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Linear Morphometric Parameters of Jia Bhareli Basin NE India

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Abstract : *Jia Bhareli basin drains more than 11000 sq. km in N E India, with ~89% of its catchment developed within Arunachal Himalaya. The Jia Bhareli trunk channel, also known as the Kameng in its upstream reach beyond Bhalukpong, flows across different lithotectonic domains which is reflected in planform geometry and the drainage development. In this study we present the linear morphometric parameters as computed for 41 selected 5th order sub basins of Jia Bhareli and establish the mutual relation between these parameters to see their conformity with available understanding on drainage development and landform evolution. The study suggests that although there is general conformity in variability of morphometric parameters and their mutual relation, there are a number of drainage anomalies that can be explained in terms of structural control and lithological characteristics.*
Key words: *Jia Bhareli basin, morphometry, N E India*

I. Introduction

Morphometric analysis pertains to quantitative evaluation of form characteristics of landscape. Drainage basin provides an ideal unit of the landscape and as such the quantitative assessment of drainage networks of a basin can provide useful clues to understanding the earth surface form and processes. Further, river channels being the most sensitive geomorphic features responding to any change in geological factors viz. lithology and tectonics as well as climate, morphometric parameters are expected to reflect mutual control of these factors. The composition of the stream system of a drainage basin is expressed quantitatively with stream order, drainage density, bifurcation ration and stream length ratio (Horton, 1945). It incorporates various components such as, stream segments, basin length, basin parameters, basin area, altitude, volume, slope, profiles of the land which indicates the nature of development of the basin. There are plethora of literature on drainage basin morphometry that have contributed towards understanding drainage development in the light of controlling variables in a particular geological terrane and a number of general bivariate relationship have been established (Strahler 1952, 1957, 1958, and 1964; Schumm, 1956; Morisawa, 1957, 1958; Scheidegger, 1965; Hack, 1973; Shreve, 1967; Gregory, 1968; Gregory and Walling, 1973 and Keller and Pinter 1996). Here we present the linear morphometric parameters of Jia Bhareli river basin of N E India to see their conformity with available understanding on drainage development and landform evolution and explain anomalies in terms of lithotectonic setup of central part of Arunachal Himalaya.

II. Study area

Jia Bhareli is a north bank tributary of the Brahmaputra flowing across Higher, Lesser and Sub Himalayan domain in Arunachal Himalaya. The upper regime of Jia Bhareli upstream of Bhalukpong is known as the Kameng which originates in Higher Himalaya at an elevation of ~5400m. It debouches into the Brahmaputra plain south of Bhalukpong and flows for about 55km downstream of Potasali to join the Brahmaputra River near Tezpur. The Jia Bhareli basin (~11,280 sq km) spread into East and West Kameng, Tawang districts of Arunachal Pradesh and Sonitpur district of Assam apart from a small area in Bhutan and China (91^{o}55′E - 93^{o}25′E and 26^{o}35′N - 28^{o}00′N). The trunk channel is characterised by high gradient in its initial mountain reach of 40km from the drainage divide followed by gentler gradient for the remaining 200 km of the channel. The river shows an average gradient of ~22m/km. However, in its upstream course north of the Main Central Thrust (MCT) the gradient is ~112 m/km changing to ~8.3 m/km between MCT and MBT (Main Boundary Thrust) and ~2.1 m/km between MBT and HFT (Himalayan Frontal Thrust) while the alluvial segment shows a substantially lower gradient of ~ 0.4 m/km. In this study a total of 41 sub basins of Jia Bhareli across different litho-tectonic settings are identified for detail analysis of linear morphometric parameters (Figure 1).

