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Assessment Of The Discharge Potential Of The River Kilange Catchment Using Morphometric Parameters

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The author solely designed, analyzed, interpreted and prepared the manuscript.

Abstract: *Morphometric analysis of the River Kilange catchment was carried out using Geographic Information System (GIS) technique. Shuttle Radar Topography Mission (SRTM) data at 30m resolution were used for preparing Digital Elevation Model –DEM in ArcGIS 10.0 software. The map of the study area was projected to Universal Transverse Mercator-UTM to enable the processing of basic drainage parameters like stream length, drainage area and perimeter in the attribute tables. The River Kilange catchment is a seventh order catchment with a dendritic drainage pattern. The total number of streams of all orders is (3273) with the first order streams constituting up to 76.26%. Total length of streams of all orders in the study catchment was calculated as (4864.16) kilometres. The overland flow of the River Kilange catchment is (0.52 km), which is high indicating gentle slopes, long flow paths, more infiltration and reduced runoff. The drainage density of the Kilange catchment is (0.97 km/km2). This low value of drainage density implies that most rainfall infiltrate into the ground and few channels are required to carry the runoff. Elongation ratio of the River Kilange catchment is 0.76 which shows that it is less elongated. Generally, the River Kilange catchment is characterized by low relief. The relief ratio of the study area (0.010) is an indication that the recharge capabilities of the basin are low and chances of ground water potential are good. The bifurcation ratio of the River Kilange catchment is (2.5), which implies that the influence of tectonic structures (folding and faulting) on the drainage basin is negligible. Based on the ruggedness number (Rn) calculated as (1.02 the River Kilange catchment falls under the category of drainage basins with extreme morphology. This is particularly true of the Loko sub-catchment with Rn value of (1.44). The steeper and longer slopes in the Loko sub-catchment make it the most vulnerable part of the River Kilange catchment in terms of flooding. Morphometric analysis can provide the necessary information on the discharge potentials of drainage basins. This approach is very important in the developing countries in general and the River Kilange catchment in particular where discharge data are either lacking or inadequate.*

Key words: *Morphometry, catchment, assessment, discharge, potential*

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I. Introduction

Morphometry is the measurement and mathematical analysis of configuration of the earth surface and the shape and dimensions of its landform which is found to be very important in evaluating drainage pattern and watershed management programmes (Khadri and Moharir, 2013). Morphometric study of the drainage basin is aimed to acquire accurate data of measurable features of stream network of the drainage basin (Lakshmamma et al., 2011). Spatial technology techniques used to analyse the morphometry of drainage basins are fast replacing manual calculation methods (Eze and Efiong, 2010). Within the past two decades, studies on the relationships of river basin morphometry and discharge have been conducted using state of the art technologies such as Geographic Information System (GIS), Remote Sensing and other geospatial software packages in various river basins (Umo, et al. 2017).

The morphometric analysis of a drainage basin and channel network plays a significant role in understanding the hydrogeological behaviour and expresses the prevailing climate, geology, geomorphology and structure of the basin (Ziaur et al., 2012). The role of rock types and geologic structure in the development of stream networks can be better understood by quantitative morphometric analysis (Doad et al., 2012). Morphometric analysis defines more clearly and precisely the general form of the basin landform as represented on a map and serve as a basis for demonstrating the effects of the environment control on fluvial system and for predicting the basin output variables such as discharge (Ezemonye and Emeribe, 2013). For unguaged watersheds where in addition to hydrology, information regarding soil, geology, geomorphology, and so forth is also scarce, morphometric analysis provides a very good alternative to understand the underlying factors controlling the hydrological behavior (Altaf et al., 2013).

Hydrological data and morphometric parameters of drainage basins in developing countries are either lacking or grossly inadequate. In Nigeria, one of the major problems of hydrological studies and water resources planning and management is that of generating adequate hydrological data for use by water resource managers and researchers (Ezemonye and Emeribe, 2013). This development has made hydrological research very difficult in the country. The situation has made many researchers in the country to abandon hydrological studies in favor of other aspects of the study (Oruonye et al., 2016).

Data on river discharge are not readily available in the River Kilange catchment and Physical measurement of runoff is labour intensive. The outlet of the River Kilange at Malabu is so wide and deep, which preclude efficient and economical data collection using the Area-velocity (flow meter) method, especially at high flow periods. These constraints necessitated the development of alternative methods for assessing hydrological processes in the study area. The discharge potential of the River Kilange catchment would thus be assessed using series of generalized relationships based on morphometric parameters.

Morphometric parameters especially basin area, stream length, length of overland flow, perimeter, relief, stream frequency, drainage density and drainage texture often exert varying degree of influences on the river discharge that is operational in a river basin over a period of time (Umo et al., 2017).

1.1: The Study Area

The River Kilange catchment has an area of 4955 km^2 encompassing parts of Fufore, Gombi, Hong, Maiha and Song Local Government Areas of Adamawa state Nigeria. It is located between latitudes 9° 23´ 26'' N to 10° 19´ 00'' N and longitudes 12° 15´ 00' E to 13° 17´ 25'' (Fig. 1.1).

