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RESEARCH ARTICLE

LINEAR MORPHOMETRY OF PINDAR BASIN UTTARAKHAND, LESSER HIMALAYA.

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Abstract

Morphometry is a measurement and mathematical analysis of the configuration of earth surface, the shape and dimensions of its landforms. Keeping these facts in view, in present paper attempts has been made to quantify the drainage properties of the Pindar basin. There 53 drainage basin of fourth order of Pindar basin has also been analyzed with particular emphasis on lithological and terrain conditions. The main objective of the present study is an attempt to find out the topological characteristics of the river segments, with the help of geomorphic properties (linear). Some of the most important elements of fluvial Morphometry have been taken into consideration for Pindar Basin which is left bank tributary of the Alakananda River. The Pindar basin presents some unique morphometry of the drainage basin. The present study has been carried out with the help of different morphometric attributes, namely stream order, stream number, stream length, mean stream length, bifurcation ratio, fitness index, wandering index and Length of overland flow. The results confirm except for few basins, with Horton's law due to variations in lithological conditions.

Introduction:-

Pindar River originates from the Pindari Glacier in district Bageshwar 32Km and flows to their Confluences with the Alaknanda River at Karanprayag in Chamoli district. The Pindar Basin extends from $29^{o}59'$N to $30^{o}21'$N latitude and $79^{o}29'$E to $80^{o}5'$E longitude having an area of 1856.56 km^2 with elevation ranging between 800 m and 6800 m. The watershed of the Ram Ganga in the South, the Saryu in the east, the Nandakini in the North and the Alaknanda in the North West delimits and gives it a distinct socio-geographical shape (Fig.1). The climate characteristic of the regions from warm temperate at the valleys to cold temperate at the higher altitudinal of the mountains followed by cold climate and the alpine at the high mountains ridges. The peaks are permanently snow covered by perennial snowfall. The climate is pre–dominantly temperate and temperature range from 5^{o}to30^{o}C in lower part and $-5^{o}$to 22^{0} C in higher parts of the valley.

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Rainfall varies between 1500 to 1800 mm. The main objective of the present study is to develop the geomorphologic strategy for the hydrological and water resources management. The topological characteristics of the river segments in terms of open links of the network system are analyzed through Linear Morphometry, nearly related with the channel patterns of the drainage network. The linear parameters of the basins includes stream order (Sμ), stream length (Lμ), mean stream length (Lsm), stream length ratio (RL), bifurcation ratio (Rb), length of overland flow (Lg), basin perimeter (P), basin length (Lb), fitness ratio (Rfn) etc. Some of the important linear aspects have been computed as shown in (Table 1). The river show Rectangular Pattern. Some small stream takes directly meet the Pindar River in Redial Pattern. Following are the drainage: dendritic, radial, parallel/ sub-parallel, rectangular, trellis, faulted.

Geology of Study area:-

The River lies in the Central Crystalline sector of the main geological divisions of Himalaya known as Vaikrita Group by Valdiya (1980). These are epitomesi grade metamorphic and marbles are the rock types forming the formation. These metamorphic have been intruded by Tertiary tourmaline bearing leucocratic granites which have at places reached to batholithic dimensions. At the contact of the intrusive granite with schist's excellent development of Migmatites are observed near the snout of Pindari Glacier. Downstream, with high grade metamorphic rocks Almora Group of rocks are observed which are also medium to high grade metamorphics but separated by Munsiari Thrust by Valdiya (1980),and Main Central Thrust by Heim and Gansser (1939).The rocks are garnetiferous mica schist's, micaceous quartzites, augen gneisses, graphite schists and phyllites. Downstream northwest of Loharkhet the rocks of Berinag group are exposed. They are predominantly quartzites and schists developing two distinguished litho-facies. They are massive to thickly bedded, saccharoidal, milky white, hard, compact, highly jointed meta-quartzite and the fine to medium grained massive to schistose quartzite interlayered with subordinate quartz chlorite and quartz sericite schist.

Downstream north-East of Kalibagar a Thrust separates the Berinag Formation from the autochthonous/par autochthonous Rautgara Formation (quartzites, slates and locally quartz-chlorite schist's and hyalites) overlain by Deoban Formation (massive dolomitic limestone inter- bedded and slates. Solution structures, weathering features, joints of more than one sets, intra-formational conglomerates, limestone breccias and Olitic structures are other important features exhibited by these carbonate rocks. North of Gwaldom these autochthonous Formation give way to the Berinag Formation. This repetition is due to folding of the Berinag Thrust sheet bringing the autochthonous units in the core of a huge synclinorium. Near Gwaldom the Berinag Formation comes in a Thrust contact with the Almora Nappe rocks which continues for about 3-4 kms. West of Tharali. Downstream up to Karnparyag of where the Pindar confluences with Alaknanda River the former River, flows along the Berinag Thrust. (Fig. 2).

Methodology:-

Analyzing the study area, a detail geospatial database was generated on Survey of India topographical Sheets, number 53N/ 2, 3, 4, 5, 6, 7, 8 & 9; 62B/3, 4 on 1:50000 scale. The topographical sheets were geo-referenced and a mosaiced on Erdas-14 software. Study area was delineated on the base of contour and drainage line, and on the base of toposheet drainage was digitized. Through geo-hydro process a drainage network was generated with Aster DEM. Then both the drainage were overlayed and updated with LISS IV image of 2015 in GIS environment.

Stream ordering was according to Strahler method (1964). The linear aspects for the delineated basin were calculated on the basis of formula given in the (Table 1).

Table 1:- Formula and Symbols of Linear Morphometric parameters used for Study

S. No.	Parameters	Formulae	References
1	**Stream Order (Su)**	**Hierarchial rank**	**Strahler (1964)**
2	**Stream Number (N)**	**Number of Stream Segment**	**Horton (1945)**
3	**Stream length (Lu)**	**Length of the stream**	**Horton (1945)**
4	**Mean stream length (Lsm)**	**Lsm=Lu/Nu:** Lsm = Mean stream length, Lu = The total stream length of order 'u', Nu = Total no of stream segments of order 'u'	**Strahler (1964)**

5	**Stream length ratio (Lur)**	**Lu/(Lu-1):** Lur = Stream length ratio, Lu = The total stream length of order 'u', Lu-1 = The total stream length of its next lower order	**Horton (1945)**
6	**Bifurcation ratio (Rb)**	**Nu/Nu+1:** Rb = Bifurcation ratio Nu = Total number of stream segments, Nu+1 = Number of segments of the next higher order	**Schumm (1956)**
7	**Weighted mean bifurcation ratio**	**Rbw = Rb1*n1+Rb2*n2+/n1+n2**	**Schumm (1956)**
8	**Channel Index (Ci)**	**Cl / Al :** Cl = Channel Length and Al = Air length	**Muller (1968)**
9	**Valley Index (Vi)**	**Vl / Al :** Vl= Valley length and Al=Air length	**Muller (1968)**
10	**Basin Perimeter (P)**	**GIS Software**	**SA Schumn (1956)**
11	**Basin Length (Lb)**	**GIS Software**	**SA Schumn (1956)**
12	**Valley length**	**GIS Software**	**-**
13	**Channel Length**	**GIS Software**	**-**
14	**Air length**	**GIS Software**	**-**
15	**Length of overland flow (Lg)**	**1/D* 2:** Lg = Length of overland flow, D = Drainage density	**Horton (1945)**
16	**Fitness ratio (R_{fn})**	**Cl/P:** CI=channel index and P=basin perimenter	**Melton (1957)**
17	**Channel maintenance**	**1/D:** 1 is constant and D = Drainage density	**Schumm (1956)**

Result and Discussion:-

Linear Aspects of the Drainage Basin:-

Linear Parameter of the drainage basin include the channels and their network in terms of open links wherein the topological properties of the stream segments are analyzed (Bhatta et.al, 2008). The drainage network which consists of all the stream segments of a particular river helps to study in graphic terms.

Stream Order (U):-

The analysis is based on method proposed by Strahler (1964a). It has observed that the maximum frequency is in the case of first order streams. It has also noticed that there is a decrease in stream frequency as the stream order increases. The Pindar river basin total number of first order streams is 5732, 1270 second order, 265 third order, 53 fourth order, 11 fifth order, 4 sixth order and 1 seventh order. The present study is on 53 forth order basins in Pindar valley (Fig. 3).

