Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2013, Volume 2, Issue 1, pp. 59-69, Article ID Tech-58
ISSN 2320 - 0243

Research Article **Open Access**

Morphometric Analysis of Tandava River Basin, Andhra Pradesh, India

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Publication Date: 29 March 2013

Article Link: http://technical.cloud-journals.com/index.php/IJARSG/article/view/Tech-58

Abstract The seasonal abrupt flood event in the Tandava River Basin was the major loss for socio-economic infrastructure. The main objective of this study is to characterize the Morphometric parameters of Tandava River Basin (TRB) which depicted on toposheets 65; K/5, K/6, K/7, K/10 and K/11 with scale 1:50,000 were used for Morphometrical analysis. In this study, morphometric parameters were delineated through onscreen digitization on topographic map in ArcGIS-9.3. The TRB is covering about 1283 Km^2 consists of hills, valleys and plains. The longest flow path was calculated and found to be 83.360 Km. The study reveals that; such information derived from GIS would be very useful in practicing water management activity and designing of water harvesting project with minimum cost, efforts and time in reducing rates of natural degradation in the basin.
Keywords *Morphometry, Tandava River Basin, Drainage Characteristic, Sub-Basins*

1. Introduction

Morphometric study has got its foundation from stream flow analysis. Morisawa [1], who observed that stream flow, can be expressed as a general function of geomorphology of a sub-basin. The assertion still stand valid following Jain and Sinha [2], Okoko and Olujimi [3] and Ifabiyi [4] who reported that the geomorphic characteristics of a drainage basins play a key-role in controlling the basins hydrology. Morphometric analysis is a bit very advantageous for the study of minor (intermittent) river like Tandava River Basin and hence this study is intended to present the characteristic of Tandava River Basin (TRB) by following scientific formula and procedures.

2. Study Area

The area of study is bounded in between latitudes 17^{0}20'N to 17^{0}50`N and longitudes 82$^0$20`E to 82^{0}40' E. It forms part of Survey of India Toposheets 65 K/5, K/6, K/7, K/10 and K/11 and covers an area of 1283 Km^2. Major part of the area is in Visakhapatnam district but adjacent part of East Godavari district is also included to see the total morphometry of the drainage basin (Figure1).