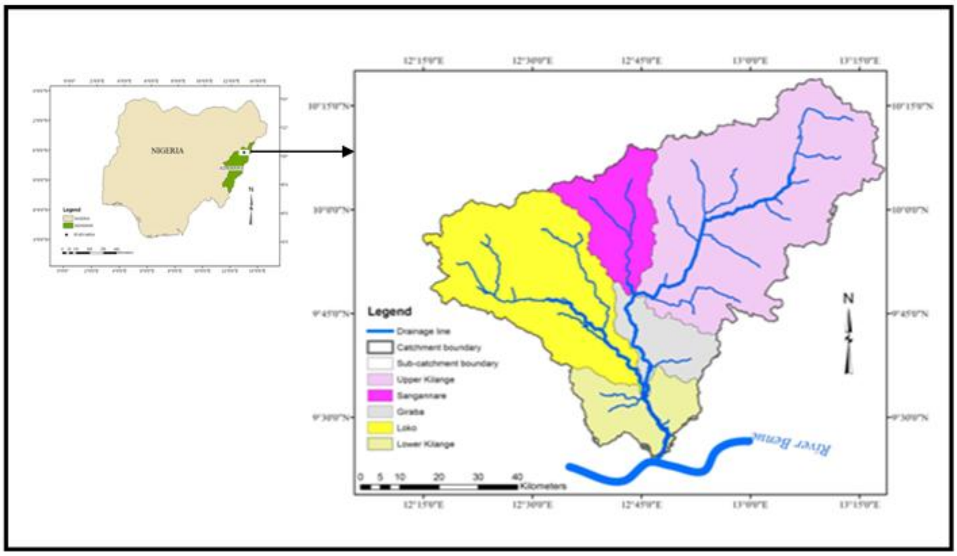

Figure 1.1: Location

Source: Arc-GIS 10 Analysis,

The River Kilange catchment area is underlain by granitic crystalline rocks of the Pre-Cambrian Basement Complex. Overlying the older Basement Complex are the sedimentary and volcanic rocks of relatively younger age ranging from the upper Cretaceous to Quaternary periods (Bawden, 1972; PFP-Nigeria, 1981).

Elevation in the River Kilange catchment ranges from 170 metres to1200 metres above mean sea level. The highest points are confined to the peaks of hills in headwater areas, while the low plains bordering the flood plains of the River Benue into which the River Kilange discharges its water constitute the lowest levels.

The major drainage feature in the study area is the River Kilange, which originates from the hills bordering the northern extreme of the catchment. Major tributaries of River Kilange are the Rivers Loko and Song draining the western portion, whereas the eastern part is drained by numerous minor tributaries, prominent among, which are Mayo-Nguli and Giraba. The central part of the study catchment is drained by River Sangannare. The River Kilange drains into the River Benue at an outlet near Wuro-Bokki, a settlement located some 45 kilometres upstream of the bridge at Jimeta (Pell, Frischmann &Partners-PFP Nigeria, 1981).

The River Kilange catchment lies in the Sub-Sudan climatic zone. The months from May to October constitute the rainy season, while the months from November to April make up the dry season period. Mean annual rainfall in the study area is about 900 mm based on data for the years1987 to 2016.

Temperature in the area is characterised by little diurnal, monthly and seasonal variations. The hottest period in the year is in the month of April, with temperatures rising to 37^o C and 39.6^o C in the northern and southern extremes of the study area respectively (Adebayo, 2004). December and January constitute the coldest months when temperatures drop to 15.3^o C and 18.3^o C in the northern and southern extremes of the study area respectively.

The dominant soil types in the River Kilange catchment are sandy loam to sandy clay with or without concretionary iron pan. The weakly developed soils of erosion and non leached ferruginous tropical soils dominate the northern part of the Kilange catchment. These occur as shallow skeletal soils on the upper slopes with deeper colluvial soils in the valleys. The middle portion of the Kilange catchment is dominated by rock outcrops, raw mineral soils and weakly developed soils of erosion. These are shallow, skeletal soils over granite, basalt, sandstone and ironstone. The southern segment of the Kilange catchment comprises of sandy loam and clay loam with varying degrees of concretion (Bawden, 1972).

Adamawa State and River Kilange catchment inclusive is located within the Sudan Savannah belt of Nigeria (Adefioye, 2013). The natural vegetation of River Kilange catchment is very lightly wooded characterized by sparse, relatively short 5-10 metre semi-deciduous trees with shrubs and grasses constituting the dominant cover. The upland pediments are characterized by shrub savannah (PFP-Nigeria, 1981). Near the towns, the native species of trees are gradually being replaced by some exotic species.

Agriculture is the major source of livelihood for the majority of people in the study area. Two basic patterns of rain-fed agriculture are practiced in the area in relation to the two fundamental soil types, the residual upland pediment soils and alluvial floodplain soils. Maize, guinea corn, cowpea, millet, groundnuts and cassava are the main crops grown on the upland pediment soils. The alluvial floodplain soils are more fertile than the upland soils and are, therefore more productive and in addition are better supplied with and better able to retain moisture. . For these reasons, the floodplains are relatively more extensively cultivated and to a certain extent on a more permanent basis in respect to individual plots. The apparent pattern of cultivation observable in the floodplain areas is that, rice, sugar cane and banana are planted in the poorly drained areas, while maize, guinea corn, cassava and a variety of mixed vegetables including onions and okra are restricted to the better drained sites (PFP- Nigeria, 1981).

II. Methodology

The threshold value of the flow accumulation raster is very essential to determine the number of stream features to be included in a watershed which affects morphometric parameters because the determination of the orders of rivers depends on the first stream in a watershed (Girma and Vijaya, 2015). In order to determine the appropriate number of stream features to be included in the morphometric analysis, a threshold less than the maximum 1%, which is the default value in Arc-Hydro Tools was used. In relation to this, Umo et al. (2017) reported that Richards (1990) made some useful observations regarding quantitative evaluation of landform properties when he stated thus:

"A conceptual image of the landform must be translated into measurable attributes that represent the concept satisfactorily, and can be quantified with accuracy, precision, and reproducibility. Thus a rigorous operational definition is essential, and this must consider: (a) delimitation of the landform boundary; (b) the quantitative index itself; (c) the sampling scheme required to define a representative subset of the relevant population; (d) the appropriate and available data sources and methods of measurement and; (e) the measurement procedures and practices"

The data used to analyse the morphometry of River Kilange were extracted from Shuttle Radar Topography Mission-Digital Elevation Model (SRTM-DEM) with resolution of 30 m. The Shuttle Radar Topography Mission-Digital Elevation Model (SRTM-DEM) was sourced from the United States Geological Survey-Global Visualisation (USGS-GloVis) for the year 2018. The four scenes of SRTM-DEM data required to cover the study area were freely downloaded from NASA website. The ArcGIS10.0 in conjunction with Arc Hydro Tools version 2.0 was used to process the data, delineate the River Kilange catchment and perform drainage network analysis. The map was projected onto WGS 1984 World Mercator UTM, Minna Zone 32N coordinate system using appropriate tools in ArcGIS.