Stream Number (NU):-

The total stream segment in each order is known as stream number. Table 2a shows maximum frequency of first order stream and stream frequency decreases considerably as order increases. The stream number range between 18 Bhalsaungad and 308 Sundardunga. A higher stream number indicates lesser permeability and infiltration vice versa. The variations in rock structures in the basin are responsible for inequalities in stream frequencies of each order. Plots of the number of streams (on log scale along the vertical axis) against the order of streams (on arithmetic scale along the horizontal axis) indicate a linear co-relationship, which means that the number of streams generally decreases in geometric progression as the stream order increases (Fig 4).

Stream Length (LU):-

The variation of stream length is from 7.90km (Bhalsaungad) to 258.50km (Sundardunga). The first-order streams are small in length and are found in the upstream area. Streams with relatively short lengths are representative of areas with steep slopes and finer texture, whereas longer lengths of stream are generally indicative of low gradients (Strahler1964a). This discrepancy is attributable to variations in relief and lithology. It is noticed that stream

segments up to fourth order traverse parts of the high to moderate altitudinal zones characterized by steep to moderate slopes.

Mean Stream Length (Lsm):-
Mean stream length (Lsm) reveals the characteristic size of components of a drainage network and its contributing surfaces (Strahler 1964b). The mean stream length obtain by dividing the total stream length by total number of segment in the order. In the study area the mean stream length varies from2.75 (Musagad) to17.87 km (Sundardunga) presented in (Table 2a).

Stream Length Ratio (RL):-
The stream length values for the Pindar's fourth order basin vary widely from 0.44 (Ratmatigad) to 13.00 (Bigungad) (Table 2a) and are strongly dependent on the topography and the slope. The analysis of 53 different basins shows an important relationship with the surface flow discharge and the erosional stage of the basin.

Bifurcation Ratio (Rb) :-
The bifurcation ratio (Rb) is defined as the ratio of the number of streams of any given order to the number of streams in the next higher order in a drainage basin (Schumm 1956). The Rb for the Pindar fourth order basin varies from 2 Khetigad to 11 Sundardunga (Table 2a) with a mean Rb of 2.62. Low Rb value indicates poor structural disturbance and the drainage patterns have not been distorted (Strahler 1964), whereas the high Rb value indicates high structural complexity and low permeability of the terrain.

Weighted Mean Bifurcation Ratio:-
The weighted mean bifurcation ratio obtained by multiplying the bifurcation ratio for each successive pair of orders by the total numbers of streams involved in the ratio and taking the mean of the sum of these values. The weighted mean bifurcation ratio varies from 2.43 to 6.16 i.e. Binota gad and Sundardunga (Table 2a).

Channel Index (CI) AND Valley Index (VI) :-
The measurement of channel length, valley length, and air length are used for calculation of Channel index, and valley index. Highest channel index 1.50 and valley index 1.40 is both of Bagargad and lowest channel index is 1.06 of Serapankhudigad and valley index is 0.97 of Kaphni gad (Table 2b).

Basin Length (Lb) :-
The basin length (Lb) is the longest length from lowest to highest point of the basin headwaters to the point of confluence (Gregory and Walling 1973). The basin length determines the shape of the basin. The Pindar's fourth order basin vary widely from 2.60 (Bhalsaungad) to 22.50km (Sundardungagad) (Table 2b). High basin length indicates elongated basin.

Basin Perimeter (P) :-
The highest perimeter 62.50 km is of Sundardunga gad and lowest 6.50 km both Bhalsaungad and Baurkholi gad sub-basin (Table 2b).

Valley Length (VL) :-
Valley length is the straight-line distance between outlet of the basin and the farthest point on the ridge. Pindar forth order basin has the highest valley length 13.00 km sundarungagad and the lowest valley length 2.40 km is of Bhalsaungad (Table 2b).

Channel Length (CL) :-
Chanel is the length along the longest flow path of the basin. Author has computed the main channel length by using ArcGIS-10.3 software, which is 14.50 km. Sundardunga gad and 2.50 Km. Bhalsaungad (Table 2b).

Air Length (AL):-
The straight measurement of length between highest and lowest point in the Basin, is known as Air length of the Basin. The highest air length is of Sundardunga gad i.e. 12.50 km and smallest length 2 km is of Bhalsaungad.

Length of overland flow (Lg) :-
Length of overland flow is important independent variables of drainage basins which affects both hydrologic and physiographic development which significantly affected by infiltration/ percolation through the soil vary in space and time. In the fourth orders of Pindar basin the value varies between 0.03 (30 m) to 0.18 (180 m), lowest in Sunderdunga (0.03) and Kichgad (0.03) due to steep slope and greater undulation of landscape and maximum (180meters) in Musagad (Southern West part of Pindar basin) due to comparatively flatness of the ground (Table 2b).

Fitness Ratio (RFN) :-
The fitness ratio was considered as the ratio of channel length to the length of the basin perimeter. The fitness ratio for are observed lowest in Sundardunga and Pindar i.e. 0.02 and heights is Baurkholigad, Bhalsaungad and Musagad i.e 0.19.

Constant of Channel Maintenance:-
Constant of channel maintenance (schumm, 1956) is the area, which is needed to maintain a stream for flowing or average distance between the streams. Constant of channel maintenance is highest in Baurkholigad (1.76 sq.km.). It is generally observed that in the dissected hilly regions, particularly in Serapankhurigad (0.26 sq.km.) basin minimum area is needed for the development of channel. In the low slopped terrain of basin maximum area is needed for the development of drainage channel.

Coefficient of Determination (R^2):-
Coefficient of Determination (R^2) is a statistical measure for evaluating the degree of adjustment. For its calculation, graphs are plotted between stream order and log of stream numbers as the value of X and Y axes respectively. If the value of R^2 is 1, there is a perfect adjustment within the prevailing conditions and zero suggests either of the parameters is nonexistent and if number is slightly above zero that means the stream is in initial phase of improvement. These two extreme conditions are rather not practical in nature.

Coefficient of determination (R^2)	Categories
≤ 0.50	poorly adjusted
0.51-0.65	slightly adjusted
0.66-0.80	moderately adjusted
0.81-0.95	sufficiently adjusted
> 0.95	perfectly adjusted

According to R^2, there is one poorly adjusted, forty five moderately and seven sufficiently adjusted sub-basin. These prevailing conditions can be topographic, climatic, tectonic or lithological conditions. Graphs between stream order and log of stream number are shown in (fig.5) with the value of R^2. The reason for perfect adjustment can be attributed to considerably old tributaries, reflected in the form of deep and wide valleys.

Conclusion:-
The basin is in early mature stage of the fluvial geomorphic cycle and stream segments in the basin area are affected by rainfall, groundwater discharge and seasonally by melt over. The mean Rb indicates that the drainage pattern is not much influenced by geological structures. Horton's law of stream numbers, stream lengths conforms to the basin morphometric state. The present study has proved that the geoprocessing technique used in GIS is an effective tool for calculation and analysis of various morphometric parameters of the basin and supports to understand various terrain parameters such as nature of the bedrock, infiltration capacity, surface runoff, etc. The study of forth order is dominated by lower order streams and the total length of stream segments is maximum in first order streams. The quantitative analysis of linear parameter is found to be of immense utility in river basin evaluation, basin prioritization for soil and water conservation and natural resource management. The geoprocessing techniques employed in this study will assist the planner and decision makers in basin development and management studies.

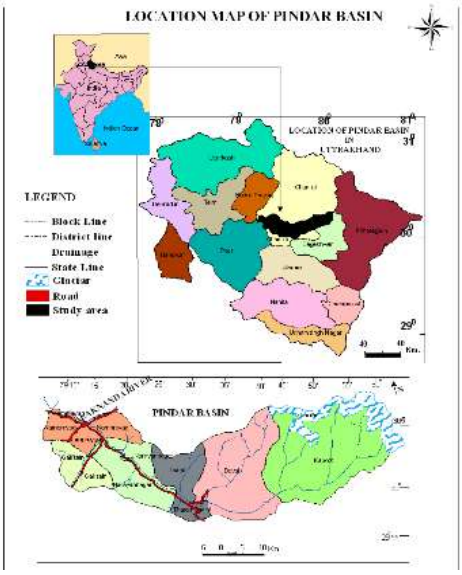


Fig. 1:- Location Map of Study Area

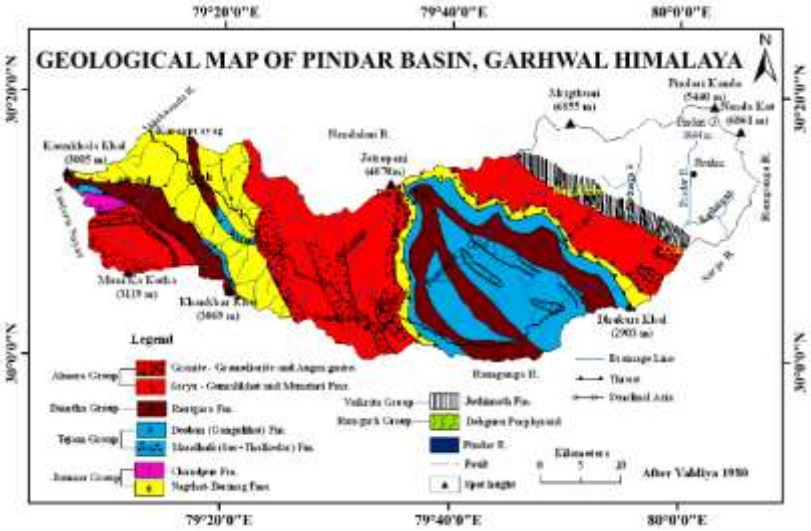


Fig. 2:- Geological Map of Study Area.

