International Research Journal of Earth Sciences _____ISSN 2321 – 2527
Vol. **8(2),** 44-54, August **(2020)** *Int. Res. J. Earth Sci.*

Watershed level Morphometric analysis of Kayadhu River, Sub-Basin of Penganga River, Maharashtra India

Chavan Sumeet and Md. Babar*
Department of Geology, Dnyanopasak College, Parbhani-431401, Maharashtra, India
mdbabar2002@rediffmail.com

Available online at: www.isca.in
Received 23rd April 2020, revised 2rd July 2020, accepted 5th August 2020

Abstract

The morphometric analysis is carried by tracing and digitizing in the GIS environments in the vicinity of the Kayadhu river. SOI topographical maps of scale 1:50,000 are used to bring out sufficient information. The morphometric analysis of 36 watersheds along Kayadhu river in order to bring out tectonic impression of the area. The Geoprocessing is done firstly with general aspects as linear, areal, shape then its asymmetry factors are analyzed. The Kayadhu river encompasses total geographical area of 1630sq.km. Kayadhu forms its course in the vicinity of Penganga which is sub-basin of Wardha River. Except some parts of the Kayadhu river, the morphometric analysis show region is tectonically slightlyunstable.

Keywords: Tectonics, Morphometry, Geoprocessing, Kayadhu river.

Introduction

Nowadays, Geographical Information System (GIS) along with Remote Sensing (RS) are very popular in analyzing and understanding the selected area. The GIS is defined by Department of the Environment[1] as, "A system for capturing, storing, checking, manipulating, analyzing, and displaying data which are spatially referenced to the earth". Most researchers stated the geomorphic indices of active tectonics are powerful tool to assess the connection amongst the tectonics and basin morphology on specified scale to analyze existing geological deformations which is reflected in their watershed. Recently many researchers have used remote sensing data and GIS generated more precise data on morphometric parameters and analysis[2-6].

The fluvial landscape is mostly dominated by the river which are sensitive to deformations if occurs. The deformations in ancient and recent times controls the surficial expression in the form of drainages. All these drainages records and changes with the deformations occurred till in recent time. The current river is sub basin of the Penganga river which may be partially active due to nearby Kaddam Fault. This makes the study area sensitive for tectonics. The detail analysis is carried with various aspects in the morphometric analysis, which encompasses drainage density (Dd), stream frequency (Sf), elongation ratio (Re), asymmetry factor (AF) and bifurcation ratio (Rb).

Study area: The extent of the kayadhu river sub-basin is traced from catchment to mouth in the SOI 1:50,000 scale toposheet as, 56A9, 56A13, 56A14, 56E1, 56E2, 56E6, 56E7, 56E10, 56E11. The location and drainage map of the study area is given in Figure-1.

The Kayadhu river flows from Hingoli district to Nanded district with total area of 1630sq.km. the area is entirely covered by Deccan Volcanic Basalt (DVB) of late Cretaceous to early Eocene age. The black cotton soil is the product of the Deccan basalt which is good for agricultural use. On an average the rainfall of the area is 890.28mm. The dendritic drainage pattern is very well developed in the study region which further indicates uniform lithological condition.

Methodology

The present study uses SOI toposheets used for building base maps. The SOI top sheets of scale 1:50000 is used for morphometric analysis. The stream ordering is used in the study region for the sake of its simplicity in the numbering of the stream networks[7].

The drainages which are considered here, have two different methodology, one the longest stretch of the Kayadhu river is traced and then the 36 watershed inside the Kayadhu Sub-Basin are digitized (Figure-2). Second the entire Kayadhu basin is considered as one Sub-Basin, in this the drainages found to be the highest 7th order (Figure-1). The numbering of the basins have been given in alphabetical manner of the concerned watersheds for the sake of the simplicity while calculations. Most basin names are directed by SOI and whereas names of remaining watersheds are captured by nearby villages. The morphometric parameters determined are bifurcation ratio, elongation ratio, drainage density, stream frequency, and asymmetry factor. Bifurcation ratio is the ratio of streams of first order (1o) to the second order (2o) and so on. Drainage density is derived from dividing the total length of streams by the total area of the basin.

Stream frequency (Fs) is also derived from the division of the total number of streams of all orders in the basin with the total area of the basin[9]. The asymmetry factor (AF) is used to measure the drainage basin asymmetry and it is calculated using formula AF = 100 (Ar/At), where: Ar means area of the basin to the right of the trunk stream and At is total area of the basin. If the value of AF is equal to about 50[8] indicating the drainage networks formed and continue to flow in a stable setting.

Results and discussion

All drainage characteristics of Kayadhu river have been examined with reference to morphometric analysis that include bifurcation ratio (Rb), drainage density (Dd), stream frequency (Sf), elongation ratio (Re) and asymmetry factor (AF).

Linear Aspects: Bifurcation Ratio (Rb): It is the ratio between the hierarchal orders in branching pattern of the stream network in the basin area. It is defined[9] as, a ratio of a number of streams of an order Nu to the number of streams of the next higher order (Nu+1). This provides quantitative information of the stream network evolution[5].

The formula expressed as,

$$Rb = \frac{Nu}{Nu + 1}$$

Where: Nμ is number of streams of a given order, Nu+1 means number of streams of next higher order.

The values lies in between 3.0 to 5.0 shows uncontrolled geological structures. Higher values indicates structural control in the region. The Rb values in the study region range from 2 to 7 (Table-2) may illustrate some structural control from 4th order to 6th order. It is observed that the Rb values between 1st and 2rd order, 2nd and 3rd order over all show normal development without structural control i.e. (2.5 to 5), but the Rb values from 3rd order onwards are lower than 5.3 except for watershed Kadalti where the value is 7. The map illustrating the bifurcation values of different watersheds is represented in Figure-3.