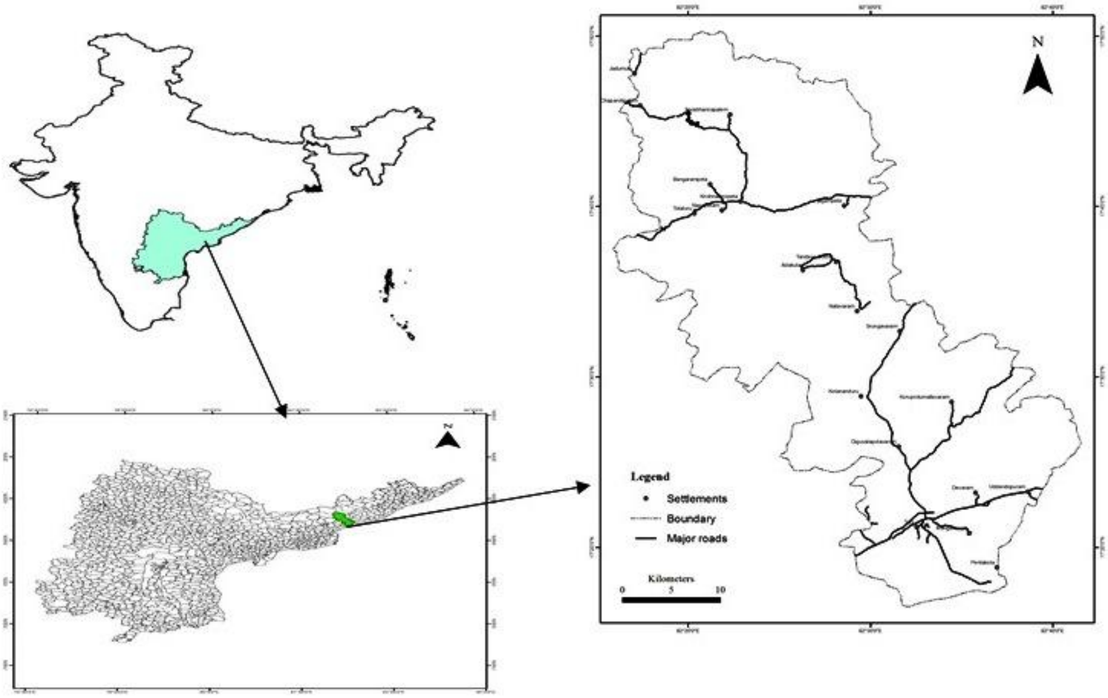

***Figure 1**: Location Map of the Study Area*

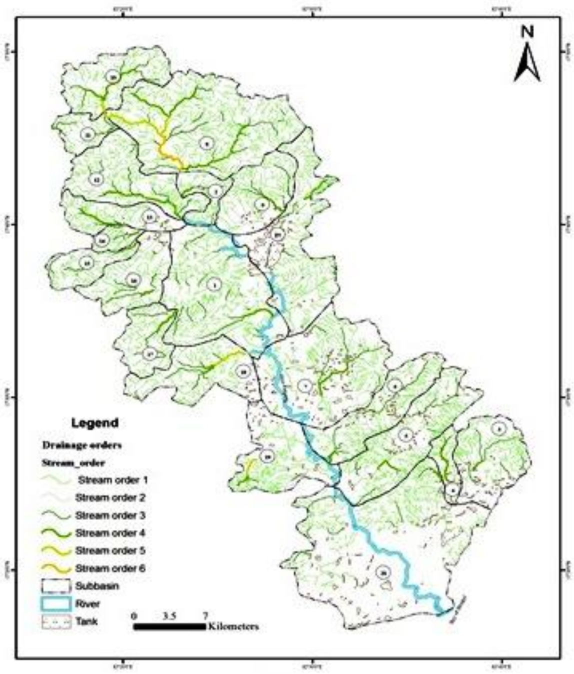

***Figure 2:** Drainage Network of Tandava River Basin*

3. Methodology

This work is based on map analysis carried out onscreen digitization. Toposheet number 65; K/5, K/6, K/7, K/10 and K/11 with the scale of 1:500,000. (Survey of India) were mosaic to subset the study region. The subset image is geometrically corrected through the process of rectification. Strahler's, Horton's and Schumm's methods have been employed to assess the fluvial characteristics of the study region [5, 6]. The maps were georeferenced and digitized in ArcGIS-9.3 and Erdas Imagine-9.1 software's and attributes were assigned to create the digital database (Figure 3). The map showing drainage pattern in the study area (Figure 2) was draped over ASTER 30m resolution and SRTM 90m resolution DEM data for further clarification. Morphometric analysis was carried out at sub-basin level in the GIS System (ArcGIS - 9.3). Based on the drainage order, the drainage channels were classified into different orders [6]. In GIS, drainage channel segments were ordered numerically as order number 1 from a stream's headwaters to a point downstream. The stream segment that results from the joining of two first order streams was assigned order 2.