Based on field experience, information derived from Google Earth, satellite images and professional judgement, a value of 57 cells (0.01%) was used as the flow accumulation threshold in this study. The stream orders of the River Kilange catchment were automatically generated based on Strahler's method of stream ordering using Arc-map 10.0. Consequently, linear, areal and relief parameters of the study catchment were computed.

The map prepared after performing the stream ordering is shown in (Fig 2.1).

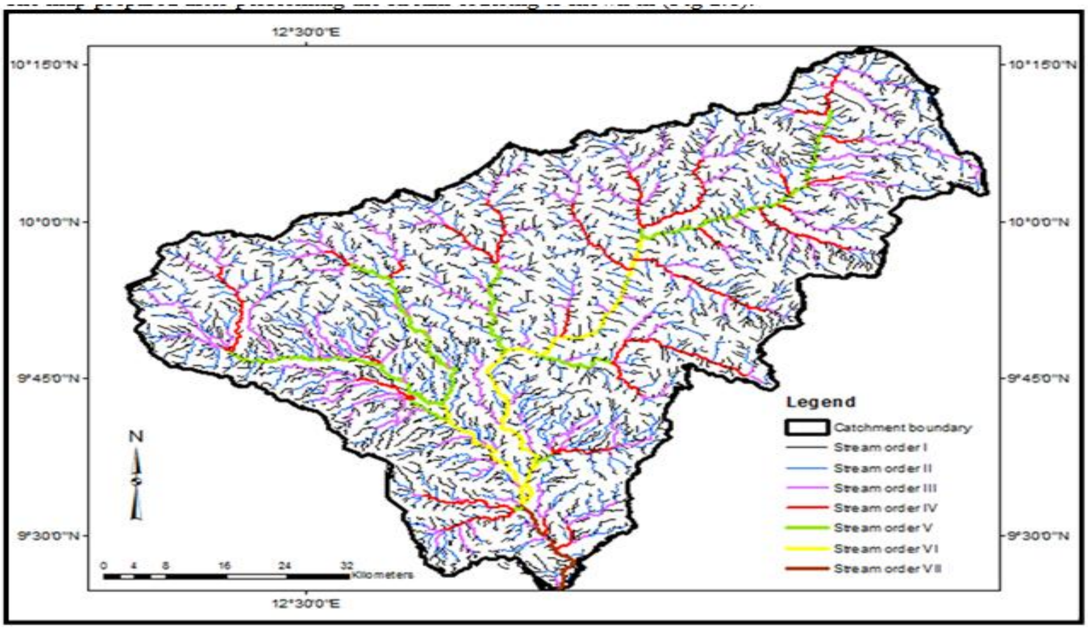

Figure 2.1: River Kilange Stream Order

Source: ArcGis Analysis, 2018

III. Results and Discussion

The results of morphometric analysis will be discussed under basic, linear, areal, shape and relief parameters.

3.1: Basic Parameters.

Some important parameters that were used to calculate other morphometric parameters are basin area, perimeter and maximum basin length (Table 3.1).

Table 3.1: Stream Order and Stream Number of River Kilange Catchment

Catchment/Sub-catchments	Area (km^2)	Perimeter (km)	Max. Basin length (km)
Kilange	4955	741.90	104
Upper-Kilange	2248	263.67	71.50
Sangannare	470	117.19	36.33
Loko	1399	194.71	64.55
Giraba	385	120.87	31.20
Lower -kilange	453	125.12	31

3.2: Linear Parameters

Linear aspects include stream ordering, stream number, length of stream, bifurcation ratio, length of over land flow etc. These aspects help to explain the evolution of drainage basin, hydrological potentialities, chance of hydrological extremities or flood behaviour and shifting course of river.

3.2.1: Stream Order (U) and Stream number (Nu)

The stream order is a measure of the degree of stream branching within a river catchment. Stream order gives an idea of the size of river catchment and approximate amount of stream flow. The streams of the River Kilange catchment have been ranked according to the Strahler's stream ordering system and the result shows that River Kilange is a seventh order catchment.

Stream number on the other hand is count of stream channels in each order. It is observed that the number of streams gradually decreases as the ordering of the streams increase. The total number of streams of all orders is 3273 as presented in (Table 3.2) with the first order streams (2496) constituting up to 76.26%. The relatively very high number of first order streams is an indication the river catchment has a mature stage of topography.

Table 3.2: Linear Aspects of the River Kilange Catchment

Stream Order	Number of Streams	Bifurcation Ratio	Total Length of Streams (km)
1	2496		2412.67
II	573	4.35	1242.05
III	145	3.95	648.32
IV	38	3.81	278.53
V	17	2.23	161.77
VI	3	5.66	98.36
VII	1	3	22.46
Total	3273	Mean = 3.83	4864.16

3.2.1: Stream Length (Lu)

The stream length is a measure of the hydrological characteristics of the bedrock and the drainage extent. Stream lengths of the River Kilange catchment were calculated in ArcGIS10.0 after converting the digital elevation model-DEM raster dataset to polygon. The map was further projected to Universal Transverse Mercator-UTM to enable the computation of stream lengths within the attribute table of stream orders. Using the add-field and calculate geometry procedure in ArcGIS 10.0 total length of streams of all orders in the study catchment was calculated to be 4864.16 kilometres (Table 3.2).