Aerial Aspects: Drainage density (Dd): The drainage density is the relationship in between total stream length and the basin area. This shows the density of the drainages in the particular region. The drainage density is defined by Horton, R.E.[9] as, a ratio of total length of all stream segments in a given drainage basin to the total area of that basin.

The drainage density (Dd) is expressed as,

$Dd = \frac{L}{A}$ L=Total length of stream segments, A= Basin area,

The values of drainage density between 0-2 is low Dd which indicates highly permeable subsoil, 2.0-4.0 is medium, 4.0-6.0 is high Dd which indicates permeable subsurface material[10-16]. The Dd values in the study region lies between 1.6 and 3.0 (Table-2) indicating medium permeability of the soil.

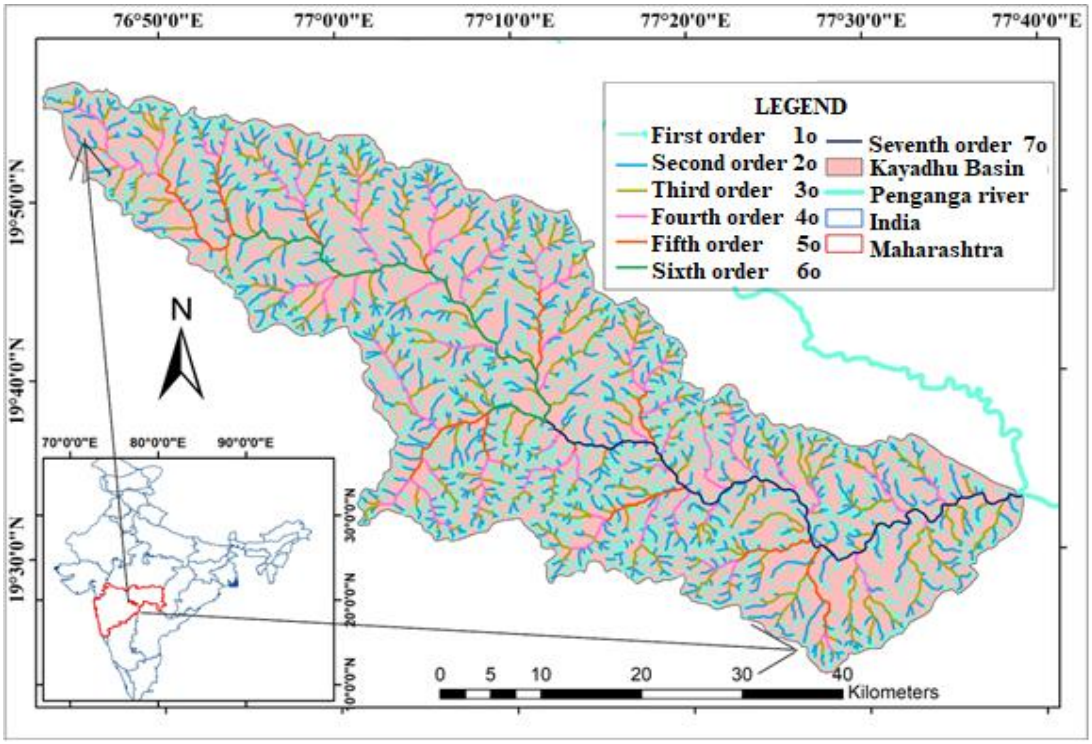

Figure-1: Location and drainage map of the study area.

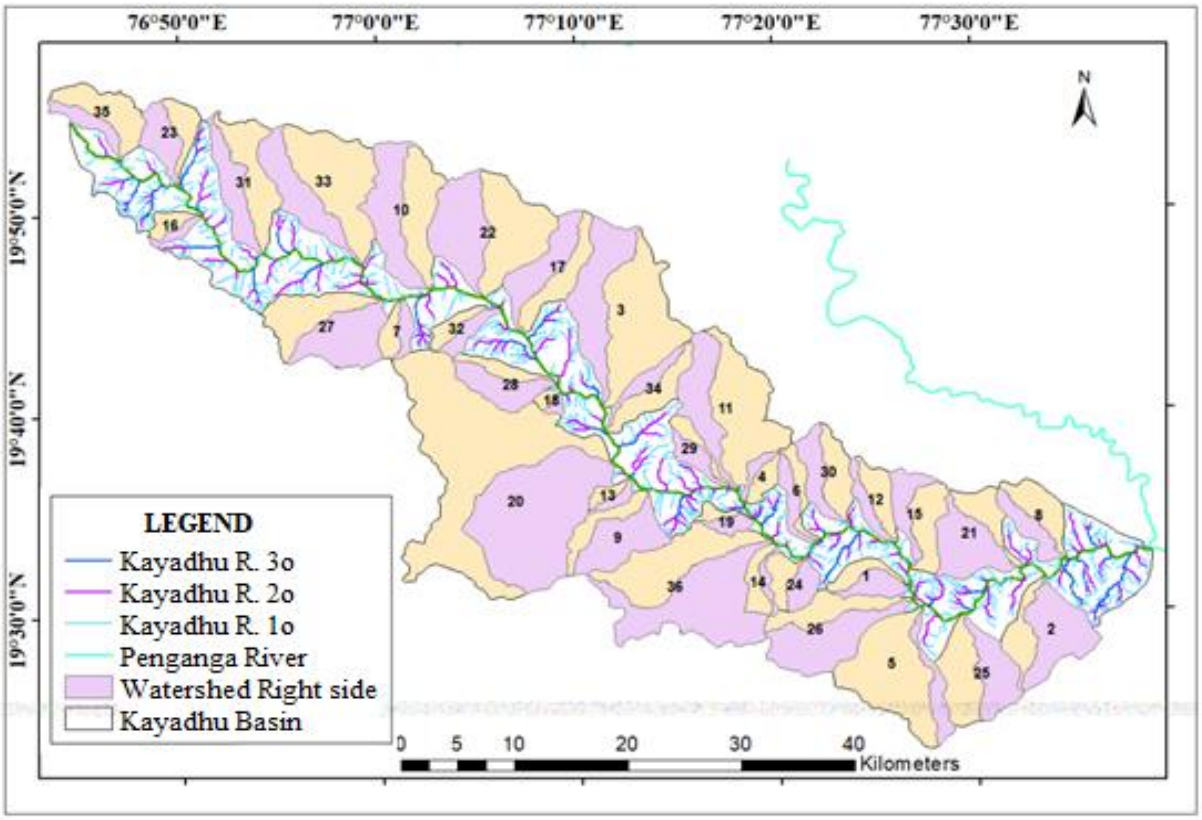

Figure-2: Map illustrating 36 watersheds in the Kayadhu river sub-basin.