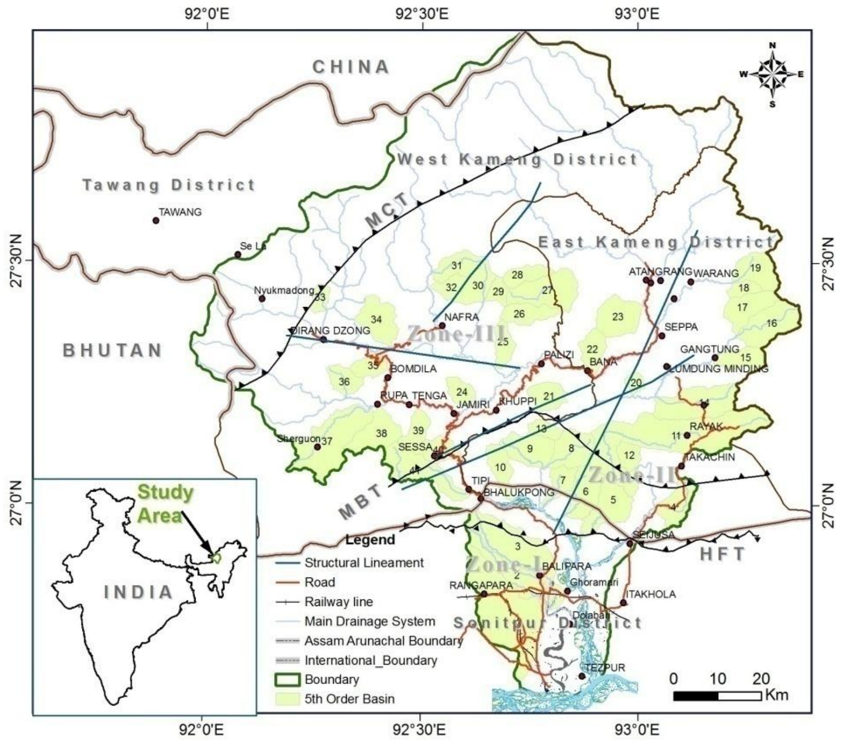

Figure 1: Location Map of the study area showing selected sub basins of Jia Bhareli basin and the delineated lithotectonic divisions

III. Geology:

Jia Bhareli river catchment has a diverse lithostratigraphy and areas of structural complexities with active tectonics. The main lithologic units are Alluvium, Neogene Clastics (Siwaliks), Gondwanas and Bomdila and Sela Group (Precambrian). The outcrops of which are found from younger to older along a south to north traverse (GSI, 2010). The major structural discontinuities which are well discernible, are – the Himalayan Frontal Thrust (HFT), Main Boundary Thrust (MBT) and Main Central Thrust (MCT) as well as numerous transverse faults (Valdiya, 1973). The area shows a regional trend of E-W to ENE-WSW in conformity with the eastern Himalayan trend. The HFT separates the Neogene Clastics (Siwaliks) from the alluvial plain of Brahmaputra, MBT separates the Siwaliks from the Gondwanas and MCT separates Bomdila sequence from the Sela group (GSI, 2010).

IV. Database and methodology

For this study, a detail geospatial database was generated based on Survey of India topomaps in 1:50000 scale (Table 1). However, unavailability of topographic maps for the areas adjacent to the international border imposed limitation in covering the entire catchment area. As such 41 representative 5th order sub basins with all available data and covering different lithotectonic domains were selected for detail morphometric analysis (Figure 1). Hierarchical ordering of stream segments were done following procedure suggested by Horton (1945) and modified by Strahler (1952). Basin boundaries were delineated based on surface water divide and joining the points of highest elevation and following the trend of elevation contours.

Table 1: Details of the Data Base

Data Type	Scale	Topographic Map Index	Year of Publication
SoI Toposheets	1:50,000	83A/7, 83A/8, 83A/11, 83A/12, 83A/15, 83A/16, 83B/5, 83B/9, 83B/10, 83B/13, 83/B14, 83E/3, 83E/4, 83F/1, 83F/2	1979

V. Results and discussion

Stream Order (U)

Stream Ordering is done using the Strahler (1952) system, which is a slightly modified of Hortons (1945) system with all fingertip streams from drainage divide forming 1st order, joining of two first order streams forming the 2nd order while two second order segments joining together to form a 3rd order segments and so on. Following this procedure and within the limitations of the coverage by topographic maps the Jia Bhareli is found to be an 8th order drainage basin. Within the area of interest 41 number of 5th order segments and as many as 107 number of 4th order segments were delineated. The high value of stream order of Jia Bhareli trunk channel reflects very high drainage development in the upstream catchment. The drainage development in the basin is mainly of dendritic, trellis and rectangular pattern. Predominant development of dendritic pattern north of MBT reflects the homogeneity of lithology. This region is largely composed of crystalline rocks. The rectangular drainage is suggestive of drainage control by the along strike structures and Himalayan transverse faults and lineaments as seen in the course of Pakke river (Basin index 11). The trellis pattern is mostly found in the folded zone of Neogene clasitcs.

