 9 m wide with the right bank standing almost 8 m above the floor of the channel. Being in built up areas, houses were precariously located close to the steep cliff. Some buildings were known to have been lost to the meandering river. Figs. 3(q), 3(r) and 3(s) show that the channel at those locations were generally U-shaped and were taken where the stream had a near straight channel and was about to join the relatively bigger River Riyadh.

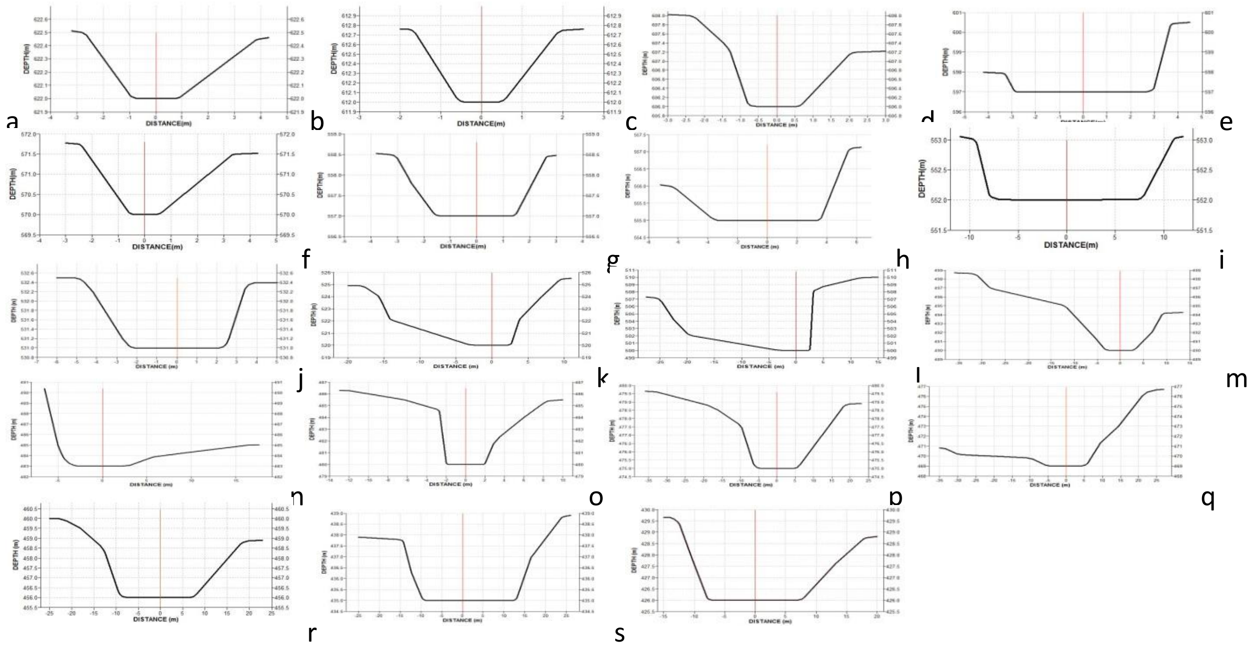

Fig. 3: Cross profiles along Bagadaza River

Source: Fieldwork, 2020

Beside the varied cross profiles, there were landforms observed at some of the cross sectional areas and included transverse bands of hard rock of Gombe Sandstone and Pindiga Formations (Benkhelil, *et al*, 1989, and Wanah and Abdullahi, 2018) which outcropped across the valley and have proved more resistant to erosion than the beds above and below them. In such areas, the river graded itself above and below the band, then concentrated its attack upon the band, and eventually created waterfalls and rapids (de Blij, *et al*, 2005). The presence of the hard bands that created waterfalls and rapids rejuvenated the erosive power of the stream through increase of water velocity and subsequently renewed down cutting. Increase in precipitation over the entire basin during the rainy season, produces down cutting due to increased volume of water (Mbaya, 2012). The result of this on the cross sectional areas of the river and its eventual long profile was the development of marked breaks of slopes known as knick-points or rejuvenation heads as observed at several places in the cross sections of Bagadaza (Wanah and Abdullahi, 2018). Since the underlying rocks downstream of the hard band are less resistant, the scouring action of the waterfalls created plunge pools. Under cutting into the hard rock caused pieces of the hard rock to break off and the waterfalls receded upstream thereby creating gorges, which are characterized by steep banks illustrated by Fig. 3(m). There were some spectacular knick-points and waterfalls along the Bagadaza River. One of such knick-points created a long, narrow and steep sided gorge exposing several layers of alternating rock strata of the Gombe Sandstone with the channel bed lying 12 m below the upper parts of the banks.