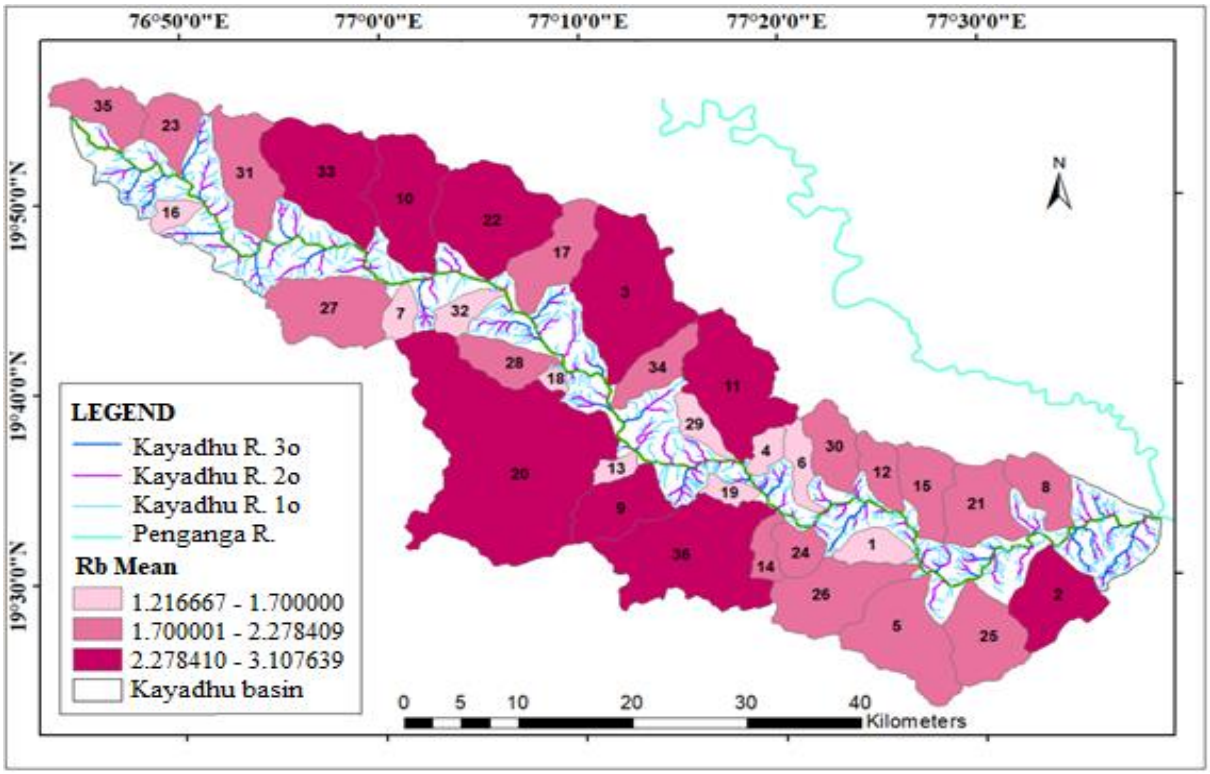

Figure-3: Bifurcation ratios of 36 watersheds in the Kayadhu river sub-basin.

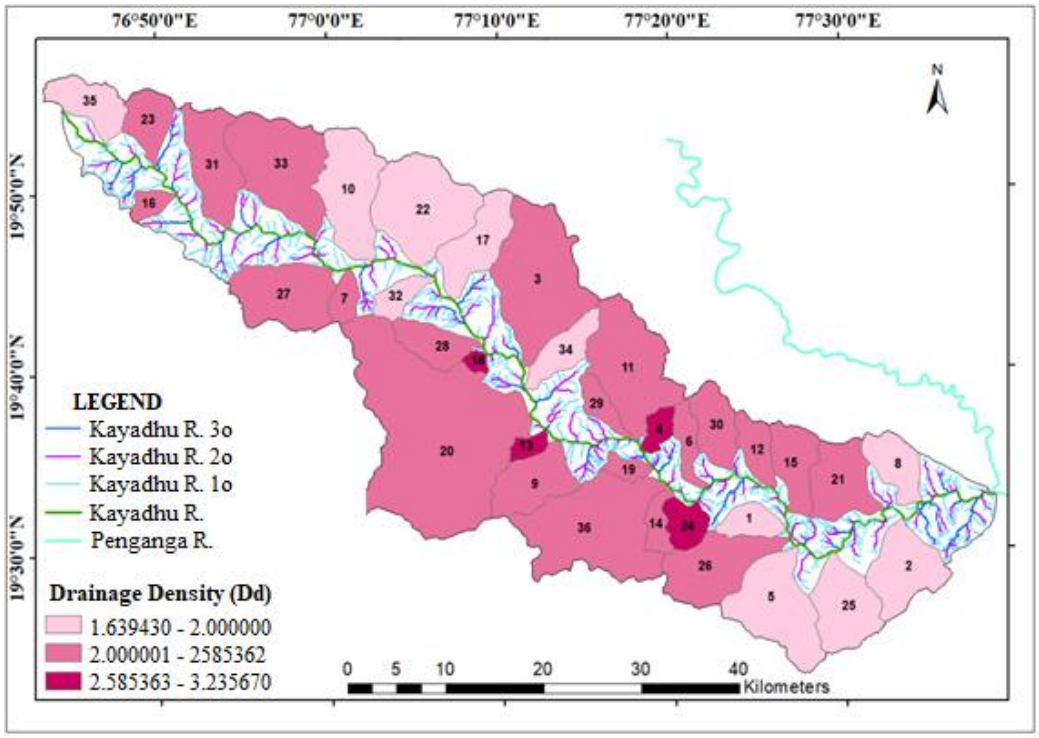

Figure-4: Drainage density variation of 36 watersheds in the Kayadhu river sub-basin.