Table 3.2 Stream Length and Bifurcation Ratio (Rb) of the River Kilange Catchment

Stream Order	Total Length of Streams (km)	Bifurcation Ratio
1	2412.67	-
II	1242.05	1.94
III	648.32	1.92
IV	278.53	2.33
V	161.77	1.72
VI	98.36	1.65
VII	22.46	4.38
Total	4864.16	Mean=2.32

3.2.1: Stream Length (Lu)

The stream length is a measure of the hydrological characteristics of the bedrock and the drainage extent. Stream lengths of the River Kilange catchment were calculated in ArcGIS10.0 after converting the digital elevation model-DEM raster dataset to polygon. The map was further projected to Universal Transverse Mercator-UTM to enable the computation of stream lengths within the attribute table of stream orders. Using the add-field and calculate geometry procedure in ArcGIS 10.0 total length of streams of all orders in the study catchment was calculated to be 4864.16 kilometres (Table 3.2).

It can be seen in Table 3.2 that total length of streams decrease with increasing stream order.

The stream length is a measure of the hydrological characteristics of the bedrock and the drainage extent. Wherever the bedrock and formation is permeable, only a small number of relatively longer streams are formed in a well-drained watershed, whereas a large number of streams of smaller length are developed where the bedrocks and formations are less permeable (Rai, et al., 2017). Numerous streams of relatively smaller lengths are characteristics of areas with larger slope in the upland pediments of the River Kilange catchment. Less numbers of streams with longer lengths are generally the characteristics of flatter surface with low gradients in the central and lower parts of the river catchment.

3.2.2: Bifurcation Ratio (Rb)

Bifurcation ratio is defined as number of streams of one order to the next higher order. The equation: $R b = Nu / Nu+1$, where, Nu = stream number, Nu +1 = stream number of higher order was used to calculate the bifurcation ratio of the study catchment. Bifurcation ratios for the successive stream orders are presented in Table 3.2.

The variation in the bifurcation ratio between successive stream orders is due to differences in slope and topographic conditions. The bifurcation ratio has an important relationship with the surface flow discharge and erosion stage of the basin (Kumar and Shetty, 2014). In regions where the network geometry of streams develops without pronounced lithological or structural control, bifurcation ratios between basins of different orders are stable showing little variation from one stream order to another (Oruonye et al., 2016).

Bifurcation ratios computed for the sub-catchments of the study area range from 2.86 in the Lower-kilange sub-catchment to 5.32 in the Sangannare (Table 3.3). Maximum bifurcation ratio for the Sangannare Sub-catchment (Rb = 5.32) indicates that the drainage system has been influenced by the geology. The mean bifurcation ratio for the entire Kilange catchment is 3.83 which indicates that the influence of geological structures on the development of drainage system is negligible..

Table 3.3: Bifurcation Ratio and Length of Overland Flow of River Kilange Sub-catchments

Catchment/Sub-catchments	Number of order	Bifurcation Ratio	Length of overland flow (km)
Kilange	7	3.83	0.52
Upper-Kilange	6	4.38	0.55
Sangannare	5	5.32	0.57
Loko	6	3.38	0.31
Giraba	6	3.91	0.30
Lower-Kilange	6	2.86	0.39

3.2.3: Length of Overland Flow (Lg)

Length of the overland flow (Lg) is the length of water over the ground before it gets concentrated into definite stream channels. Lengths of overland flow for the sub-catchments are presented in (Table 3.3). The highest value of Lg is 0.57 km found in the Sangannare sub-catchment followed by Upper-Kilange with Lg of 0.55. In these two areas, water has to flow for a distance of more than 500 metres on the ground before it gets into any defined channel. There are three classes of Lg i.e., low value < 0.2, moderate value 0.2 – 0.3 and high value >0.3 (Sukristiyanti et al., 2017). The overland flow for the entire River Kilange catchment is 0.5.2 km, which is high. High value of Lg means gentle slopes, long flow paths, more infiltration and reduced runoff. Low value of Lg indicates high relief, short flow paths, more runoff and less infiltration which leads to more vulnerability to the flash flooding.

3.3: Areal Parameters

Areal parameters calculated which will be discussed in this section include drainage density (Dd), stream frequency (Fs), form factor (Rf), elongation ratio (Re) drainage texture (Rt), infiltration number (If) circulatory ratio (Rc) and Form factor (Rf).

3.3.1: Drainage density (Dd)

Drainage density is a measure of how frequent streams occur on the land surface. It indicates the closeness of spacing between channels and is a measure of the total length of the stream segment of all orders per unit area. Drainage density reflects a balance between erosive forces and the resistance of the ground surface, and is therefore related closely to climate, lithology and vegetation (Koshak and Dawod, 2011; Altaf et al., 2013; Rai et al., 2017). The drainage density is governed by the factors like rock type, runoff intensity, soil type, infiltration capacity and percentage of rocky area (Harinath and Raghu, 2013).The drainage density for the entire Kilange catchment is 0.97 km/km^2 (Table 3.4). This low value of drainage density indicates that most rainfall infiltrates into the ground and few channels are required to carry the runoff.

Table 3.4: Some Important Areal Parameters of the River Kilange Catchment

Catchment/ Sub-catchment	Drainage density (Km/km^2)	Drainage texture (km)	Stream frequency	Infiltration number
Kilange	0.97	4.41	0.66	2.91
Upper-Kilange	0.91	5.40	0.63 0.63	3.40
Sangannare	0.87	2.52	0.63	1.59
Loko	1.64	4.71	0.66	3.11
Giraba	1.65	2.15	0.68	1.46
Lower Kilange	1.28	2.88	0.79	2.28

Drainage density values for the various sub-catchments are also shown in (Table 3.4). The relatively high drainage density values for the Loko and Giraba sub-catchments indicate that a large proportion of rainfall becomes runoff, which can be attributed to the less permeable sub-soil material and steep slopes in these areas.