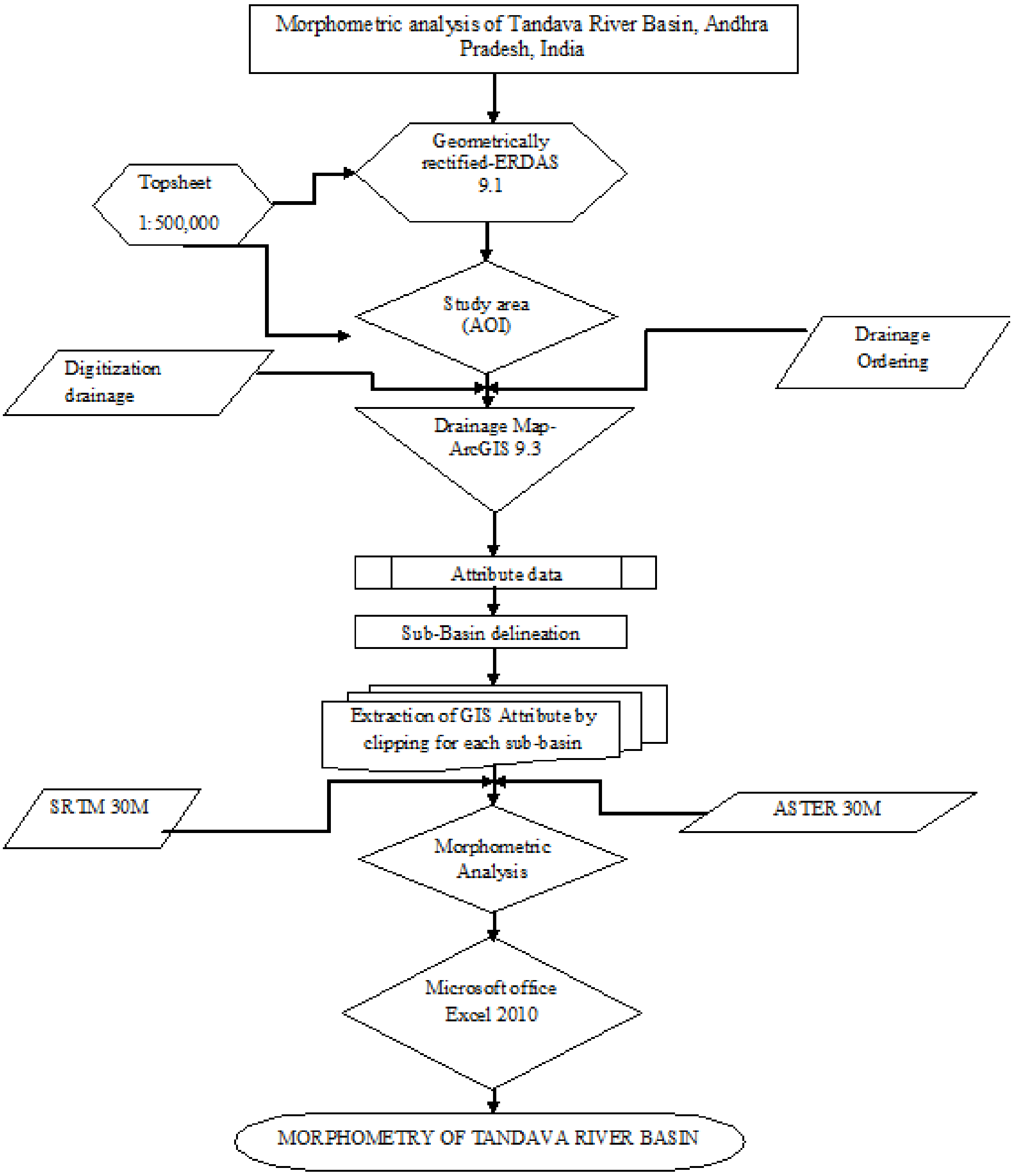

Figure 3: *Flow Chart of Methodology*

4. Results and Discussion

Various morphometric result of TRB is calculated in ArcGIS-9.3 and is summarized in tables. The basin area is divided into 21 sub-basins of fourth order streams. Orders above the fourth were disregarded because the relatively small sample of these streams is less reliably representative than those of the lower order [7] (Table 1).