Stream frequency (Sf): It is expressed as a division of the sum of total number of streams with the total basin area. This shows frequency of the stream segments in the particular region.
The stream frequency (Sf) is as follows,

$Sf = \frac{N}{A}$ N= total number of stream, A= Basin area

The values of the stream frequency lies between 0-2 is very poor, 2-4 is poor, 4-6 is moderate, 6-8 is high[11-14]. The Sf values in the study region lies in 1.6-4.9 (Table-2) indicating the moderate stream frequency.

Shape Aspects: Elongation ratio (Re): The basin elongation ratio (Re) is the ratio of diameter of a circle of the same area as the basin to the maximum basin length[17]. The elongation ratio is aerial morphometric variable which given an information of degree of the maturity of the basin. It deals with maximum length of the basin that may indicate structural control. The tectonically active areas shows elongated nature of the basin, whereas near to circular nature of the basin are tectonically inactive areas[18].

The elongation ration is expressed as,

$Re = \left(\frac{2\sqrt{A}/\sqrt{\pi}}{Lb}\right)$ A= Basin area, $\sqrt{\pi}$= 1.7720, Lb= Maximum length of the basin.

The value lies closer to the <0.50 are tectonically active regions, 0.5-0.75 are moderately active, >0.75 are inactive regions[8]. The study region has value range in between 0.48-0.97 (Table-2). The Re value of watershed 6 is less than 0.50 is tectonically active, that of watershed numbers 1 to 5, 7 to 17, 19, 23, 26, 28 to 36 the value is between 0.50 and 0.75 indicating moderately active and the Re value of greater than 0.75 is found in the watersheds of 18, 20 to 22, 24, 25 and 27 suggesting the inactive regions. This study points out that except watersheds 18, 20, 21, 22, 24, 25 and 27 all other watersheds are slightly to moderately tectonically active.

Asymmetry factor (Af): It is the aerial relationship between left and right side of the middle trunk stream. This relationship indicates tilting of the basin from the main trunk stream. The drainages in the basin areas are developed with in relation of the tectonics which is reflected in the asymmetry factor. The asymmetry of whole Kayadhu sub-basin is shown in Figure-7.

The value lies closer to the 50 suggests stable tectonic setting, whereas more or less than values 50 suggests tilt which indicates active tectonic environments[19] the values in the study region ranges from16 to 71 (Table-2). Here we consider values of AF closer to 50 means between 45 and 55 as stable values. The values of AF between 45 and 55 are found in watershed numbers 6, 7 10, 13, 22, 24, 25, 27, 30 and 32 indicating stable tectonic setting, while watershed numbers 3, 4, 5, 8, 11, 12, 14, 15, 16, 18, 20, 31, 33, 34, 35 have AF values less than 45 and watershed numbers 1,2, 9, 17, 19, 21, 23, 26, 28, 29, 36 have AF values greater than 55, both indicate tectonic tilt.

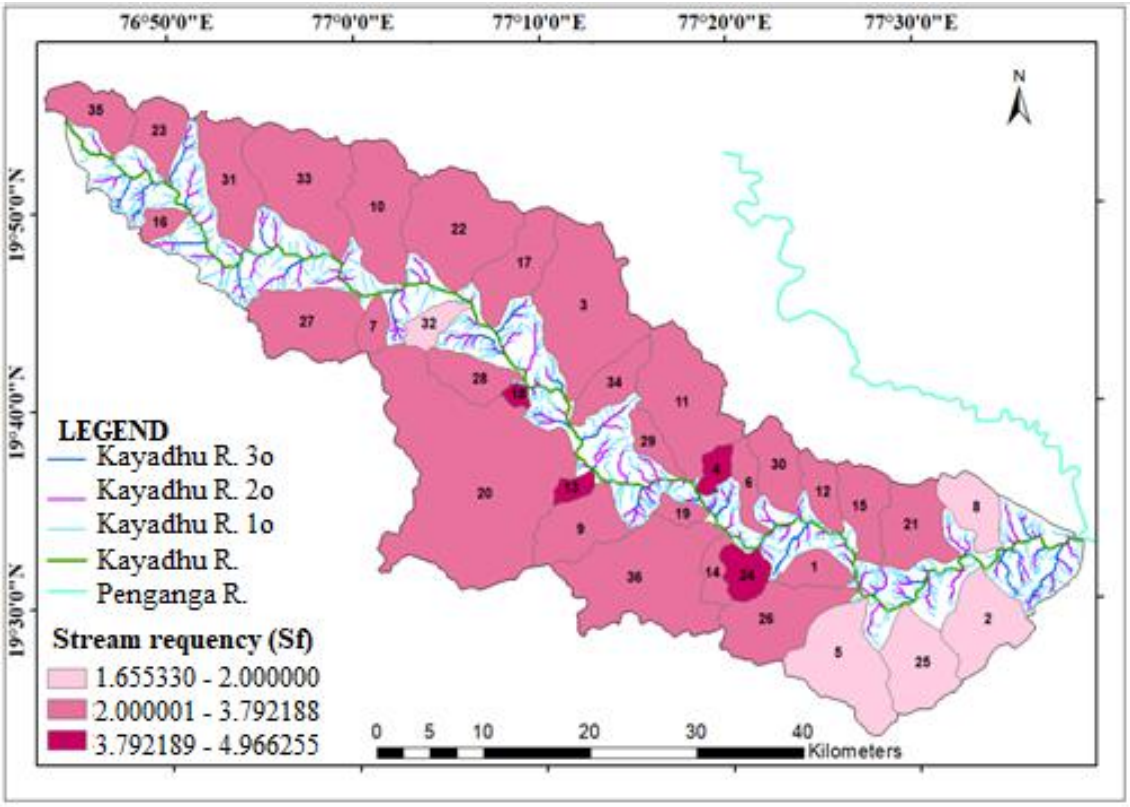

Figure-5: Stream frequency variation of 36 watersheds in the Kayadhu river sub-basin.