The width of the stream floor and depth of the river at each cross section are shown in Table 1 and were analyzed using Spearman's Rank

Correlation Coefficient to study if there were correlation between the width of floor of Bagadaza River and the depth of its channel. To test that, the following hypotheses were formulated:

H_0 There is no correlation between the width of the floor of Bagadaza River and the depth of the channel at the respective cross sections along the stream channel.

H_1 There is correlation between the width of the floor of Bagadaza River and the depth of the channel at the respective cross sections along the stream channel.

Calculated value of the correlation coefficient is 0.87 while the critical value at 1% level of significance is 0.575. Since the calculated value is greater than the critical value at DF = 17, H_0 was rejected and accepted H_1 and therefore concluded that there was geomorphological correlation between the width of floor of Bagadaza River and depth of its channel. This conformity with Zhang, Shi and Xiong (2020) asserted that there is a relationship between the width and depth of Wuhan-Jiujiang River.

Table 1: Width and depth along Bagadaza River (Cross sections)

S/No	W	D	Wr	dr	D	d^2
1.	14.30	4.88	3	8	-5	25
2.	22.00	4.98	1	7	-6	36
3.	11.10	4.80	4	9	-5	25
4.	5.10	7.58	10	5	5	25
5.	11.00	6.98	5	-6	-1	1
6.	3.10	10.95	14	4	10	100
7.	6.30	3.30	9	10	-1	1
8.	6.35	15.90	7	2	5	25
9.	4.40	19.95	13	1	12	144
10.	4.45	10.98	12	3	9	81
11.	4.65	1.38	11	16	-5	25
12.	15.50	1.00	2	17	-15	225
13.	6.70	1.55	6	14	-8	96
14.	0.45	1.63	19	12	7	49
15.	2.75	1.48	15	15	0	0
16.	5.55	2.20	8	11	-3	9
17.	1.10	1.60	17	13	4	16
18.	0.90	0.75	18	18	0	0
19.	1.60	0.70	16	19	-3	9
						$\sum d^2 = 892$

Source: Fieldwork, 2020

4.3 Effect of Bagadaza River Width and Depth on Structural Development

The formation of deep stream channel, wide stream bed, occurrence of meanders along the Bagadaza River channel, as well as the presence of many deep tributaries have posed difficulties in structural development in the basin. It suffices to say that stream systems have rendered the Bagadaza drainage basin, especially the lower and middle courses, a bad land for both agricultural and for construction of residential dwellings as it raised costs for those operations very high. Walls constructed were known to have been removed by channel erosion through undercutting of banks during the rainy seasons as reported by Mbaya (2012); Wanah and Abdullahi (2018) that houses were lost to stream erosion in the basin and that some were left precariously located on the banks of encroaching stream channels. There were very few roads developed across Bagadaza River and its tributaries. The conspicuous absence of roads across and along the river is attributed to the difficulties of the terrain in infrastructural development.

5. Conclusion

Nineteen cross sections were produced each at different location along Bagadaza River and they depicted varied cross profiles. The sections show that the stream channel was generally deep in many places. The deep stream channel, together with those of its equally deep tributaries, has rendered the basin a bad land. In spite of the fact that the basin bordered Gombe built up area, it was poorly settled upon for lack of roads. The cross sections revealed deep gorges in places formed where the channel cut through Gombe Sandstone and Pindiga Formations. The cross profile of the source tributary showed a flat streambed instead of the theoretical V-shape in upper courses of rivers and it is attributed to the deposition of sediments of the Kerri-Kerri Formation. Flat riverbeds were observed in all the cross profiles and were also associated with deposits of sediments from the same source, the Kerri-Kerri Formation.