Table 1: *Area and Perimeter of Sub-Basin of TRB*

Sub-Basin	Area	Perimeter
1	113	49
2	17	25
3	51	31
4	14	20
5	74	47
6	54	41
7	61	39
8	111	44
9	140	56
10	74	43
11	46	35
12	17	20
13	60	43
14	30	30
15	10	13
16	23	24
17	43	32
18	31	27
19	53	41
20	55	39
21	206	74

4.1. Linear Aspect

Drainage basin analyses begin by designation of stream orders. The channel segment of the drainage basin has been ranked according to Strahler stream ordering system using ArcGIS-9.3 The study area is a 6th order drainage basin [6] (Figure 2). The total number of 3882 streams identified of which 2851 are 1st order which is 73.44%, 828 are 2nd order which amounts 21.32%, 176 are 3rd order which is 4.53% and 27 in 4th order which is 0.69% (Table 2) .

Table 2: *Number of Streams in Each Order in Each Sub-Basin*

Sub-Basin No.	Number of Streams in Each Order				
	N_1	N_2	N_3	N_4	$\sum N$
1	277	67	25	1	370
2	55	15	5	1	76
3	100	23	6	1	130
4	38	13	4	1	56
5	243	51	12	1	307
6	146	179	12	1	338
7	171	47	9	1	228
8	383	89	22	3	497
9	97	25	5	1	128
10	109	23	6	2	140
11	42	9	4	2	57
12	164	41	11	1	217
13	65	18	5	1	89
14	31	7	3	1	42
15	68	23	6	1	98
16	103	23	6	1	133
17	79	17	4	1	101
18	97	29	9	2	137
19	126	30	6	2	164
20	266	56	9	1	332
21	191	43	7	1	242
Total Streams	**2851**	**828**	**176**	**27**	**3882**

In the study, streams of relatively smaller lengths are characteristics of areas with larger slopes such as sub-basin 2, 4, 10, 11, 14, 15 and 18 shows large slope and finer texture. The relationship between stream order Vs log of number of stream and log of total length was examined (Figures 4a & 4b), it seems to be in geometric progression and agree with Horton's law of stream length. The study shows the total length of stream decreases with increasing order of stream. The stream lengths of different order of streams of TRB are given in Table 3.

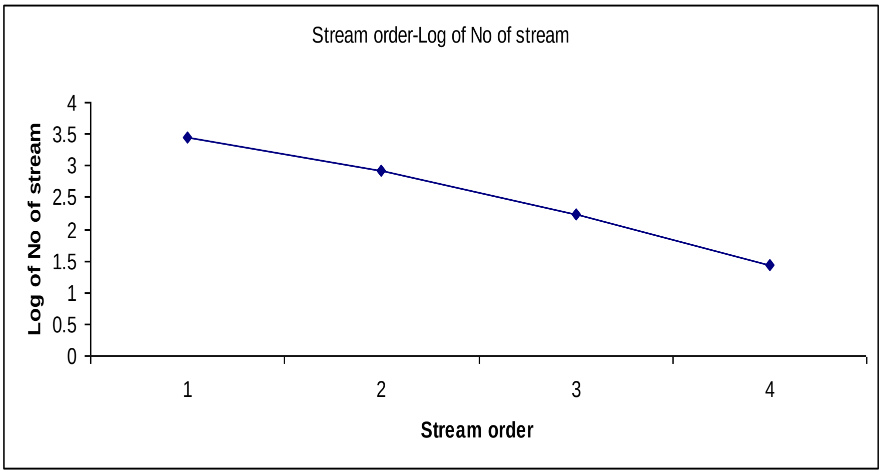

Figure 4: *a) Stream Order V_S Log of No. of Streams*

Table 3: *Area (Km²), Number of Streams Length in Each Order, and Mean Stream Length and Cumulative Stream Length in 21 Sub-Basins of TRB*