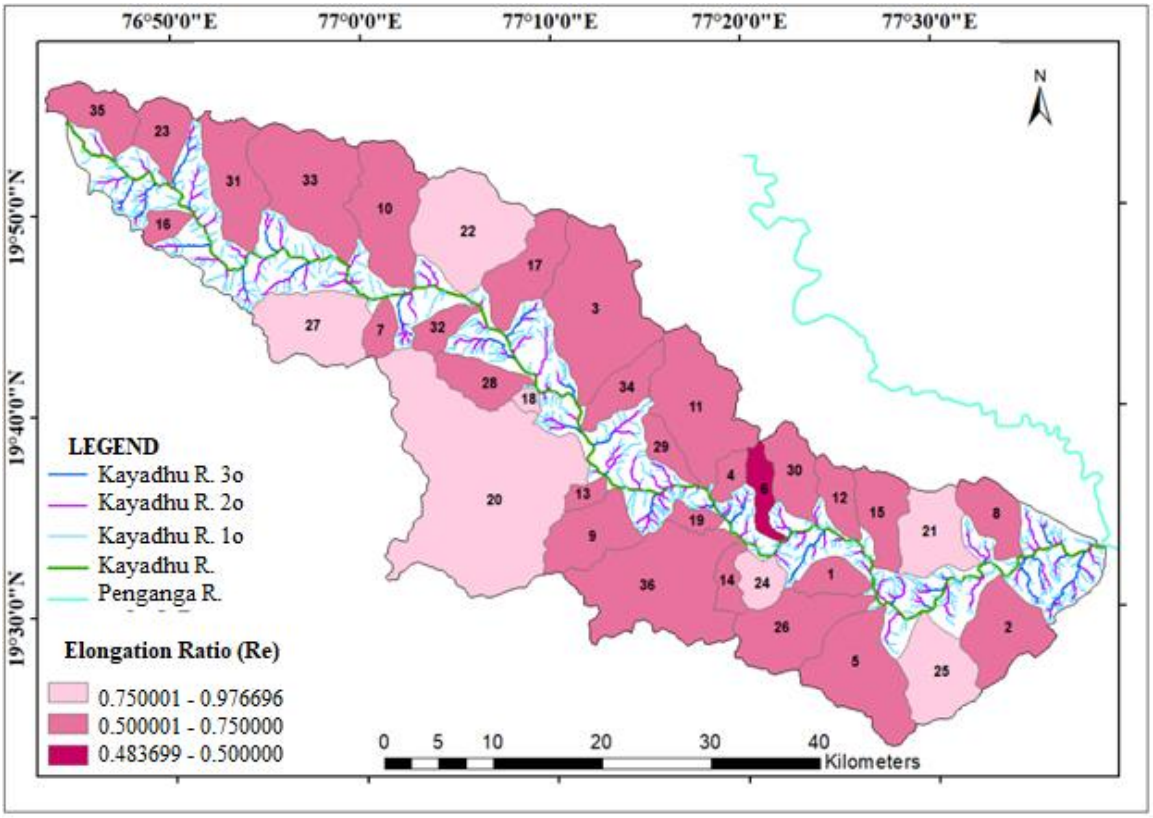

Figure-6: Elongation ratios of 36 watersheds in the Kayadhu river sub-basin.