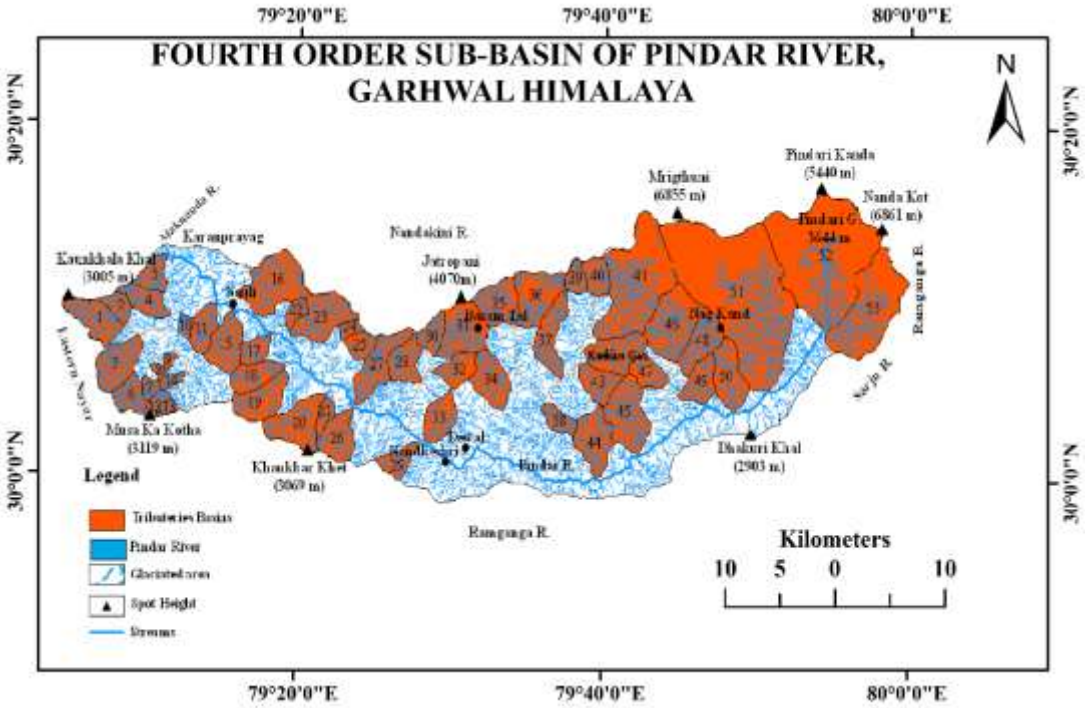


Fig. 3:- Fourth Order Sub-Basin of Study Area

Table 2a: Linear Morphometric Parameters of Study Area

Basin No.	Name	Stream Numbers				Total	Stream Lengths (Km)				Total	Mean Stream Lengths				Total	Stream Length Ratio			Bifurcation Ratio			Weighted Mean Bifurcation Ratio
		I	II	III	IV		I	II	III	IV		I	II	III	IV		II-I	III-II	IV-III	I-II	II-III	III-IV	
1	Kirsalgad	109	22	4	1	136	52.00	15.000	6.50	5.50	79.00	0.48	0.68	0.61	5.50	7.27	1.43	0.89	9.02	4.95	5.50	4	5.00
2	Khetigad	34	10	2	1	47	16.00	8.000	3.50	2.000	29.50	0.47	0.80	1.75	2.000	5.02	1.70	2.19	1.14	3.40	5.000	2	3.65
3	Dewalkotgad	102	27	5	1	135	48.80	18.500	7.20	7.20	81.70	0.48	0.69	1.44	7.20	9.81	1.43	2.10	5.00	3.78	5.400	5	4.13
4	Bainoligad	47	14	3	1	65	28.00	11.500	5.50	4.000	49.00	0.60	0.82	1.83	4.000	7.25	1.38	2.23	2.18	3.36	4.67	3	3.61
5	Manjiyarigad	56	14	3	1	74	25.00	6.500	4.000	4.500	40.00	0.4	0.4	1.3	4.500	6.74	1.0	2.887	3.38	4.0	4.67	3	4.08

												5	6	3			4			0			
6	**Waragad**	84	18	4	1	107	35.50	10.50	8.90	4.00	58.90	0.42	0.58	2.23	4.00	7.23	1.38	3.81	1.80	4.67	4.50	4	4.61
7	**Pandaungad**	27	5	2	1	35	11.50	3.000	2.50	1.75	18.75	0.43	0.60	1.25	1.75	4.03	1.41	2.08	1.40	5.40	2.50	2	4.67
8	**Baurkholigad**	14	4	2	1	21	5.00	1.75	1.40	1.50	9.65	0.36	0.44	0.70	1.50	3.00	1.23	1.60	2.14	3.50	2.00	2	3.00
9	**Bhalsaungad**	11	4	2	1	18	3.00	1.85	1.75	1.30	7.90	0.27	0.46	0.88	1.30	2.91	1.70	1.89	1.49	2.75	2.00	2	2.47
10	**Simgad**	22	6	2	1	31	9.50	4.000	2.50	1.00	17.00	0.43	0.67	1.25	1.00	3.35	1.54	1.88	0.80	3.67	3.000	2	3.40
11	**Khankergad**	40	10	2	1	53	25.00	7.75	4.50	1.75	39.00	0.63	0.78	2.25	1.75	5.41	1.24	2.90	0.78	4.000	5.000	2	4.09
12	**Langtaigad**	49	12	2	1	64	20.00	6.000	1.25	3.25	30.50	0.41	0.50	0.63	3.25	4.79	1.23	1.25	5.20	4.008	6.000	2	4.35
13	**Musagad**	20	5	2	1	28	9.00	4.000	2.000	0.50	15.50	0.45	0.80	1.000	0.50	2.75	1.78	1.25	0.50	4.000	2.500	2	3.53
14	**Pyonragad**	28	7	2	1	38	9.20	3.500	1.20	2.25	16.15	0.33	0.50	0.60	2.25	3.68	1.52	1.20	3.75	4.000	3.500	2	3.78
15	**Jenthagad**	62	16	5	1	84	40.00	9.000	7.000	5.000	61.00	0.65	0.56	1.40	5.000	7.61	0.87	2.49	3.57	3.88	3.20	5	3.80
16	**Serapankhudigad**	87	25	6	1	119	52.00	14.000	13.000	6.000	85.00	0.60	0.56	2.17	6.000	9.33	0.94	3.87	2.77	3.48	4.17	6	3.74
17	**Bamiyalagad**	34	7	2	1	44	19.00	5.000	3.500	3.000	30.50	0.56	0.71	1.75	3.000	6.02	1.28	2.45	1.71	4.86	3.500	2	4.46
18	**Garseragad**	48	10	2	1	61	29.00	8.500	2.500	4.000	44.00	0.60	0.85	1.25	4.000	6.70	1.41	1.47	3.20	4.800	5.000	2	4.72
19	**Kewargadhe**	51	12	2	1	66	35.0	9.0	6.0	3.0	53.0	0.	0.	3.	3.0	7.4	1.	4.0	1.00	4.	6.0	2	4.47