Sub-basin	Area	Basin length	L_1	L_M	L_2	L_M	L_3	L_M	L_4	L_M	Cumulative stream length
1	113	58.694	159.80	0.58	43.96	0.66	15.48	0.56	3.53	3.53	61.92
2	17	10.820	29.60	0.54	7.70	0.51	2.46	0.53	1.38	1.38	14.09
3	51	24.302	60.95	0.61	20.15	0.88	15.06	1.00	1.05	1.05	27.21
4	14	8.309	21.38	0.56	4.53	0.35	3.10	1.26	4.86	4.86	12.55
5	74	46.553	130.33	0.54	37.41	0.73	16.06	1.00	2.41	2.41	50.56
6	54	36.097	90.83	0.62	31.32	0.17	20.38	1.00	1.85	1.85	38.32
7	61	41.962	103.75	0.61	37.05	0.79	13.12	0.61	5.37	5.37	45.04
8	111	83.360	209.84	0.55	69.28	0.78	21.67	0.61	18.83	6.28	31.29
9	140	25.760	63.57	0.66	26.08	1.04	12.16	1.18	3.12	3.12	29.57
10	74	27.682	68.52	0.63	24.06	1.05	7.63	0.74	7.77	3.89	17.97
11	46	11.559	20.56	0.49	8.94	0.99	11.83	0.72	0.21	0.11	8.04
12	17	38.620	93.10	0.57	35.80	0.87	3.64	0.23	9.70	9.70	42.23
13	60	17.158	45.25	0.70	15.52	0.86	27.48	8.49	4.62	4.62	23.68
14	30	7.055	18.48	0.60	5.49	0.78	3.24	0.89	0.62	0.62	10.23
15	10	14.741	35.10	0.52	15.22	0.66	4.60	0.60	1.02	1.02	17.53
16	23	23.617	54.31	0.53	26.88	1.17	15.87	1.34	1.45	1.45	26.87
17	43	18.120	43.29	0.55	14.13	0.83	8.26	0.68	2.89	2.89	20.90
18	31	25.564	59.57	0.61	27.10	0.93	12.29	0.94	2.46	1.23	15.88
19	53	28.065	78.01	0.62	29.65	0.99	10.38	3.34	1.50	0.75	24.23
20	55	52.424	144.28	0.54	48.73	0.87	20.19	1.30	1.21	1.21	56.94
21	206	44.881	121.52	0.64	47.73	1.11	7.38	1.00	2.89	2.89	52.24

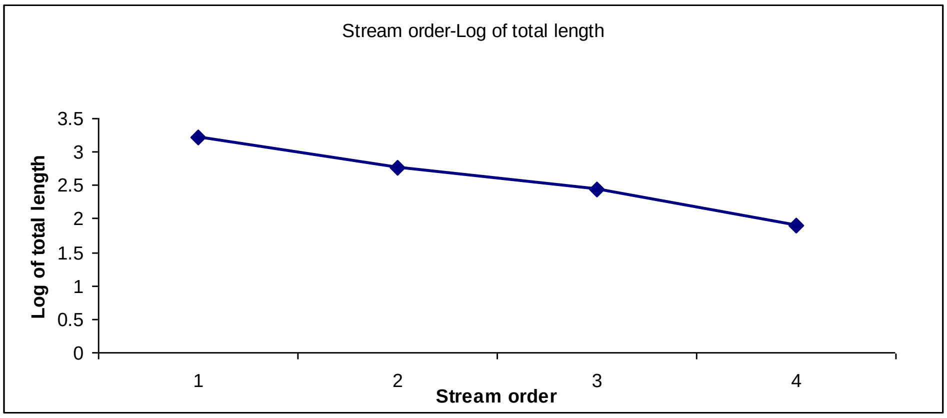

Figure 4: *b) Stream Order Vs log of Total Length*

4.2. Areal Aspects

4.2.1. Drainage Density (D_d)

The drainage density of the study area is 0.702 Km/ Km². This value indicates that for every square kilometer of the basin, there is 0.702 kilometer of stream channel. In other word, 0.702 is the mean length of stream channel for each unit area. According to Deju values of drainage density under 0.5 are poor density; those with values of 0.5 to 1.5 are medium density basins while basins with values above 1.5 are excellent density basins [8]. From this classification, TRB falls into the group of medium density basins. It is suggested that the poor drainage density in sub-basin 8, 9, 10, 11, 13, 14, 17, 19 and 21 indicates highly permeable subsoil and thick vegetative cover [9]. The type of rock also affects the drainage density.