Stream Number (Nu)

The total number of stream segments in each order is found to decrease as the stream order increases in all the sub basins (Table 2). Highest number of stream segments (1410) is found in the Pakke sub basin (Basin index 11) whiles the lowest number (95) is found for the Lengpla sub basin (Basin index 20). In general however, total number of stream segments is more within the Himalayan domain than the alluvial domain (Table 3). Further the basins towards north show higher stream number and more particularly within the crystalline terrane north of MBT. Similarly the numbers of 2nd and 3rd order streams are gradually high from alluvial to highly dissected hills from south to north. Bivariate analysis of the total stream length against the stream order as a semi-log plot shows that the number of stream segment increases with decreasing stream order in all the sub basins (Figure 2) i.e. these parameters show a negative correlation which corroborates the law of stream number (Strahler , 1957). A grouping of the sub basins into Zone I, II and III do not suggest any anomalies in pattern.

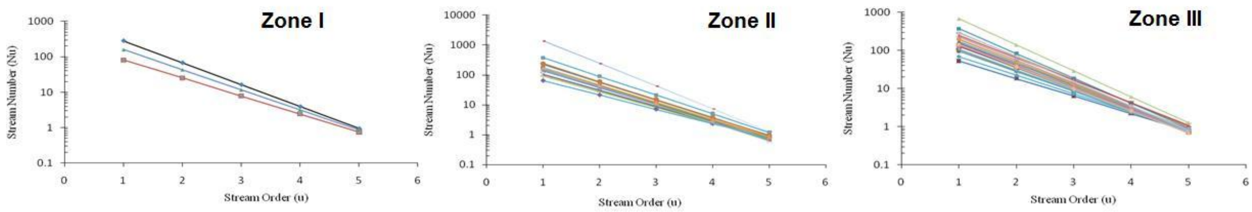

Figure 2. Bivariate plot of stream order against stream number in Jia Bhareli basin

Stream Length (Lu)

The Pakke sub basin is characterized by highest total stream length (~974km) while the Lengpla sub basin has minimum total stream length (~53km). Thus there is a relation between number of drainage and total stream length in these basins. However, this is not reflected in other basins. Contrary to higher number of stream segments, the total stream length is less for the basins north of MBT with the exception of the Pakke river (Basin index 11) and Dublo Kho (Basin index 37) sub basins.

It is observed that the frequency of the drainage development is less in the alluvial part (0.7 km^{-2}) and high in the north of Main Boundary Thrust (MBT) (4.5 km^{-2}) whereas the overall drainage frequency is 3.8 km^{-2} (Table 3). The drainage density also shows variations with respects to the structural and lithological characteristics. The alluvial part has a drainage density of ~1 km^{-1} where as the area north of MBT is ~3.0 km^{-1} and average drainage density of the whole Jia Bhareli basin is 2.6 km^{-1} (Table 3). Between HFT and MBT the average density is ~2.9 km^{-1} . Thus, both Df and Dd shows their variability north and south of the main structural lineaments viz., HFT and MBT which define major lithological boundaries.

Mean Stream Length (L□)

Mean stream length is computed by dividing the total stream length by the total stream number which rationalize the drainage development scenario in a basin. Average mean stream length of the 5th order sub basins are found in the range of 0.5-1.4km which is however, variable for different stream orders and in different parts of the Jia Bhareli basin. Usually mean stream lengths increase with the increase in stream order. However, in some of the basins under study it is found to bear an opposite relation viz., higher orders streams have a less mean stream length. The 5th order channels in particular show wide variation in mean stream length (0.3-33.9km) thus presenting drainage anomalies. In Zone-I, basin 2, in Zone-II, basin 4, 12, 13, 16 and in Zone-III, basin 18, 24, 29, 33, 35 shows extremely short development of 5th order segments (.03-2.0 km). These segments are found to follow well describable structural lineaments. The sub basins draining the Alluvium and without well discernible structural lineament, in general shows higher Lū values. In order to find the relation between basin area and the total stream length for respective sub basins a regression line is constructed using a double log graph. It is observed that the drainage area bears a power function relationship with stream length (Figure 3)

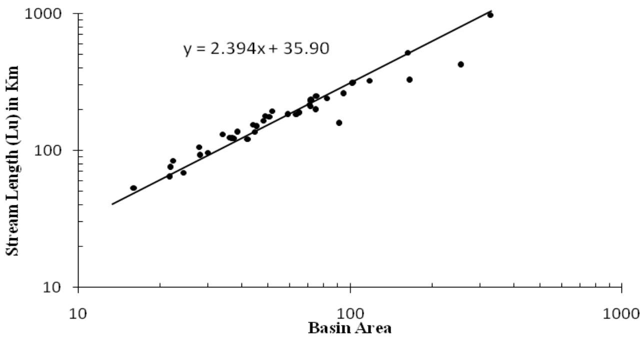

Figure 3: Log-Log plot of Basin Area (Au) vs. Total Stream Length (Lu) shows conformable relation of basin area and total stream length.