	ra						0	0	0	0	0	69	75	00	0	4	09	0		25	0		
20	**Minggadhera**	51	14	3	1	69	38.50	10.000	6.000	6.50	61.00	0.75	0.71	2.00	6.50	9.96	0.95	2.80	3.25	3.64	4.67	3	3.82
21	**Sanyargad**	15	5	3	1	24	9.00	7.000	2.500	0.50	19.00	0.60	1.40	0.83	0.50	3.33	2.33	0.60	0.60	3.000	1.67	3	2.67
22	**Tunergad**	28	5	2	1	36	12.00	3.500	1.500	2.50	19.50	0.43	0.70	0.75	2.50	4.38	1.63	1.07	3.33	5.60	2.50	2	4.84
23	**Bhangotagad**	106	27	7	1	141	51.50	14.500	10.000	6.80	82.80	0.49	0.54	1.43	6.80	9.26	1.111	2.66	4.76	3.93	3.86	7	4.05
24	**Binotagad**	18	8	3	1	30	7.50	8.200	3.200	2.50	21.40	0.42	1.03	1.07	2.50	5.02	2.46	1.04	2.34	2.25	2.67	3	2.43
25	**Sankotigad**	23	7	3	1	34	13.00	4.200	2.500	2.000	21.70	0.57	0.60	0.83	2.000	4.000	1.06	1.39	2.40	3.29	2.333	3	3.04
26	**Baramgad**	55	14	3	1	73	32.50	11.500	4.500	5.000	53.50	0.59	0.82	1.50	5.000	7.91	1.39	1.83	3.33	3.93	4.67	3	4.03
27	**Chorgad**	116	24	4	1	145	51.50	12.500	6.000	7.50	77.50	0.44	0.52	1.50	7.50	9.96	1.17	2.88	5.00	4.83	6.000	4	5.00
28	**Ghinapanigad**	32	11	3	1	47	25.00	10.000	3.500	2.50	41.00	0.78	0.91	1.17	2.50	5.36	1.16	1.28	2.14	2.91	3.67	3	3.09
29	**Devijangad**	29	7	3	1	40	21.00	4.500	4.000	2.50	32.00	0.72	0.64	1.33	2.50	5.19	0.89	2.07	1.88	4.14	2.333	3	3.69
30	**Parantchockgad**	38	7	2	1	48	24.50	7.000	2.500	1.25	35.25	0.64	1.000	1.25	1.25	4.14	1.55	1.25	1.00	5.43	3.500	2	4.94
31	**Pranmatigad**	58	12	3	1	74	46.00	18.000	4.000	3.25	71.25	0.79	1.50	1.33	3.25	6.887	1.889	0.89	2.44	4.83	4.000	3	4.61
32	**Kichgad**	21	6	2	1	30	16.50	5.550	2.000	12.500	36.50	0.79	0.92	1.000	12.50	15.211	1.17	1.09	12.50	3.500	3.000	2	3.28
33	**Junid**	3	7	3	1	4	24	6.	3.	3.	38	0	0	1	3.	6.	1	1.	3.	5	2.	3	4.74

3	**harga d**	8				9	.50	50	50	50	.00	.64	.93	.17	50	24	.44	26	00	.43	33		
34	**Bigun gad**	56	13	4	1	74	36.00	11.000	2.000	6.50	55.50	0.64	0.85	0.500	6.50	8.49	1.32	0.59	13.00	4.31	3.25	4	4.09
35	**Bagar gad**	86	16	3	1	106	51.00	12.500	8.500	3.50	75.50	0.59	0.78	2.83	3.50	7.70	1.32	3.63	1.24	5.38	5.33	3	5.29
36	**Bedini ganga**	101	22	7	1	131	52.00	14.000	11.000	7.50	84.50	0.51	0.64	1.57	7.50	10.022	1.24	2.47	4.77	4.59	3.14	7	4.45
37	**Halke ngad**	83	20	3	1	107	46.50	10.000	4.000	7.50	68.00	0.56	0.50	1.33	7.50	9.89	0.89	2.67	5.63	4.15	6.67	3	4.56
38	**Gura mtoligad**	55	9	2	1	67	27.00	6.000	1.500	4.50	39.00	0.49	0.67	0.75	4.50	6.41	1.36	1.13	6.00	6.11	4.50	2	5.73
39	**Kuru mtoligad**	33	7	2	1	43	20.00	4.500	3.500	2.500	30.50	0.61	0.64	1.75	2.50	5.50	1.06	2.72	1.43	4.71	3.50	2	4.35
40	**Barat oligad**	43	8	3	1	55	24.00	7.500	2.000	2.500	36.00	0.56	0.94	0.67	2.50	4.667	1.68	0.71	3.75	5.38	2.67	3	4.78
41	**Kailga nga**	167	35	7	1	210	65.00	30.000	14.000	8.000	117.00	0.39	0.86	2.000	8.000	11.225	2.220	2.33	4.00	4.77	5.00	7	4.88
42	**Kuma ngad**	78	17	3	1	99	43.00	12.000	7.500	5.50	68.00	0.55	0.71	2.50	5.50	9.26	1.28	3.54	2.20	4.59	5.67	3	4.72
43	**Dolam gad**	50	7	2	1	60	26.50	6.000	5.500	2.75	40.75	0.53	0.86	2.75	2.75	6.889	1.62	3.21	1.00	7.14	3.50	2	6.44
44	**Milkk hetgad**	80	19	6	1	106	45.00	12.000	8.000	6.000	71.00	0.56	0.63	1.33	6.000	8.52	1.12	2.11	4.50	4.21	3.17	6	4.11
45	**Saurg ad**	123	23	3	1	150	62.50	23.000	9.000	5.50	100.00	0.51	1.00	3.000	5.50	10.001	1.97	3.000	1.83	5.35	7.67	3	5.64
46	**Baura gad II**	126	22	5	1	154	122.00	18.000	7.000	4.000	151.00	0.97	0.82	1.40	4.000	7.19	0.85	1.71	2.86	5.73	4.40	5	5.51

47	**Ratmatigad**	23	5	2	1	31	15.60	5.00	4.50	1.00	26.10	0.68	1.00	2.25	1.00	4.93	1.47	2.25	0.44	4.60	2.50	2	4.01
48	**Baura gad II**	89	18	4	1	112	46.00	12.000	5.00	4.00	67.00	0.52	0.67	1.25	4.00	6.44	1.29	1.88	3.20	4.94	4.50	4	4.84
49	**Ghatiyagad**	67	16	5	1	89	33.00	9.000	5.00	4.00	51.00	0.49	0.56	1.00	4.00	6.05	1.14	1.78	4.00	4.19	3.20	5	4.04
50	**Suraggad**	63	14	3	1	81	39.00	11.000	3.25	6.50	59.75	0.62	0.79	1.08	6.50	8.99	1.27	1.38	6.00	4.50	4.67	3	4.47
51	**Sundardunga R.**	256	40	11	1	308	175.50	40.000	29.500	13.500	258.50	0.69	1.00	2.68	13.500	17.887	1.46	2.68	5.03	6.40	3.64	11	6.16
52	**Pindar**	106	23	4	1	134	77.50	30.000	6.50	6.50	120.50	0.73	1.30	1.63	6.50	10.116	1.78	1.25	4.00	4.61	5.75	4	4.78
53	**Khaphani**	132	26	6	1	165	80.00	25.000	4.50	7.00	116.50	0.61	0.96	0.75	7.00	9.32	1.59	0.78	9.33	5.08	4.33	6	4.99

Table 2b: Linear Morphometric Parameters of Study Area

Basin No.	Name	Channel Index (CI)=CL/AL	Valley Index (VI)=VL/AL	Air Length (Km)	Valley Length (Km)	Channel Length (Km)	Basin Length (Km)	Periphery Length (Km)	Length of overflow (km)	Channel maintaince (Km)	Fitness ratio (Km)
1	**Kirsalgad**	1.07	1.03	7.50	7.75	8.00	8.50	22.00	0.07	0.40	0.05
2	**Khetigad**	1.30	1.13	4.00	4.50	5.20	5.50	12.50	0.10	0.73	0.10
3	**Dewalkotgad**	1.10	1.03	7.30	7.50	8.00	8.50	20.00	0.05	0.37	0.06
4	**Bainoligad**	1.17	1.12	6.50	7.30	7.60	8.00	17.75	0.07	0.96	0.07
5	**Manjiyarigad**	1.44	1.11	4.50	5.00	6.50	6.70	15.00	0.07	0.54	0.10
6	**Waragad**	1.29	1.15	4.80	5.50	6.20	5.50	14.50	0.07	0.53	0.09
7	**Pandaungad**	1.36	1.09	2.75	3.00	3.75	4.00	9.50	0.12	1.00	0.14
8	**Baurkholigad**	1.25	1.14	2.20	2.50	2.75	3.50	6.50	0.17	1.76	0.19
9	**Bhalsaungad**	1.25	1.20	2.00	2.40	2.50	2.60	6.50	0.17	1.67	0.19
10	**Simgad**	1.14	1.06	3.30	3.50	3.75	4.00	8.75	0.15	0.95	0.13
11	**Khankergad**	1.25	1.08	6.00	6.50	7.50	7.80	15.50	0.09	0.61	0.08
12	**Langtaigad**	1.33	1.03	3.00	3.10	4.00	5.30	9.00	0.10	0.90	0.15
13	**Musagad**	1.44	1.30	2.50	3.25	3.60	4.00	7.50	0.18	1.18	0.19