4.2.2. Stream Frequency (F_u)

Stream frequency is the ratio of number of streams in a drainage basin to the area of the drainage basin [4]. The TRB area has a stream frequency of 85.267 streams per Km. The value of stream frequency for the basin exhibit positive correlation with the drainage density value of the area indicating the increase in stream population with respect to increase in drainage density.

***Table 4**: Stream Frequency, Drainage Density, Types of Drainage, Constant Channel Maintenance*

Sub-basin No.	Area	Stream Frequency	Drainage Density	Types of Drainage	Constant of Channel Maintenance
1	113	3.274	0.548	M	1.825
2	17	4.471	0.829	M	1.207
3	51	2.549	0.534	M	1.874
4	14	4.000	0.897	M	1.115
5	74	4.149	0.683	M	1.464
6	54	6.259	0.710	M	1.409
7	61	3.738	0.738	M	1.354
8	111	4.477	0.282	P	3.548
9	140	0.914	0.211	P	4.735
10	74	1.892	0.243	P	4.119
11	46	1.239	0.175	P	5.722
12	17	12.765	2.484	E	0.403
13	60	1.483	0.395	P	2.534
14	30	1.400	0.341	P	2.932
15	10	9.800	1.753	E	0.570
16	23	5.783	1.168	M	0.856
17	43	2.349	0.486	P	2.057
18	31	4.419	0.512	M	1.953
19	53	3.094	0.457	P	2.187
20	55	6.036	1.035	M	0.966
21	206	1.175	0.254	P	3.943

4.2.3. Drainage Texture (T)

According to Smith the drainage texture may be defined as the relative spacing of drainage lines. The drainage density and drainage frequency have been collectively defined as drainage texture. Based on the values of T it is classified as [10]:

0 – 4 – Coarse
4 – 10 – Intermediate
10- 15 – Fine
>15 – Ultra Fine (bad land topography)

A. *Texture Ratio* The first order streams being the maximum in number, they are considered to be equivalent number to crenulations in the present investigation. The texture ratio directly or indirectly reflects the drainage density. It has been generally marked that the texture ratio increases with the increase in the area of the intrabasins. The texture and texture ratio are calculated for the 21 sub-basins using definition and the values are given in Table 5. The value varies from low of 0.193 for Sub-basin No. 9 to high 31.71 for sub-basin No. 12. For TRB the mean drainage texture ratio is 3.765 indicating the massive and resistant rocks cause coarse texture. Coarse drainage density is likely to appear in areas of permeable rocks and low rainfall intensity. A drainage basin in humid regions often shows medium drainage density. The value of Weighted means texture ratio (T_m) for TRB is 0.174. Thus, the weighted mean topographic texture (0.18) of TRB is a coarse texture.

Table 5: *Texture, Texture Ratio, Weighted Mean Texture*

Sub-Basin No.	Texture	Texture Ratio (T_m)	Weighted Mean (T_m)
1	1.794	5.653	0.498
2	3.705	2.200	0.029
3	1.360	3.226	0.128
4	3.586	1.900	0.021
5	2.834	5.170	0.298
6	4.441	3.561	0.150
7	2.760	4.385	0.208
8	1.262	8.705	0.753
9	0.193	1.732	0.189
10	0.459	2.535	0.146
11	0.217	1.200	0.043
12	31.709	8.200	0.109
13	0.585	1.512	0.071
14	0.477	1.033	0.024
15	17.181	5.231	0.041
16	6.755	4.292	0.077
17	1.142	2.469	0.083
18	2.263	3.593	0.087
19	1.415	3.073	0.127
20	6.250	6.821	0.292
21	0.298	2.581	0.414