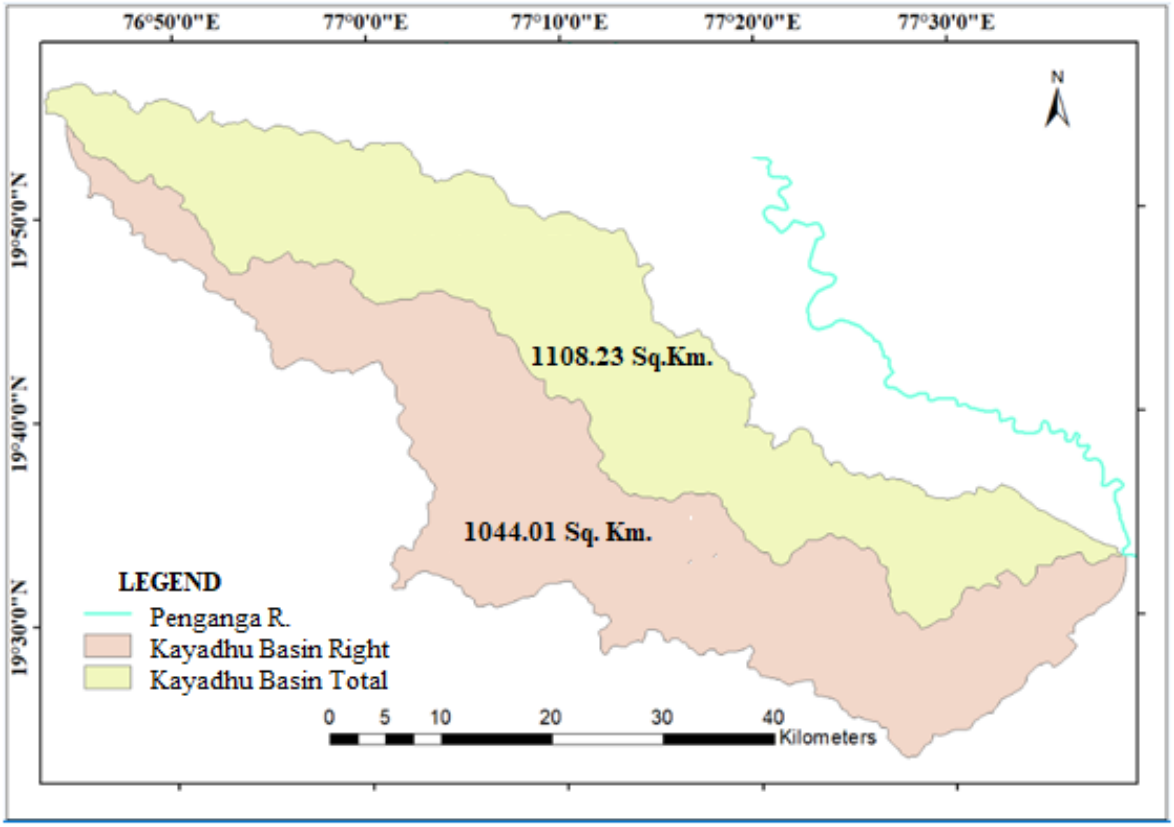

Figure-7: Asymmetry map of the Kayadhu river sub-basin.

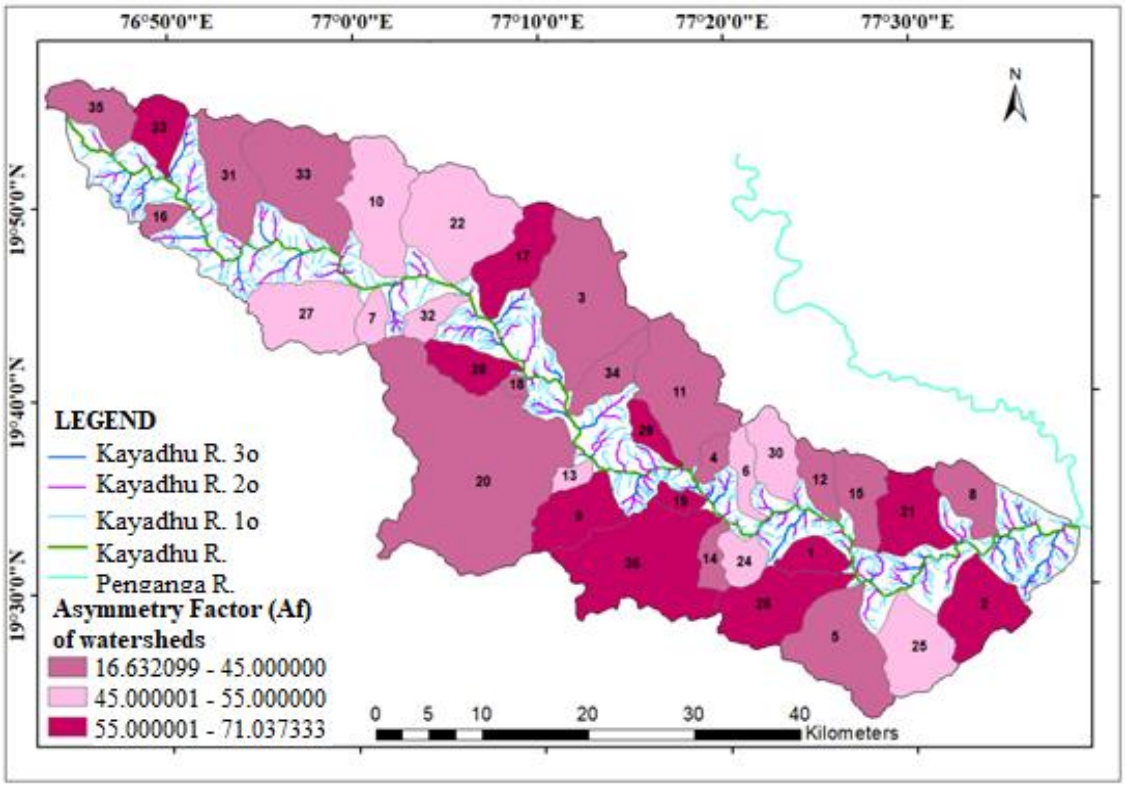

Figure-8: Asymmetry factors of 36 watersheds in the Kayadhu river sub-basin.

Table-1: Linear aspects and area of watersheds of Kayadhu river basin.

Watershed Nos.	Kayadhu Watershed	Area sq. km	Streams of 1o (u)	Streams of 2o (u)	Streams of 3o (u)	Streams of 4o (u)	Streams of 5o (u)	Streams of 6o (u)
1	Balapur	17.902	26	7	2	1	--	--
2	Baradshevala	49.173	67	15	2	1	--	--
3	Bori Shikari	107.006	205	51	12	3	1	--
4	Chapnath	10.747	37	10	4	1	--	--
5	Dati	71.889	87	22	7	2	1	--
6	Gotwadi	15.891	29	8	2	1	--	--
7	Haladwadi	12.206	25	7	2	1	--	--
8	Hastra	28.764	37	11	2	1	--	--
9	Jamgawhan	41.862	114	27	5	2	1	--
10	Kadati	65.238	110	31	7	1	--	--
11	Kaldoh and Palodwadi Nala	81.721	207	56	15	3	1	--
12	Kamthe	19.998	52	13	2	1	--	--
13	Kanjara	7.853	29	7	2	1	--	--
14	Karda	13.185	39	8	2	1	--	--
15	Kaudi	32.724	77	21	4	1	--	--
16	Kautha	9.777	17	4	2	1	--	--
17	Khambala	43.025	77	21	5	1	--	--
18	Kothlaj	4.536	14	5	2	1	--	--
19	Malagovhan	8.994	16	5	2	1	--	--
20	Moth Nadi	254.338	549	144	32	6	2	1
21	Newri	43.58	85	20	4	1	--	--
22	Pangri	84.493	141	34	7	2	1	--
23	Pankanergaon	25.999	44	11	4	1	--	--
24	Peth Wadgaon	18.477	55	15	4	1	--	--
25	Phutana	49.894	73	18	3	1	--	--
26	Pimpri Khurd	58.118	128	33	8	3	1	--
27	Pusegaon	59.99	107	26	7	2	1	--