3.3.2: Drainage Texture (Rt)

Drainage texture is the total number of stream segments of all orders in a river basin to the perimeter of the basin (Sukristiyanti et al., 2017). Drainage texture depends on a number of natural factors such as, rainfall intensity, vegetation cover, rock and soil types, relief and stage of topographic development of drainage basin

(Oruonye et al., 2016). There are five different texture classes: very coarse <2, coarse 2–4, moderate 4–6, fine 6–8, and very fine >8 (Altaf, et al., 2013).

The drainage texture of the River Kilange catchment is 4.41 (Table 3.4) indicating a moderate value. Drainage texture values in the study catchment are variable. Loko and Upper-kilange have drainage texture values of 4.71 and 5.40 respectively, which can be classified as moderate texture. In the other three sub-catchments namely; Sangannare, Giraba and Lower-kilange, the values are 2.52, 2.15 and 2.66 respectively, classified as coarse texture. The relatively higher drainage texture in the Loko and Upper-kilange sub-catchments can be attributed to the steep slopes and less permeable sub-soil materials in these two areas.

3.3.3: Stream Frequency (Fs)

The stream frequency (Fs) of a basin may be defined as the ratio between the total number of stream segments cumulated for all orders within a basin and the basin area (Kumar and Shetty, 2014). Stream frequency values in the study area range from 0.63 to 0.79 (Table 3.4). This indicates that there is less than one stream segment per square kilometer in the river catchment. By implication, the study catchment has moderate response potential for surface runoff. The relatively lower Stream frequency values signify high groundwater recharge capacity since the less numbers of streams limit the amount of water for runoff and hence more water will infiltrate.

3.3.4: Infiltration Number (If)

Infiltration number of a drainage basin is the product of drainage density and stream frequency. It is a parameter which gives an idea of the infiltration characteristics of the basin (Ziaur et al., 2012). High infiltration number (If), implies low infiltration and high runoff potentiality. The infiltration number of the River Kilange catchment is 2.91 as presented in (Table 3.4), which is moderate. The relatively higher values for the Upper-kilange and Loko sub-catchments (3.40 and 3.11) respectively indicate low infiltration and high runoff in these areas. The relatively steep slopes and the less permeable sub-soil material in these two sub-catchments partly account for the low infiltration rate, and high runoff in these two sub-catchments.

3.4: Shape Parameters

3.4.1: Form factor (Rf)

The form factor value varies from 0 in highly elongated basin to 1 for perfectly circular basin. The Rf values (Table 3.5) in the study area vary from 0.34 to 0.47 in the Loko and Lower-kilange sub-catchments respectively. These values of form factor suggest that the Loko sub-catchment is more elongated in shape whereas the highest value in Lower-kilange implies it is relatively circular in shape. An elongated watershed means it has low peak flows for longer duration while a circular watershed means it has high peak flows for a shorter duration (Sukristiyanti et al., 2017).

3.4.2: Elongation Ratio (Re)

Elongation ratio (Re) is the ratio between the diameter of a circle of the same area as the basin and the maximum basin length. The Re is calculated by using the following formula:
$Re = (2A/\pi)/L2$ (Kumar and Shetty, 2014).
Where, Re is the elongation ratio, 2 is constant, A = area and L is the maximum length of the basin.

It is a measure of the shape of the river basin and it depends on the climatic and geologic types. A circular basin is more efficient in runoff discharge than an elongated basin (Rai et al., 2017). Elongation ratio of the River Kilange catchment is 0.76 which shows that it is less elongated. The Re values for the different sub-catchments namely; Loko, Sangannare, Giraba, Upper-kilange and Lower-kilange are 0.65, 0.67, 0.71, 0.75 and 0.77 respectively as presented in (Table 3.5).

Catchment/Sub-catchments	Form factor	Elongation ratio
Kilange	0.46	0.76
Upper-Kilange	0.44	0.75
Sangannare	0.36	0.67
Loko	0.34	0.65
Giraba	0.40	0.71
Lower Kilange	0.47	0.77

Table 3.5: Shape Parameters of the River Kilange Catchment

Higher values of elongation ratio show high infiltration capacity and low runoff, whereas lower Re values which are characterized by high susceptibility to erosion and sediment load (Rai et al., 3017).

The Giraba, Upper-kilange and Lower-kilange show relatively higher values (0.71, 0.75and 0.770) representing the less elongated sub-catchments, while Sangannare and Loko with values of (0.65 and 0.67) are elongated (Fig.3.1).