4.2.4. Bifurcation Ratio (R_b)

Horton [5] had defined the bifurcation ratio as the ratio of the number of streams of an order to the number of those in the next higher order. According to Strahler [6], the values of bifurcation ratio characteristically range between 3.0 and 5.0 for drainage basin in which the geological structures do not disturb the drainage pattern. The bifurcation ratio varies with the variations in drainage basin geometry and lithology and displays geometric similarity. The bifurcation ratio is estimated to be 5.17; on the average, there are 3 times as many channel segments of any given order as of the next higher order. It varies between 2.97 and 10.60, which indicates the control of the lithology and geologic structures giving rise to the distorted trellis drainage pattern and the geological disturbances such as faults and folds are encountered frequently in the sub-basin 1, 5, 6, 7, 8, 11, 12, 20 and 21 and hence, the mean bifurcation ratio of all 21 sub-basin lies between 2.97 and 10.60 (Table 6).

Miller [11], Strahler [6], opined that lithological variations do not cause differences in bifurcation ratio. Because of chance of irregularities, bifurcation ratio between successive orders differ within the same basin even if a general observance of a geometric series exists [12], thus, the bifurcation ratio of the first, second and third orders differ from each order in each of the sub-basin. In the present study, the higher values of Rb indicates strong structural control on the drainage pattern, while the lower values indicative of sub-basin that are not affect by structural disturbances.

Table 6: *Bifurcation Ratio in Individual Sub-Basins of TRB*

Sub-Basin No.	Bifurcation Ratio			
	Rb_1	Rb_2	Rb_3	Mean Rb
1	4.13	2.68	25	10.60
2	3.67	3.00	5	3.89
3	4.35	3.83	6	4.73
4	2.92	3.25	4	3.39
5	4.76	4.25	12	7.00
6	0.82	14.92	12	9.24
7	3.64	5.22	9	5.95
8	4.30	4.05	7.33	5.23
9	3.88	5.00	5	4.63
10	4.74	3.83	3	3.86
11	4.67	2.25	2	2.97
12	4.00	3.73	11	6.24
13	3.61	3.60	5	4.07
14	4.43	2.33	3	3.25
15	2.96	3.83	6	4.26
16	4.48	3.83	6	4.77
17	4.65	4.25	4	4.30
18	3.34	3.22	4.5	3.69
19	4.20	5.00	3	4.07
20	4.75	6.22	9	6.66
21	4.44	6.14	7	5.86

4.2.5. Elongation Ratio

Smaller the fraction more elongated is the shape of the basin, and larger the fraction the more circular is the shape of the basin. It is generally marked that the elongation ratio remains high where rock strata is hard and slope remains steep. The elongation ratio value of the study area is 0.172; the basin in the study area assumes a rotundity and low degree of integration characteristics.

4.2.6. Circulatory Ratio (R_c)

The study reveals that the circularity ratio value (0.505) of the basin does not corroborates the Miller's range which indicated that the basin is weakly elongated in shape, high discharge of runoff and highly impermeability of the subsoil condition but rather the basin of the study area is rotundity and low degree of integration characteristics.

4.2.7. Form Factor (R_f)

The ratio of the basin area to the square of basin length is called the form factor. The form factor of the TRB is 0.12 Km^{-1}. It is used as a quantitative expression of the shape of basin form which is stretched elliptical. The form factor for all sub-basin varies from 0.01 – 0.6 (Table 7). This observation shows that the sub-basins are more or less circular. The elongated Sub-basin with low value of R_f indicates that the basin will have a flatter peak flow for longer duration. Flood flows of such circular basins are difficult to manage than from the elongated. Among the TRB's Sub basins; Sub-basin 14 with the form factor 0.6 seems to be highly elongated when compared to other Sub-basins of the drainage basins. Analysis of form factor (R_f) reveals that sub-basins having low R_f have less side flow for shorter duration and high main flow for longer duration. The sub-basin with high R_f have side flow for longer duration and low main flow for shorter duration causing high peak flows in a shorter duration.