28	Raholi Khurd	26.929	53	12	4	1	--	--
29	Salegaon	14.304	25	5	2	1	--	--
30	Salwa	30.657	66	19	4	1	--	--
31	Sapatgaon	49.408	109	25	6	2	1	--
32	Savad	14.743	21	5	2	1	--	--
33	Shivani Budruk	84.044	160	42	8	2	1	--
34	Takli Nandapur	25.757	51	14	2	1	--	--
35	Wadhona	31.64	50	15	4	1	--	--
36	Yelegaon Govli	114.756	291	69	12	3	1	--

u – Number of streams, 1o – First order to 6o –Sixth order streams.

Table-2: Aerial and shape aspects of watersheds of Kayadhu river basin.

Watershed Nos.	Kayadhu Watershed	Drainage Density (Dd)	Stream Frequency (Fs)	Elongation Ratio (Re)	Asymmetry Factor (AF)	Rb 1o/2o	Rb 2o/3o	Rb 3o/4o	Rb 4o/5o	Rb 5o/60
1	Balapur	1.85	2.01	0.65	57.00	3.7	3.5	2	--	--
2	Baradshevala	1.76	1.73	0.74	71.04	4.5	7.5	2	--	--
3	Bori Shikari	2.03	2.54	0.66	40.26	4	4.3	4	3	--
4	Chapnath	3.03	4.84	0.65	35.61	3.7	2.5	4	--	--
5	Dati	1.64	1.66	0.74	16.63	4	3.1	3.5	2	--
6	Gotwadi	2.08	2.52	0.48	54.09	3.6	4	2	--	--
7	Haladwadi	2.16	2.87	0.67	46.42	3.6	3.5	2	--	--
8	Hastra	1.87	1.77	0.67	42.48	3.4	5.5	2	--	--
9	Jamgawhan	2.48	3.56	0.68	70.69	4.2	5.4	2.5	2	--
10	Kadati	1.94	2.28	0.64	54.83	3.5	4.4	7	--	--
11	Kaldoh and Palodwadi	2.54	3.45	0.67	35.11	3.7	3.7	5	3	--
12	Kamthe	2.42	3.40	0.59	39.05	4	6.5	2	--	--
13	Kanjara	3.06	4.97	0.63	49.37	4.1	3.5	2	--	--
14	Karda	2.59	3.79	0.59	30.23	4.9	4	2	--	--
15	Kaudi	2.49	3.15	0.73	41.86	3.7	5.3	4	--	--
16	Kautha	2.07	2.45	0.67	37.06	4.3	2	2	--	--
17	Khambala	1.89	2.42	0.59	57.17	3.7	4.2	5	--	--

18	Kothlaj	3.24	4.85	0.98	44.88	2.8	2.5	2	--	--
19	Malagovhan	2.42	2.67	0.62	59.98	3.2	2.5	2	--	--
20	Moth Nadi	2.27	2.89	0.82	41.20	3.8	4.5	5.3	3	2
21	Newri	2.21	2.52	0.77	68.50	4.3	5	4	--	--
22	Pangri	1.74	2.19	0.88	46.78	4.1	4.9	3.5	2	--
23	Pankanergaon	2.10	2.31	0.71	58.99	4	2.8	4	--	--
24	Peth Wadgaon	3.02	4.06	0.88	50.55	3.7	3.8	4	--	--
25	Phutana	1.76	1.90	0.79	46.94	4.1	6	3	--	--
26	Pimpri Khu.	2.27	2.98	0.61	66.14	3.9	4.1	2.7	3	--
27	Pusegaon	2.12	2.38	0.83	54.91	4.1	3.7	3.5	2	--
28	Raholi Khu.	2.31	2.60	0.60	70.61	4.4	3	4	--	--
29	Salegaon	2.01	2.31	0.52	58.89	5	2.5	2	--	--
30	Salwa	2.36	2.94	0.63	47.33	3.5	4.8	4	--	--
31	Sapatgaon	2.39	2.89	0.57	42.66	4.4	4.2	3	2	--
32	Savad	1.75	1.97	0.61	52.03	4.2	2.5	2	--	--
33	Shivani Bu.	2.13	2.53	0.71	35.47	3.8	5.3	4	2	--
34	Takli Nandapur	1.94	2.64	0.51	33.80	3.6	7	2	--	--
35	Wadhona	1.90	2.21	0.71	28.66	3.3	3.8	4	--	--
36	Yelegaon Govli	2.55	3.28	0.72	60.58	4.2	5.8	4	3	--

Rb – Bifurcation Ratio, 1o – First order to 6o – Sixth order streams, Dd – Km/Km^2, Sf –streams/ Km^2.

Table-3: Linear aspects of watersheds of Kayadhu river basin.