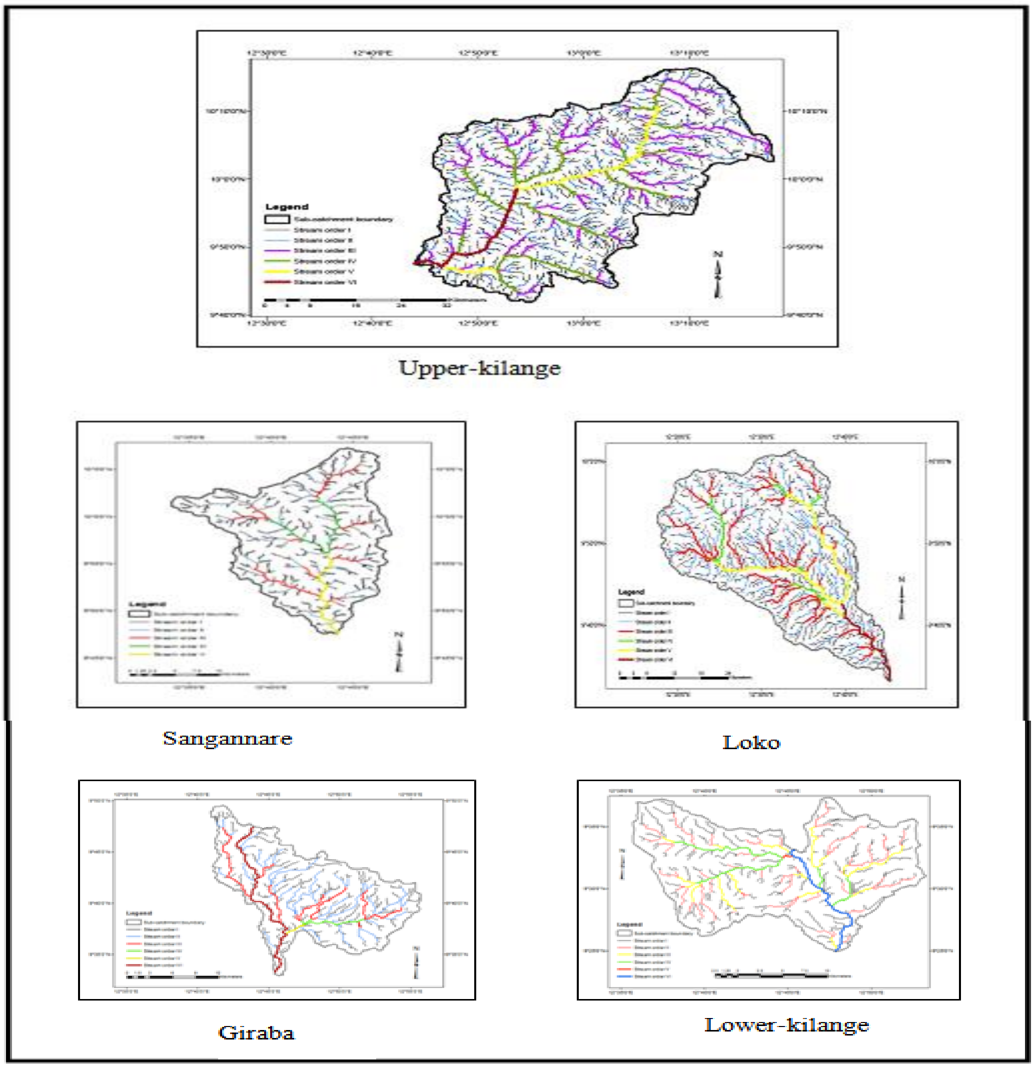

Figure 3.1: Stream Order and Shape of River Kilange Sub-catchments
Source: ArcGIS Analysis, 2018

3.5: Relief Parameters

Basin relief refers to the relative heights of points on the earth surface with respect to the horizontal base of reference. Vertical inequalities of an area plays an important role in controlling the distribution of precipitation, formation of surface water features like stream and occurrence of groundwater.

3.5.1: Basin relief (H)

Basin relief is the difference between maximum elevation and minimum elevation in a river catchment. The maximum relief of the study area is1228m (1.228km) and the minimum relief is 170m (0.170km). The basin relief for the study catchment is 1058m (1.058km) as presented in (Table 3.6). Basin relief of Upper-kilange, Sangannare, Loko, Giraba and Lower-kilange are 0.991, 0.468, 0.882, 0.304 and 0.407 kilometres respectively.

It is observed that higher relief is found in Upper-kilange located in the northern part, while the lowest is in Giraba in the southern part of the study catchment (Fig.3.2).

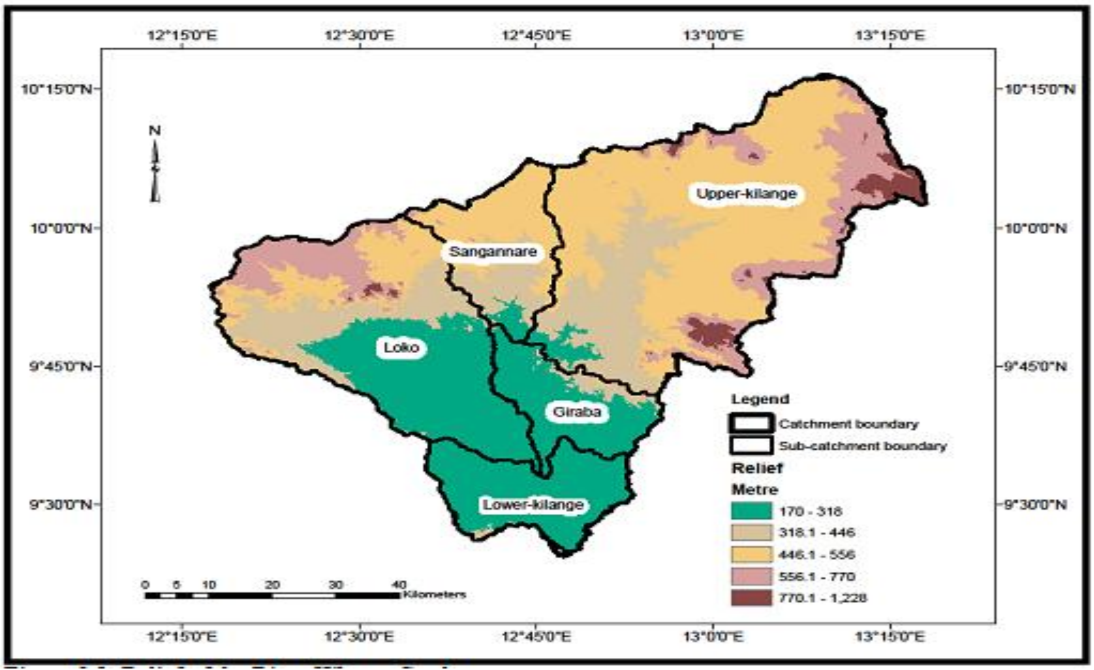

Figure 3.2: Relief of the River Kilange Catchments

Source: ArcGis Analysis, 2018

3.5.2: Relative Relief (Rr)

Relative relief (Rr) is the ratio of basin relief to basin perimeter (Melton, 1957). The calculated Rr for the River Kilange catchment is 0.0014, which is lower than all the relative relief values for all the sub-catchments (Table 3.6).