14	**Pyonragad**	1.23	1.15	3.25	3.75	4.00	4.50	8.50	0.14	1.42	0.14
15	**Jenthagad**	1.13	1.11	7.50	8.30	8.50	8.80	20.50	0.07	0.44	0.06
16	**Serapankhudigad**	1.06	1.02	8.50	8.70	9.00	9.30	26.00	0.05	0.26	0.04
17	**Bamiyalagad**	1.20	1.10	5.00	5.50	6.00	6.50	13.00	0.08	0.75	0.09
18	**Garseragad**	1.28	1.19	6.50	7.75	8.30	8.50	17.50	0.07	0.56	0.07
19	**Kewargadhera**	1.13	1.07	7.50	8.00	8.50	9.00	19.00	0.07	0.41	0.06
20	**Minggadhera**	1.12	1.09	7.80	8.50	8.75	9.00	21.00	0.05	0.34	0.05
21	**Sanyargad**	1.22	1.11	4.50	5.00	5.50	6.00	10.50	0.15	1.13	0.12
22	**Tunergad**	1.30	1.13	4.00	4.50	5.20	5.50	11.50	0.11	0.88	0.11
23	**Bhangotagad**	1.21	1.12	8.50	9.50	10.30	10.60	23.50	0.05	0.41	0.05
24	**Binotagad**	1.27	1.10	3.00	3.30	3.80	4.00	9.00	0.10	0.83	0.14
25	**Sankotigad**	1.29	1.14	3.50	4.00	4.50	5.50	11.50	0.13	0.53	0.11
26	**Baramgad**	1.17	1.08	6.00	6.50	7.00	7.40	18.50	0.06	0.46	0.06
27	**Chorgad**	1.24	1.09	8.50	9.30	10.50	12.00	26.00	0.05	0.53	0.05
28	**Ghinapanigad**	1.11	1.06	4.50	4.75	5.00	6.60	17.25	0.09	0.35	0.06
29	**Devijangad**	1.09	1.05	5.50	5.75	6.00	6.30	15.50	0.10	0.66	0.07
30	**Parantchockgad**	1.19	1.13	4.00	4.50	4.75	6.00	18.50	0.12	0.50	0.06
31	**Pranmatigad**	1.12	1.07	7.25	7.75	8.10	8.50	21.25	0.07	0.31	0.05
32	**Kichgad**	1.09	1.05	5.50	5.75	6.00	6.50	15.00	0.03	0.47	0.07
33	**Junidhargad**	1.08	1.04	6.50	6.75	7.00	8.00	16.50	0.08	0.82	0.07
34	**Bigungad**	1.31	1.23	6.50	8.00	8.50	9.00	18.50	0.06	0.45	0.07
35	**Bagargad**	1.50	1.40	5.00	7.00	7.50	8.00	18.80	0.06	0.37	0.08
36	**Bedini ganga**	1.16	1.05	9.50	10.00	11.00	10.30	23.50	0.05	0.44	0.05
37	**Halkengad**	1.20	1.10	10.00	11.00	12.00	12.30	45.00	0.05	0.62	0.03
38	**Guramtoligad**	1.16	1.05	4.75	5.00	5.50	5.80	12.50	0.08	0.69	0.09
39	**Kurumtoligad**	1.25	1.13	4.00	4.50	5.00	5.50	11.50	0.09	0.66	0.11
40	**Baratoligad**	1.35	1.13	4.00	4.50	5.40	5.70	13.50	0.11	0.51	0.10
41	**Kailganga**	1.18	1.06	8.50	9.00	10.00	16.50	42.00	0.04	0.14	0.03
42	**Kumangad**	1.17	1.08	6.00	6.50	7.00	9.00	21.00	0.05	0.31	0.06
43	**Dolamgad**	1.30	1.20	5.00	6.00	6.50	7.50	17.50	0.07	0.95	0.07
44	**Milkkhetgad**	1.14	1.07	7.00	7.50	8.00	9.30	21.50	0.06	0.37	0.05
45	**Saurgad**	1.13	1.07	7.50	8.00	8.50	10.00	26.00	0.05	0.28	0.04
46	**Bauragad II**	1.15	1.04	4.80	5.00	5.50	10.30	25.00	0.07	0.15	0.05
47	**Ratmatigad**	1.19	1.13	4.20	4.75	5.00	5.50	14.00	0.10	0.44	0.09
48	**Bauragad II**	1.14	1.07	7.00	7.50	8.00	8.50	22.00	0.08	0.42	0.05
49	**Ghatiyagad**	1.30	1.24	5.00	6.20	6.50	7.50	18.00	0.08	0.50	0.07

50	**Suraggad**	1.24	1.20	7.50	9.00	9.30	10.00	22.00	0.06	0.48	0.06
51	**Sundardunga R.**	1.16	1.04	12.50	13.00	14.50	22.50	62.50	0.03	0.09	0.02
52	**Pindar**	1.14	1.05	11.00	11.50	12.50	17.00	49.50	0.05	0.10	0.02
53	**Khaphani**	1.16	0.97	7.75	7.50	9.00	15.50	37.50	0.05	0.24	0.03