Stream Length Ratio (RL)

The Length Ratio (RL), which is computed as ratio of the mean length of the streams of a given order (Lu_1) to the mean length of the streams of the next lower order (Lu_{-1}). For the basin within alluvial zone the length ratios between 1^{st}-2^{nd} and 2^{nd} -3^{rd} order streams are found to be higher than the basin of the other two zones. Elongated basins (Basin index 7, 14, 37, 41) shows high length ration (up to 14.1 in case of Basin index 41) in the higher order where as the basins (Basin index 12, 13, 16, 29, 35) with comparatively high circularity ratio shows the low length ratio (<1). The variation in length ratio, attributed to variation in slope and topography indicate youth stage of geomorphic development in the streams of the study area (Singh and Singh, 1997, Vittala et al., 2004)

Stream order vs. the stream length

Generally, the total length of stream segments decreases with stream order i.e., there exists a negative correlation between stream order and total stream length. The bivariant plots for the basins following Strahler (1957) and Horton (1945) from all three lithotectonic zones corroborate this law of stream length (Figure 4). However, the plot of mean stream length against order gives largely positive correlation (Figure 5). Anomaly is found in sub-basin 18 of Zone III which shows a nearly straight regression curve suggesting no significant change in mean stream length with increasing order. Such drainage anomalies may suggest high relief and/or moderately steep slopes of the terrane underlain by various lithology and probable uplift across the basin (Singh and Singh 1997, Vittala et al., 2004).

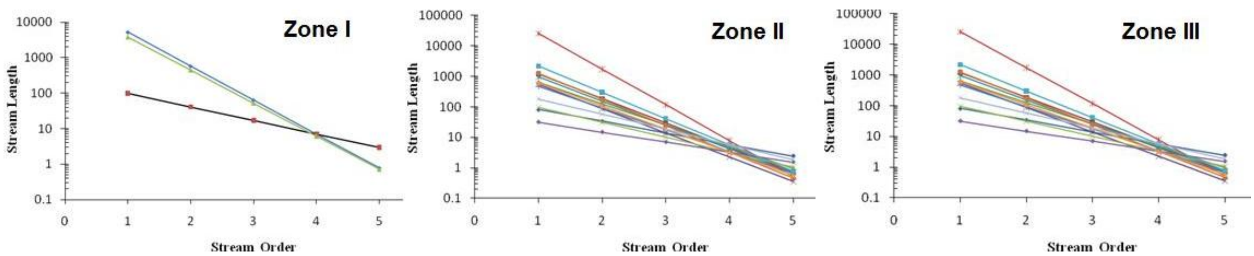

Figure 4: Stream order vs total stream length

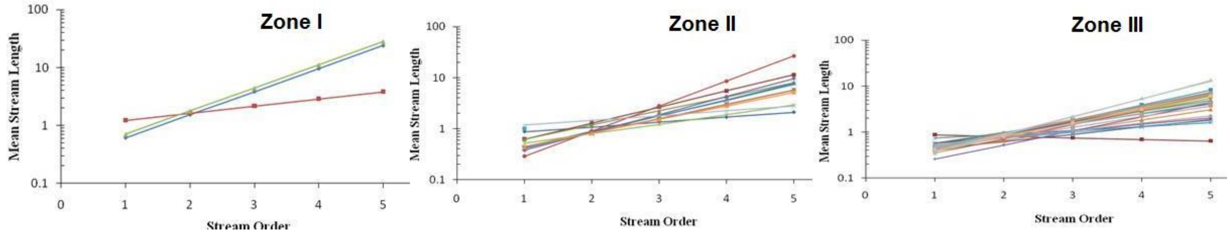

Figure 5 : Stream order vs. mean stream length

Bifurcation Ratio (Rb)