Table 3.6: Relief Parameters of the River Kilange Catchment.

Sub-catchment	Maximum Elevation (km)	Minimum Elevation (km)	Basin relief (km)	Relative Relief	Relief ratio	Ruggedness number
Upper- kilange	1.228	0.237	0.991	0.0037	0.0138	0.90
Sangannare	0.705	0.237	0.468	0.0039	0.0128	0.40
Loko	0.1068	0.186	0.882	0.0045	0.0136	1.44
Giraba	0.490	0.186	0.304	0.0025	0.0097	0.50
Lower-kilange	0.577	1.170	0.407	0.0032	0.0131	0.52
Kilange	1.228	0.170	1.058	0.0014	0.0101	1.02

3.5.3: Relief Ratio (Rh)

The relief ratio is a term used to express the ratio of the difference between maximum elevation and minimum elevation (basin relief) to horizontal distance along the line of longest dimension parallel to the main stream. The Rh values of the River Kilange catchment as given in (Table 3.6) range from 0.0097 to 0.0138. The relatively higher value of Rh for the Upper-kilange (0.0138) indicates moderate slope, while the lower value for the Giraba (0.0097) indicates a lower degree of slope**.** Generally, the River Kilange catchment is characterized by low relief ratio with a value of 0.010. Low relief ratios also indicate that the recharge capabilities of the basin are low and chances of ground water potential are good (Oruonye et al., 2016). . Low value of relief ratios is mainly due to the resistant basement complex rocks of the basin and low degree of slope (Rai et al., 2017).

3.5.4: Ruggedness number (Rn)

Ruggedness number is the product of maximum basin relief (H) and drainage density (Dd). Ruggedness number reflects the degree of slope steepness and length. High values of ruggedness number occur when slopes are very steep and long. Following the procedure of Farhan et al. (2015) it is possible to classify river catchments into five ruggedness number categories: <0.1 subdued morphology; 0.1 - 0.4 slight morphology; 0.4 - 0.7 moderate morphology; 0.7 - 1.0 sharp morphology; >1.0 extreme morphological expression including badlands topography. The Rn for the entire River Kilange Catchment is 1.02, which falls under the extreme morphology category. Ruggedness number of Upper-kilange, Sangannare, Loko, Giraba and Lower Kilange are 0.90, 0.40, 1.44, 0.50 and 0.52 respectively. High values of raggedness number can be attributed to steep slope of the land, while low values are associated with gentle slopes. The Loko sub-catchment has the highest Rn (1.44) in the study area. This indicates that the slopes are steeper and longer than those of other sub-catchments in the study area. This can partly be the cause of frequent and disastrous seasonal flooding in the Loko area.

IV. Conclusion

The morphometric analysis of the River Kilange catchment was carried out using Geographic Information System (GIS) technique. Shuttle Radar Topography Mission (SRTM) data at 30m resolution were used for preparing Digital Elevation Model –DEM in ArcGIS 10.0 software. The map of the study area was projected to Universal Transverse Mercator-UTM to enable the processing of drainage parameters like stream length, drainage area and perimeter in the attribute tables.

The River Kilange catchment is a seventh order catchment with a dendritic drainage pattern. The study area is underlain by uniform bedrock formation (the basement complex rocks) which makes the hydrological response in the area closely related to the geomorphology, the existing topographical condition and the prevailing vegetation cover. This has made it easy to understand the relationship between morphometric parameters and the physiographic characteristics of the river catchment. The area is characterized by permeable subsoil material and moderate slopes owing partly to the underlying resistant rock formation. Mean elevations in the area vary from 170 metres in the south where the river discharges into the River Benue to a height of over 1200 metres on the peaks of hills bordering the catchment's northern boundary.

The morphometric parameters of the River Kilange catchment indicate that the influence of tectonic structures (folding and faulting) on the drainage basin is negligible. Based on the topography, geomorphology and lithology of the River Kilange catchment, it falls under the category of drainage basins with extreme morphology. This is particularly true of the Loko sub-catchment, where the steeper and longer slopes render the area the most vulnerable to flooding in the River Kilange catchment. The high discharge potential of the Loko sub-catchment can be harnessed through the construction of dams for flood control and surface water supply.
From the foregoing discussions, it can be concluded that morphometric analysis of the River Kilange catchment has provided information regarding the topography, lithology and sub-surface soil conditions that helped to understand the areas vulnerability to flooding, erosion and or discharge potentials.