Table 7: *Dimensionless Ratio (Elongation, Circularity and Form Factor)*

Sub-Basin No.	Area(A_u)	Perimeter	Mean Stream Length	Elongation	Circularity	Form Factor
1	113	49	58.69	0.102	0.591	0.03
2	17	25	10.82	0.215	0.342	0.15
3	51	31	24.30	0.166	0.667	0.09
4	14	20	8.31	0.254	0.440	0.20
5	74	47	46.55	0.104	0.421	0.03
6	54	41	36.10	0.115	0.403	0.04
7	61	39	41.96	0.105	0.504	0.03
8	111	44	83.36	0.071	0.720	0.02
9	140	56	25.76	0.259	0.561	0.21
10	74	43	27.68	0.175	0.503	0.10
11	46	35	11.56	0.331	0.472	0.34
12	17	20	38.62	0.060	0.534	0.01
13	60	43	17.16	0.255	0.408	0.20
14	30	30	7.06	0.438	0.419	0.60
15	10	13	14.74	0.121	0.743	0.05
16	23	24	23.62	0.115	0.502	0.04
17	43	32	18.12	0.204	0.527	0.13
18	31	27	25.56	0.123	0.534	0.05
19	53	41	28.07	0.146	0.396	0.07
20	55	39	52.42	0.080	0.454	0.02
21	206	74	44.88	0.180	0.472	0.10

5. Conclusion

The study come across the conclusion is that the Morphometric study for river basin especially for those which exposed seasonal fluctuation has a boost impact for water development, water sustainability and water resource management. The result presented and the conclusion derived in this paper will suggested and recommended to develop better water usage mechanisms for better application of the river basin.

References

[1] Morisawa M.E. *Measurement of Drainage Basin Outline Form*. Journal of Geol., 1957. 66; 86-88.

[2] Jain V., et al. *Evaluation of Geomorphic Control on Flood Hazard Through Geomorphic Instantaneous Unit Hydrograph.* Current Science .2003. 85 (11) 26-32.

[3] Okoko E.E., 2003: *The Role of Geomorphic Features in Urban Flooding: The Case of Ala River in Akure, Nigeria.* Int. Journal of Environmental Issues, 1 (1) 192-201.

[4] Ifabiyi I.P. *A Reduced Rank Model of Drainage Basin Response to Runoff in Upper Kaduna Catchment of Northern Nigeria*. Geostudies Forum. 2004. 2 (1) 109-117.

[5] Horton R.E. *Erosional Development of Streams and Their Drainage Basins: Hydro Physical Approach to Quantitative Morphology.* Geol. Soc. Am. Bull. 1945. 56: 275-370.

[6] Strahler A.H, 1964: *Quantitative Geomorphology of Drainage Basins and Channel Networks*. Handbook of Applied Hydrology, McGraw Hill Book Company, New York, 4-39/4-76.

[7] Strahler A.N. *Hypsometric (Area – Altitude) Analysis of Erosional Topography.* Geol. Soc. Amer. Bull., 1952. 63; 117-142.

[8] Deju A. Raul, 1971: *Regional Hydrology Fundamentals*. Gordon & Breach Publishing Group, Newark, New Jersey, United States 204.

[9] Nag S.K. *Morphometric Analysis Using Remote Sensing Techniques in the Chaka Sub basin Purulia District, West Bengal*. J. Indian Soc. Remote Sensing. 1998. 26; 6976.

[10] Smith K.G. *Standards for Grading Texture of Erosional Topography*. Am J Sci. 1950. 248; 655668.

[11] Miller V.C., 1953: *A Quantitative Geomorphic Study of Drainage Basin Characteristics in the Clinch Mountain Area*, Virginia and Tennessee. NR Technical Report 3, Office Naval Research Project.

[12] Schumm S.A. *The Evolution of Drainage Systems and Slopes in Badlands at Perth Amboy, New Jersey*, Geol. Soc. Amer. Bull., 1956. 67: 597-646.