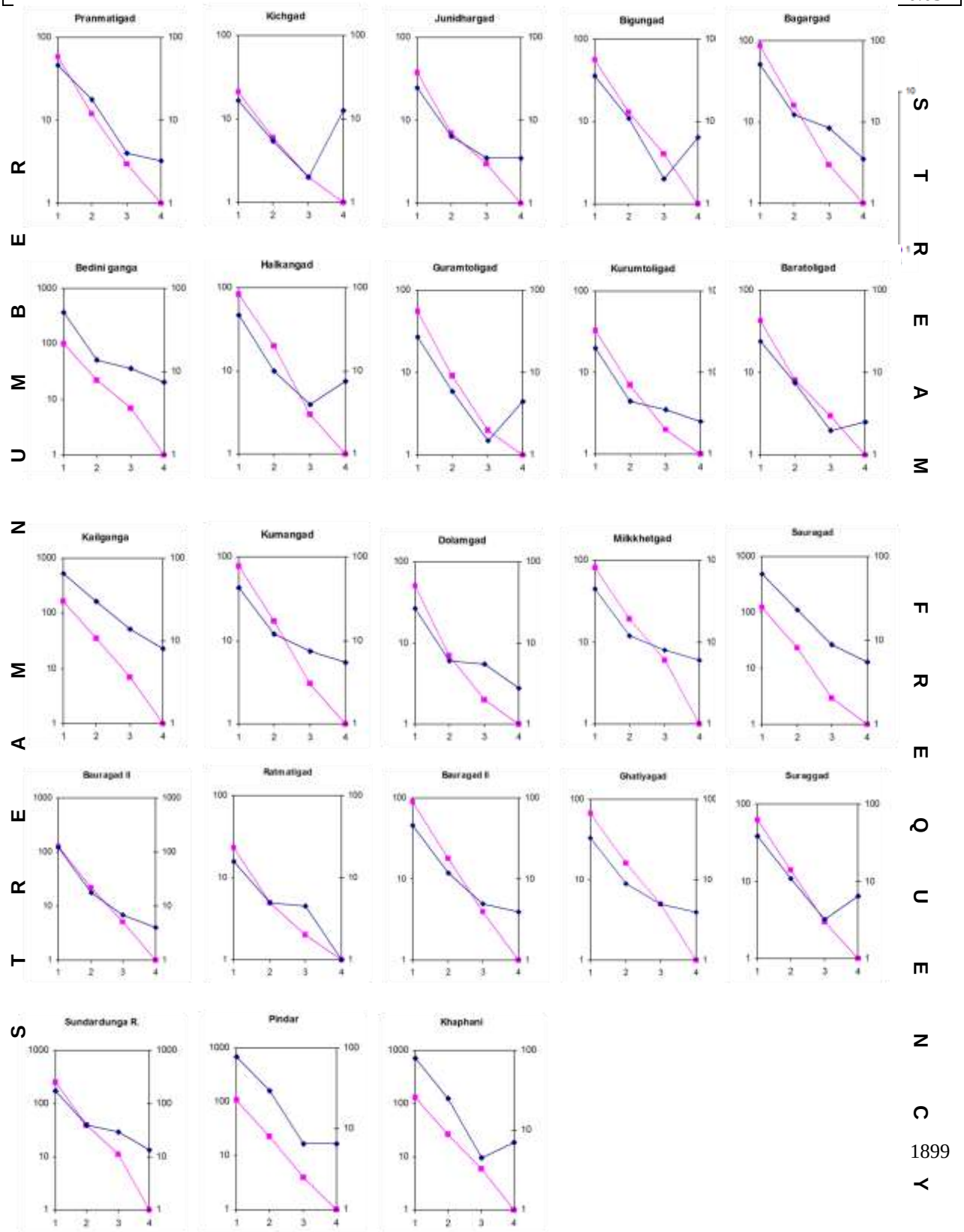
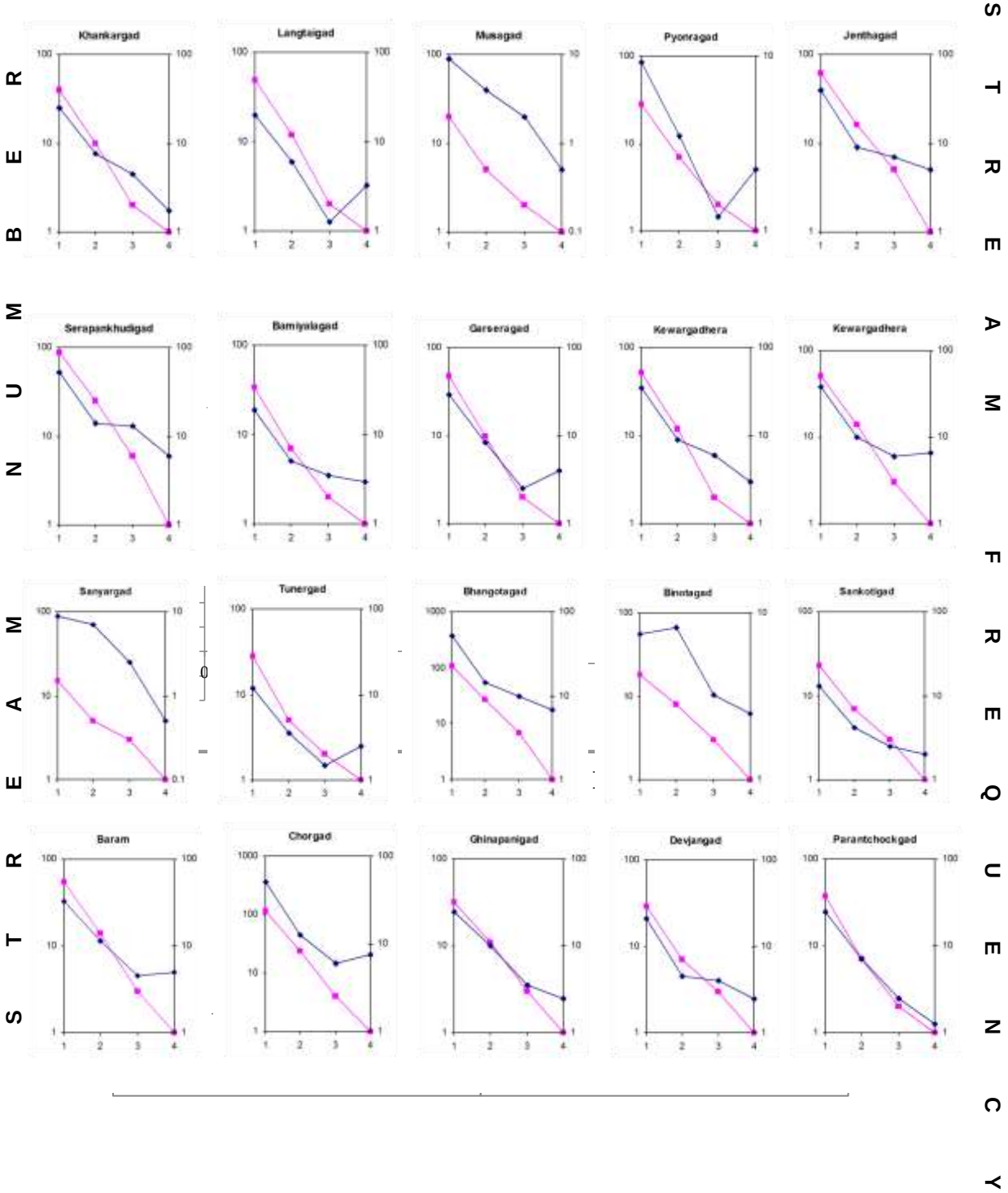


Fig. 4 contd.


NUMBER OF STREAM FREQUENCY
Khankargad
Langtaigad
Musagad
Pyonragad
Jenthagad
Serapankhudigad
Bamiyalagad
Garseragad
Kewargadhera
Kewargadhera
Sanyargad
Tunergad
Bhangotagad
Binotagad
Sankotigad
Baram
Chorgad
Ghinapanigad
Devjargad
Parantchockgad