The average of all mean bifurcation ration of all the selected 41 basins is found to be 3.9 which however, varies between 3.1 – 4.7 for individual basins (Figure 7A). The bifurcation ratios of the basins of alluvial region are comparatively lower than those from Himalayan domain. Average bifurcation ratio is found to be in the range of 3-5 with higher values between 1st -2nd and 2nd-3rd order channels. The sub basins of Zone-I show mean bifurcation ratio in between 3.3-4.2. Similarly the Zone-II basins of eastern part of the Kameng River having origin along the MBT with N-S directional flow and basins originating in the extreme eastern boundary with a E-W flow have a mean bifurcation ratio of 3.1-6.0. These high values of bifurcation ratio suggest high degree of dissection in the uplands. An example is the Pakke (Basin index 11) and Dublo Kho (Basin index 37) basin having conspicuous structural control which give higher bifurcation ratio of 6 and 5.2 respectively. Significantly these two basins are from either side of the trunk channel and north of MBT. In plain areas the bifurcation ratio is usually in the range of 2 to 4 (Horton, 1945). In this study it is found that the bifurcation ratio for higher order segments in the basins of alluvial plain is around 2 while north of MBT the value is much higher, in the range of 5.2 to 6 (Table 3). Variation in bifurcation ratio reflects the lithologcal and geological variations in the basin (Rawat et. all, 2011)**.** High value of bifurcation ratio is generally found in highly dissected drainage basin (Horton 1945). The mountains catchment of Jia Bhareli basin show a higher Rb in western part than the eastern part and thus suggest higher dissection in western block. Bivariate plots of stream order against bifurcation ratio (Figure 6) shows wide variability in Zone III while restricting to a narrow range in Zone I. The anomalous nature and wide range of values reflect a rugged topography and high degree of dissection and drainage development. In general it is observed that the sub basins with larger areas have higher bifurcation ratio (Figure 7B).

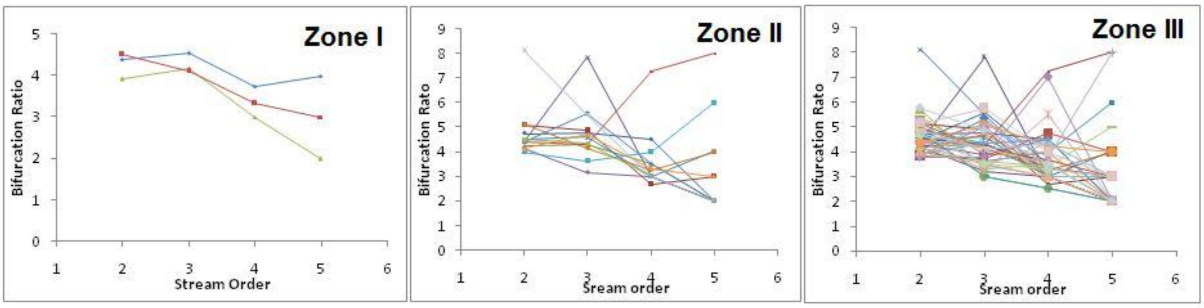

Figure 6: Plot of Bifurcation ratio and stream order of different basins

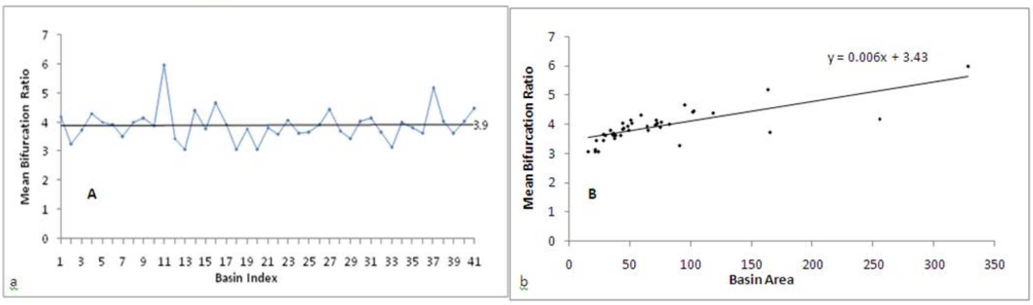

Figure 7 **A**. Variation of mean bifurcation ratio. **B.** The trend of mean bifurcation ratio variability against basin area

Mean

Bifurcation Ratio ($\overline{Rb}$) is calculated as the Arithmetic Mean Bifurcation Ratio sing Strahler's (1957) which is found in the range of 3.1-6.0. The basin having index 18 has the lower mean bifurcation ratio of 3.1 and the basin 11 has the higher mean bifurcation ratio of 6.0. It is observed that in the bivariate plot of mean bifurcation ratio against basin area the two parameters show a positive correlation (Figure 7B).