6. Recommendations

The characteristic deep and wide channel of Bagadaza River as revealed by the cross sections drawn from the farthest source tributary to its mouth, and the numerous deep tributaries, informed the following recommendations:

i. Cultivation should be done such that ridges are ploughed across the general gradient of the basin to minimize soil loss and concentration of water into the channel, which could aggravate their dimensions.

ii. It is recommended that erosion need to be controlled through construction of roads across the slope of the basin, construction of drainages, and planting of fast growing plant species such as *Paniculatu/Pitadeniastrum africanum* (popularly known as Kafi-Kansila in Hausa) should be carried out in stream channels to stabilize soil loss from the banks and stream floor. The application of stone bags on watercourses, and planting of bahama grasses on open surfaces should be done by individuals, communal groups and by Akko and Gombe Local Government Councils.

iii. State government should consider stabilizing the banks of the river and other streams within the area by concreting them in order to confine the channel thereby protecting residential dwellings close to them from being lost to the stream.

iv. The methodology of drawing cross sections of stream channels as reported in this work is recommended for students and researchers of physical geography.

References

Alabyan, A. M. and Chalove, R. S. (1998) Types of River Channel Patterns and Their Natural Controls, *Earth Surface Processes and Landforms*, Vol. 23, pp0467-474.

Benkhelil, J, Guiraud, M, Ponsard, J. F. & Saugy, L. (1989) The Bornu-Benue Trough, the Niger Delta and its Offshore: Tectono-Sedimentary reconstruction during the Cretaceous and T Tertiary from Geophysical data and geology In *Geology of Nigeria*, Edited by Kogbe, C. A. Pp 278-319.

de Blij, H. J, Muller, P. O, Williams, R. S, Conrad, C. T. and Long, P (2005) *Physical Geography: The Global Environment*, Canadian Edition, Ontario, Oxford University Press. Pp530- 534; Pp 549-552.

Faniran, A. and Jeje, L. K. (2002): *Humid Tropical Geomorphology: A Study of the Geomorphological Processes and Landforms in Warm Humid Climate* pp 75-111, Heinemann, Ibadan.

Jackson, A. (2015) *Changing Long and Cross Profiles along a river* http://www.coolgeography.co.uk Retrieved on 3th August, 2015.

Mejia, A. I. and Reed, S. M. (2011) Role of Channel and Floodplain Cross-section Geometry in the basin response, Water Resources Research, Vol. 47, Issue 9.

Mbaya, L.A. (2012) *An Assessment of Gully Erosion in Gombe Town, Gombe State, Nigeria*, PhD Thesis, Submitted to the Department of Geography, University of Maiduguri, Maiduguri, Pp 48-53: 88-89.

Ministry of Land and Survey, Gombe State, 2000

Nimako, D.A. (2004) *Map Reading for West Africa*, Lagos, Longman, Pp 32-44.

Oyegoke, S.O and Ifeadi, C (2007) Relationship between Drainage Basin Area and Stream Length For River Gongola, Nigeria, *The Pacific Journal of Science and Technology*, Vol. 8, No 2, November, 2007, Pp 184-189. Retrieved on 6th October, 2012 from http://www.akamaiuniversity.us/PJST.htm

Wanah, B. B. (2017) *Analysis of Morphometric Properties and Sediment Discharge of Bagadaza Drainage Basin, Gombe, Gombe State, Nigeria*. Unpublished PhD Thesis of the Department of Geography, University of Maiduguri, Nigeria

Wanah, B. B. and Abdullahi, J. (2018) Analysis of Longitudinal Profile of Bagadaza River in Akko Local Government Area of Gombe State, Nigeria *Journal of Environmental Sciences and*

Policy Evaluation, Vol. 8, No 4. Pp1-24.

Waugh, D. (1990) *Geography: an Integrated Approach,* London, Nelson, Pp 50-80.

Zhang, O, Shi, Y. and Xiong, M. (2020) Geometric properties of river cross sections and associated hydrodynamic implications in Wuhan-Jiujiang River reach, the Yangtze River, *Springer Nature,*