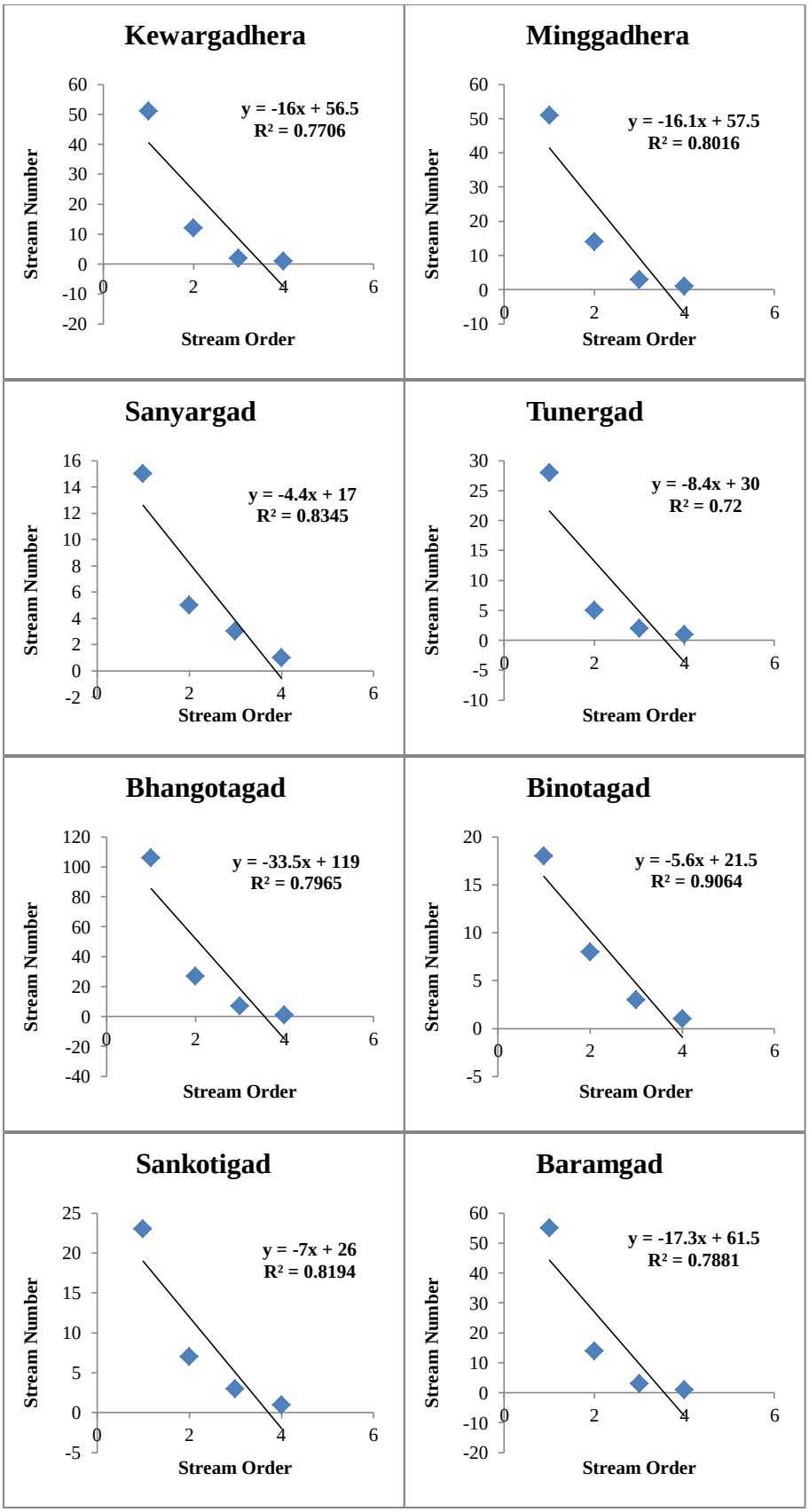
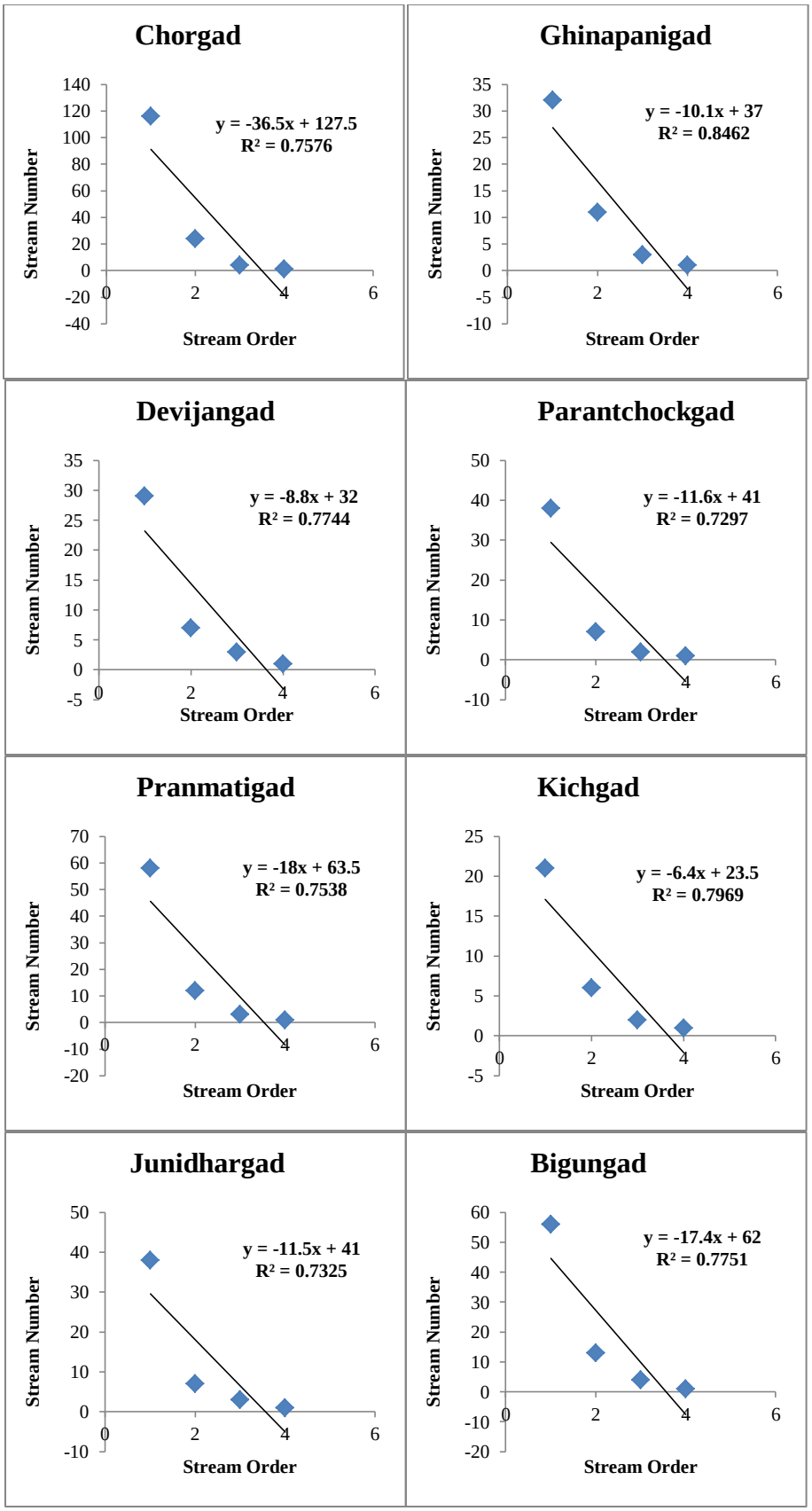
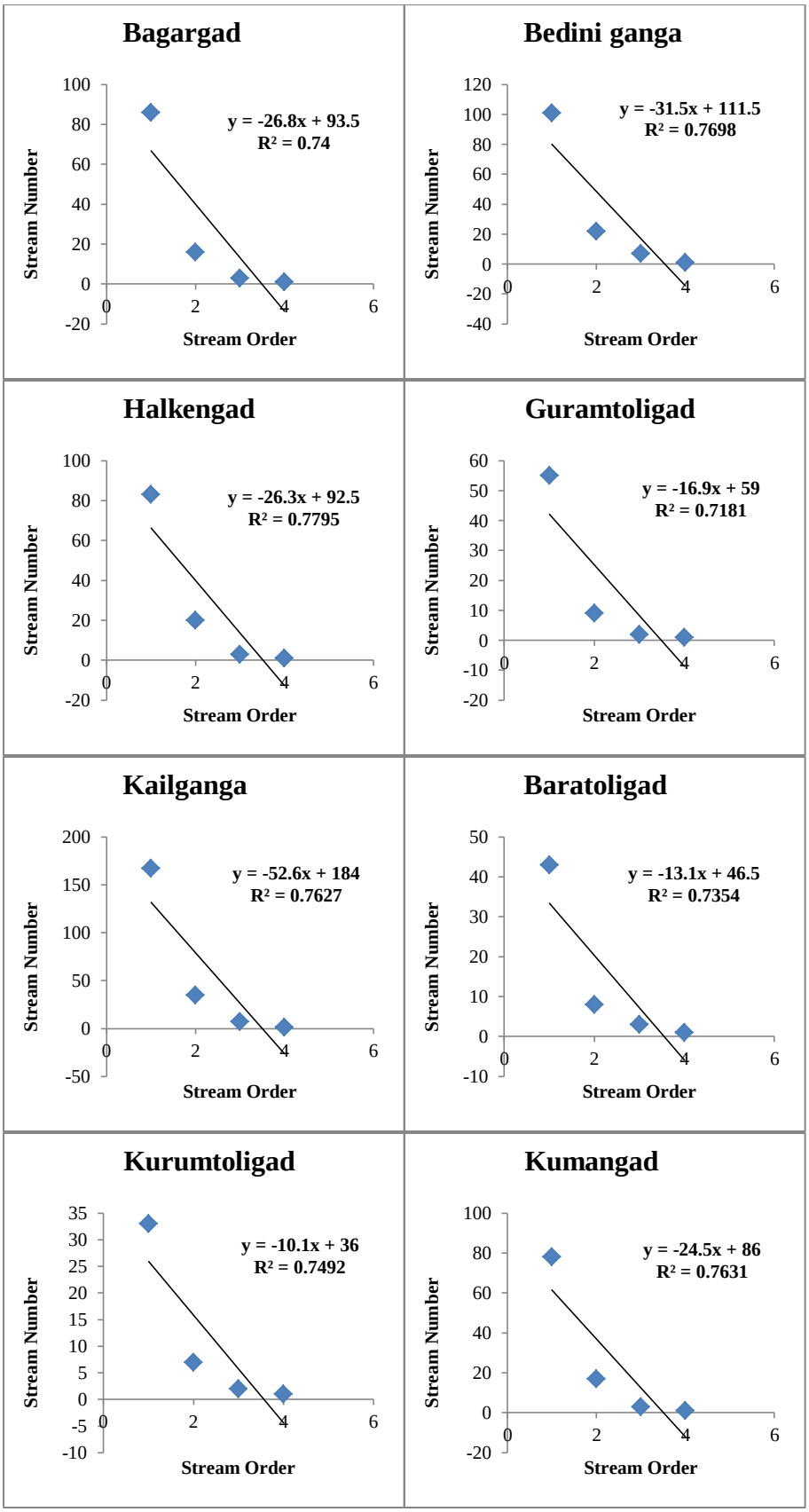
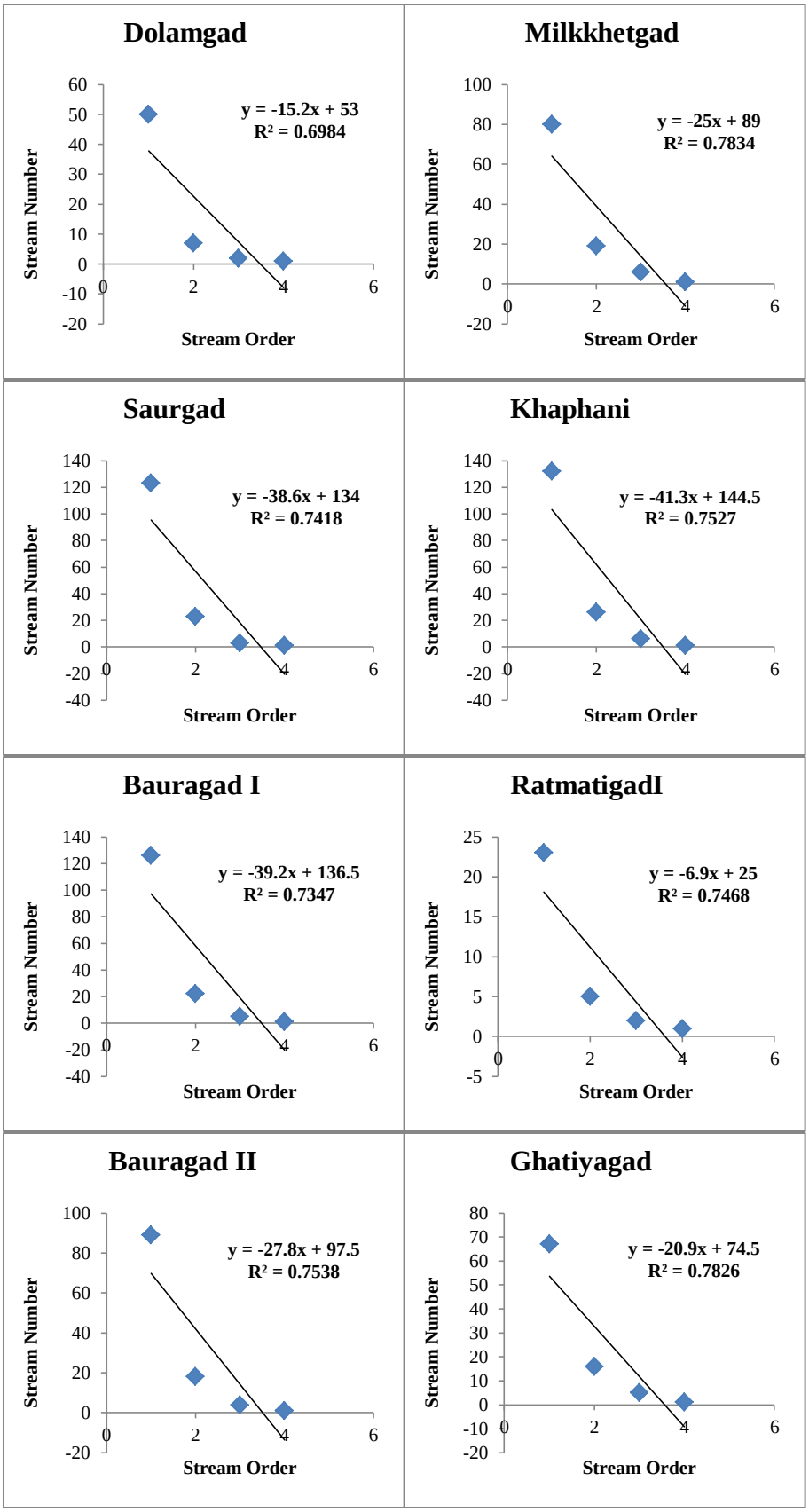
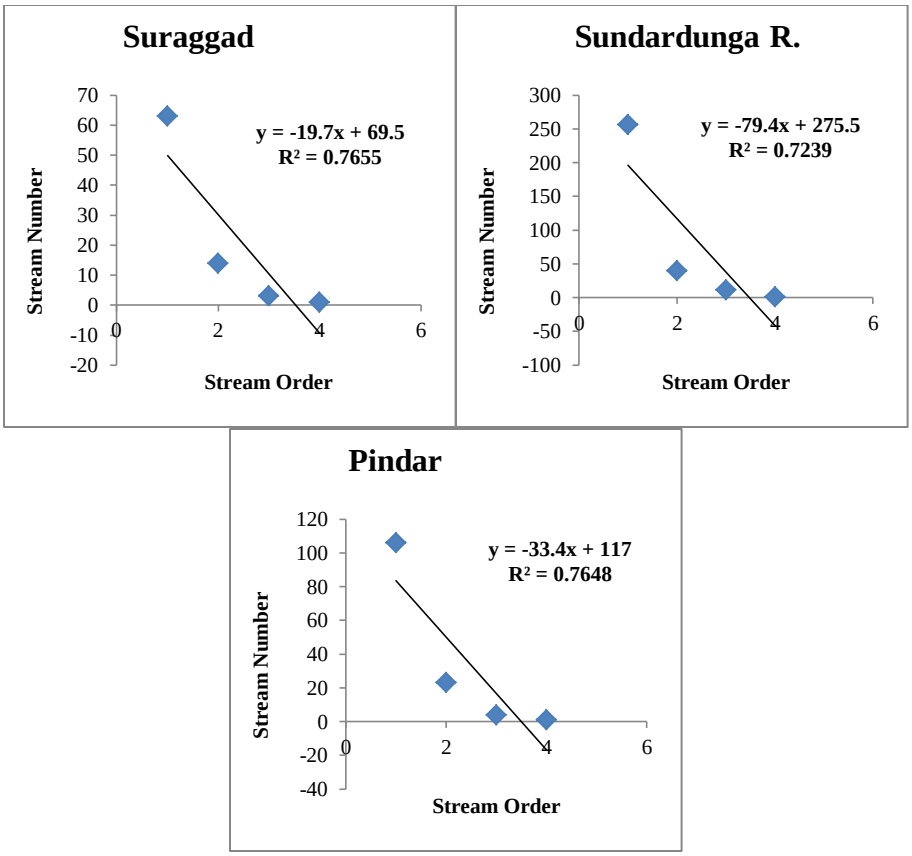