Table 2: Summary of Linear parameter of the 41 fifth order basin

Basin Index	Total Stream Number (Nu)	Mean Bifurcation Ratio	Total Stream Length (Lu) in km	Maximum Basin Length (Lb) in km	Basin Perimeter (P) in km
1	387	4.2	423	33.8	84.7
2	132	3.3	158	27.1	64.2
3	240	3.7	327	28.8	77.6
4	263	4.3	183	10.8	36.1
5	259	4.0	242	15.4	46.4
6	250	3.9	198	14.4	41.0
7	167	3.5	123	12.5	33.1
8	318	4.0	210	14.1	40.9
9	349	4.1	231	11.3	37.0
10	222	3.9	150	13.8	35.9
11	1410	6.0	974	32.6	135.1
12	152	3.5	92	7.1	22.4
13	107	3.1	69	5.7	23.2
14	464	4.4	326	20.4	57.8
15	255	3.8	180	12.2	31.9
16	310	4.7	260	15.9	42.6
17	284	3.9	185	13.4	39.1
18	95	3.1	64	7.0	20.5
19	252	3.8	188	10.8	35.2
20	95	3.1	53	5.5	16.6
21	209	3.8	137	8.5	28.7
22	172	3.6	122	10.2	28.2
23	368	4.1	252	12.0	34.7
24	164	3.6	97	7.7	22.7
25	197	3.7	125	10.9	28.8
26	240	3.9	165	14.2	34.7
27	490	4.4	312	13.0	47.1
28	205	3.7	124	11.0	29.2
29	154	3.5	85	7.2	22.6
30	335	4.0	194	9.9	33.2
31	270	4.1	177	12.8	34.2
32	205	3.7	106	9.1	24.3
33	114	3.1	75	6.3	19.8
34	294	4.0	216	12.9	37.5
35	210	3.8	132	6.8	24.6
36	214	3.6	136	8.2	26.9
37	780	5.2	522	24.5	71.3
38	321	4.0	233	13.3	41.3
39	180	3.6	123	9.9	27.7
40	240	4.0	154	11.7	31.0
41	440	4.5	315	22.5	61.0

Table 3: Summary of morphometric parameters in Jia Bhareli basin

Division	**Order**	**Stream Number**	**Bifurcation Ratio**	**Mean Bifurcation Ratio**	**Stream Length (km)**	**Mean Stream Length (km)**	**Area (sq km)**	**Drainage Density (km^{-1})**	**Drainage Frequency (km^{-2})**
	u	**Nu**			**Lu**	**L□**	**Au**	**Dd**	**Df**
South of HFT	1	556			479.5	0.9	1027.0	1.0	0.7
	2	134	4.1		213.5	1.6			
	3	33	4.1		162.5	4.9			
	4	9	3.7	3.5	81.9	9.1			
	5	4	2.3		80.4	20.1			
		∑Nu=736			∑Lu=1017.7				
Between HFT-MBT	1	3346			1995.8	0.6	1150.4	2.9	3.7
	2	706	4.7		690.9	1.0			
	3	149	4.7	4.1	307.3	2.1			
	4	44	3.4		176.8	4.0			
	5	12	3.7		162.7	13.6			
		∑Nu=4257			∑Lu=3333.5				
Between MBT-MCT	1	15624			8763.2	0.6	4426.1	3.0	4.5
	2	3418	4.6		2438.2	0.7			
	3	762	4.5	4.8	1202.1	1.6			
	4	172	4.4		595.6	3.5			
	5	30	5.7		269.8	9.0			
		∑Nu=20006			∑Lu=13268.9				
North of MCT	1	220			129.7	0.6	50.4	3.6	5.7
	2	54	4.1		32.2	0.6			
	3	12	4.5	4.8	13.1	1.1			
	4	2	6.0		4.5	2.3			
	5	0							
		∑Nu=287			∑Lu=179.5				
Total	1	19602			11261.5	0.6	6653.9	2.6	3.8
	2	4256	4.6		3276.3	0.8			
	3	939	4.5	4.7	1629.2	1.7			
	4	212	4.4		802.1	3.8			
	5	41	5.2		402.6	9.8			
		∑Nu=25050			∑Lu=17371.7				

VI. Conclusion:

Drainage basin morphometry in terms of the linear aspects of 41 selected 5th order sub basins of Jia Bhareli show general conformity with available understanding on drainage development and landform evolution. There are however, drainage anomalies reflected in the quantitative basin parameters that can be correlated with geotectonic elements. Such anomalies are mostly recorded from the areas with pronounced structural control on drainage.

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