References

[1]. Adebayo, A. A. and Dayya, S. V. (2004) Geology, Relief and Drainage: In A. A. Adebayo (Ed), Mubi Region-A Geographical Synthesis, Paraclete Publishers, Yola

[2]. Adefioye, S. A. (2013). Analysis of Land Use/Land Cover Pattern along the River Benue Channel in Adamawa State, Nigeria, Academic Journal of Interdisciplinary Studies; Volume 2 No.5, Published by MCSER-CEMAS-Sapienza University of Rome

[3]. Altaf, F., Meraj, G. and Shakil A. R. (2013) Morphometric Analysis to Infer Hydrological Behaviour of Lidder Watershed, Western Himalaya, India,

[4]. Volume 2013, Article ID 178021, 14 pages, Hindawi Publishing CorporationGeography Journal, http://dx.doi.org/10.1155/2013/178021

[5]. Bawden, M.G. (1972) Hydrology: In P. Tuley, The Land Resources of North Eastern Nigeria, Volume 1, The Environment, Land Resources No. 9 Land Resources Division, Tolworth Tower, Surbiton, Surrey, EnglandDoad A.P. Warghat, S.R. and Khadse, S.P. (2012) Morphometric Analysis for Hydrological Studies using Geographical Information System: A Case Study, International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 5, Accessed 26 August 2013

[6]. Eze, B. E. and Efiong, J. (2010) Morphometric Parameters of the Calabar River Basin: Implication for Hydrologic Processes, Journal of Geography and Geology Vol. 2, No.1; www.ccsenet.org/jgg, Accessed, 27 August 2013

[7]. Ezemonye, M. N. and Emeribe, C. N. (2013) Appraisal of the Hydrological Potential of Ungauged Basin Using Morphometric Parameters, Ethiopian Journal of Environmental Studies and Management Vol. 6 No.4,http://dx.doi.org/10.4314/ejesm.v6i4.5

[8]. Farhan, Y., Anbar, A., Enaba, O. and Al-Shaikh, N. (2015) Quantitative Analysis of Geomorphometric Parameters of Wadi Kerak, Jordan,Using Remote Sensing and GIS. Journal of Water Resource and Protection, 7, 456-475.http://dx.doi.org/10.4236/jwarp.2015.76037

[9]. Girma, M. and Vijaya, B. (2015) Morphometric Characteristics and the Relation of Stream Orders to Hydraulic Parameters of River Goro: An Ephemeral River in Dire-dawa, Ethiopia, Universal Journal of Geoscience 3(1): 13-27, 2015 http://www.hrpub.org DOI: 10.13189/ujg.2015.030102

[10]. Harinath, V. and Raghu, V. (2013) Morphometric Analysis using Arc GIS TechniquesA Case Study of Dharurvagu, South Eastern Part of Kurnool District, Andhra Pradesh, India, International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064,Volume 2 Issue 1, January 2013, www.ijsr.net

[11]. Khadri, S.F.R. and Moharir, K. N.(2013) Estimation of groundwater prospectus zone mapping and morphometric analysis of WRD-4 watershed in Wardha District of Maharashtra, India using Remote Sensing and GIS Techniques, International Journal of Advancements in Research & Technology, Volume 2, Issue 5, Copyright © 2013 SciResPub. IJOART, Accessed, 27 August 2013

[12]. Koshak.N. and Dawod.G (2011) A GIS morphometric analysis of hydrological catchments within Makkah Metropolitan area, Saudi Arabia, International Journal of Geomatics and Geosciences Volume 2, No 2, 2011,Integrated Publishing services, Research article ISSN 0976 – 4380

[13]. Kumar, R.B.C. and Shetty, A. (2014) Morphometric Analysis of Netravathi River Basin Using GIS Techniques, https://www.researchgate.net/publication/261047912

[14]. Lakshmamma, N.D., Mahadevaswamy.G., Siddalingamurthy.S. and Manjunatha, S. (2011) Morphometric Analysis of Gundal Watershed, Gundlupet Taluk, Chamarajanagar District, Karnataka, India, International Journal of Geomatics and Geosciences, Volume 1, No. 4, Accessed 26 August 2013

[15]. Melton, M.A. (1945). Correlation Structures of Morphometric Properties of Drainage Systems and their Controlling Agents, Journal of Geology. 1958;66:442-460

[16]. Oruonye, E. D. (2016) Morphometry and Flood in Small Drainage Basin: Case Study of Mayogwoi River Basin in Jalingo, Taraba State Nigeria, Journal of Geography, Environment and Earth Science International, 5(1): 1-12, 2016; Article no.JGEESI.23379, ISSN: 2454-7352, SCIENCEDOMAIN international, www.sciencedomain.org Oruonye, E. D., Ezekiel, B. B., Atiku1, H. G., Baba, E. and Musa, N. I. (2016)

[17]. Drainage Basin Morphometric Parameters of River Lamurde: Implication for Hydrologic and Geomorphic Processe, Journal of Agriculture and Ecology Research International 5(2): 1-11, 2016; Article no.JAERI.22149 ISSN: 2394-1073

[18]. Pell, Frischmann and Partners-PFP Nigeria (1981) Kilange River Basin Feasibility Study, Volume IV, Upper Benue River Basin Development Authority, Federal Government of Nigeria

[19]. Rai, P.K., Mohan, K, Mihra, S., Ahmad, A. and Mihra, N. V. (2017) A GIS-based Approach In Drainage Morphometric Analysis of Kanhar River Basin, India, Appl.] Water Sci (2017) 7:217–232 DOI 10.1007/s13201-014-0238-y

[20]. Sukristiyanti, S., Maria, R. and Lestiana, H. (2017) Watershed-based Morphometric

[21]. Analysis: A Review, Global Colloquium on GeoSciences and Engineering 2017 IOP Publishing, IOP Conf. Series: Earth and Environmental Science **118** (2018) 012028 doi :10.1088/1755-1315/118/1/012028

[22]. Umo, I. S., Ezemonye, M. N., Ike, M. C. and Enwereuzor, A. I. (2017)

[23]. Dimensional Basin Morphometry and Discharge in the Coastal Plains Sands of Ikpa River, Akwa Ibom State, Nigeria, Journal of Geography, Environment and Earth Science, International, 13(3): 1-12, 2017; Article no.JGEESI.38699

[24]. ISSN: 2454-7352

[25]. Ziaur R. A., Rao, L. A. K. and Alia Y. (2012) GIS based Morphometric Analysis of Yamuna Drainage Network in parts of Fatehabad Area of Agra District, Uttar Pradesh, Journal Geological Society of India, Vol.79, pp.505-514

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