Fig. 5:- Stream Order Vs Stream Length


Chorgad
y = -36.5x + 127.5
R² = 0.7576
Stream Number
Stream Order
Ghinapanigad
y = -10.1x + 37
R² = 0.8462
Stream Number
Stream Order
Devijangad
y = -8.8x + 32
R² = 0.7744
Stream Number
Stream Order
Parantchockgad
y = -11.6x + 41
R² = 0.7297
Stream Number
Stream Order
Pranmatigad
y = -18x + 63.5
R² = 0.7538
Stream Number
Stream Order
Kichgad
y = -6.4x + 23.5
R² = 0.7969
Stream Number
Stream Order
Junidhargad
y = -11.5x + 41
R² = 0.7325
Stream Number
Stream Order
Bigungad
y = -17.4x + 62
R² = 0.7751
Stream Number
Stream Order


Bagargad
y = -26.8x + 93.5
R² = 0.74
Stream Number
Stream Order
Bedini ganga
y = -31.5x + 111.5
R² = 0.7698
Stream Number
Stream Order
Halkengad
y = -26.3x + 92.5
R² = 0.7795
Stream Number
Stream Order
Guramtoligad
y = -16.9x + 59
R² = 0.7181
Stream Number
Stream Order
Kailganga
y = -52.6x + 184
R² = 0.7627
Stream Number
Stream Order
Baratoligad
y = -13.1x + 46.5
R² = 0.7354
Stream Number
Stream Order
Kurumtoligad
y = -10.1x + 36
R² = 0.7492
Stream Number
Stream Order
Kumangad
y = -24.5x + 86
R² = 0.7631
Stream Number
Stream Order


Dolamgad
y = -15.2x + 53
R² = 0.6984
Milkkhetgad
y = -25x + 89
R² = 0.7834
Saurgad
y = -38.6x + 134
R² = 0.7418
Khaphani
y = -41.3x + 144.5
R² = 0.7527
Bauragad I
y = -39.2x + 136.5
R² = 0.7347
RatmatigadI
y = -6.9x + 25
R² = 0.7468
Bauragad II
y = -27.8x + 97.5
R² = 0.7538
Ghatiyagad
y = -20.9x + 74.5
R² = 0.7826
Stream Number
Stream Order



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