Watershed Nos.	Kayadhu Watershed	1o total Length (Km)	2o total length (Km)	3o total length (Km)	4o total length (Km)	5o total length (Km)	6o total length (Km)	Total no. of stream (Nu)	Total Stream Length (Lu) (Km)	Basin Area (RS) (Km^2)	Max Basin Length (L) (Km)
1	Balapur	18.34	5.7	8.374	0.788	--	--	36	33.20	10.20	7.39
2	Baradshevala	45.695	21.984	17.79	0.841	--	--	85	86.31	34.93	10.70
3	Bori Shikari	119.756	45.355	29.725	13.24	9.136	--	272	217.21	43.08	17.62
4	Chapnath	21.841	3.164	4.369	3.204	--	--	52	32.58	3.83	5.65
5	Dati	57.742	31.523	14.478	3.046	11.068	--	119	117.86	11.96	12.97
6	Gotwadi	19.546	2.348	2.584	8.585	--	--	40	33.06	8.60	9.30
7	Haladwadi	16.249	4.364	2.518	3.182	--	--	35	26.31	5.67	5.90

8	Hastra	31.551	11.043	6.77	4.562	--	--	51	53.93	12.22	9.02
9	Jamgawhan	66.169	16.694	8.634	11.609	0.863	--	149	103.97	29.59	10.74
10	Kadati	72.335	24.363	18.521	11.241	--	--	149	126.46	35.77	14.28
11	Kaldoh and Palodwadi Nala	118.747	42.42	24.215	15.151	6.719	--	282	207.25	28.69	15.32
12	Kamthe	26.918	10.023	7.034	4.403	--	--	68	48.38	7.81	8.51
13	Kanjara	16.42	3.098	1.434	3.103	--	--	39	24.06	3.88	5.00
14	Karda	19.501	8.105	1.153	5.329	--	--	50	34.09	3.99	6.95
15	Kaudi	44.4	14.781	16.963	5.297	--	--	103	81.44	13.70	8.80
16	Kautha	10.235	4.012	5.183	0.813	--	--	24	20.24	3.62	5.23
17	Khambala	42.663	20.553	8.529	9.42	--	--	104	81.17	24.60	12.45
18	Kothlaj	10.162	2.633	1.329	0.553	--	--	22	14.68	2.04	2.46
19	Malagovhan	13.601	4.303	1.71	2.163	--	--	24	21.78	5.39	5.45
20	Moth Nadi	335.162	125.49	59.515	34.844	16.46	6.835	734	578.31	104.78	21.94
21	Newri	53.023	23.591	12.306	7.526	--	--	110	96.45	29.85	9.70
22	Pangri	74.269	38.827	19.48	12.226	2.273	--	185	147.08	39.53	11.78
23	Pankanergaon	30.39	8.089	11	5.057	--	--	60	54.54	15.34	8.16
24	Peth Wadgaon	34.005	12.316	6.584	2.917	--	--	75	55.82	9.34	5.49
25	Phutana	47.328	16.355	19.331	5.039	--	--	95	88.05	23.42	10.14
26	Pimpri Khurd	73.347	28.321	14.585	6.735	8.898	--	173	131.89	38.44	14.15
27	Pusegaon	69.922	28.803	16.567	10.853	0.799	--	143	126.94	32.94	10.58
28	Raholi Khurd	37.968	9.309	8.159	6.821	--	--	70	62.26	19.01	9.75
29	Salegaon	14.785	5.221	5.798	2.926	--	--	33	28.73	8.42	8.23
30	Salwa	40.299	16.106	6.683	9.281	--	--	90	72.37	14.51	9.99
31	Sapatgaon	69.101	28.335	5.976	6.016	8.691	--	143	118.12	21.08	13.84
32	Savad	11.668	7.271	2.341	4.574	--	--	29	25.85	7.67	7.10
33	Shivani Budruk	101.602	41.587	19.623	12.04	3.948	--	213	178.80	29.81	14.63
34	Takli Nandapur	27.288	10.533	9.84	2.38	--	--	68	50.04	8.71	11.29
35	Wadhona	29.897	17.232	6.235	6.772	--	--	70	60.14	9.07	8.89
36	Yelegaon Govli	180.873	57.487	31.588	12.819	9.407	--	376	292.17	69.52	16.78

1o – First order to 6o – Sixth order streams.

Conclusion

The map of Kayadhu drainages shows high Stream frequency in the zone A and zone B which may indicate this area may have affected by recent tectonism and it may turn in the future site for the neotectonism. It also indicate that high permeable strata may be present at the site whereas whole basin shows entirely dendritic drainage pattern which shows presence of homogenous lithology. Stream bifurcation ratio, elongation ratio and asymmetry factor of 36 watersheds indicates that the major part of the area is structurally and tectonically controlled. The map of the Kayadhu river asymmetry factors shows nearly same values from both right and left side of the basin which indicate some tilting and region is tectonically unstable.

References

1. Department of the Environment (DoE) (1987). #Handling Geographical Information.# HMSO, London.

2. Babar Md, Ghute BB and Chunchekar RV (2010). #Application of hydrogeology, geomorphology and remote sensing for evaluation of groundwater potential zones of Dhamoda nala catachment in parbhani district, Maharashtra.# *Proceeding Volume of Workshop on "Application of Remote Sensing and GIS in Water Resources Management", Held at Hyderabad* 65-73.

3. Muley RB, Kulkarni PS and Babar Md (2010b). #Hydrogeological Studies of Mendhwan Watershed Ahmadnagar District, Maharashtra, India.# *In: Advance in Geoscience, 23:Hydrogeological Science* 237-246.

4. Babar Md and Shah II (2011). #Remote Sensing and GIS Applications For Groundwater Potential Zones in Tawarja River Sub-Basin, Latur District, Maharashtra, India.# *International Journal of Earth Sciences and Engineering*, 4(3), 71-79.

5. P.A. Pisal, A.S. Yadav and A.B. Chavan (2013). #Morphometric Analysis of Bhogavati River Basin, Kolhapur District, Maharashtra, India.# *IOSR journal of Mechanical and Civil Engineering* (IOSR-JMCE). PP: 01-08

6. Ghatge R. S. and Babar Md (2015). #Mophometric Anlysis of Indrayani River, Parbhani District, Maharashtra Using GIS.# *International Journal of Geology, Earth and Environmental Science*, 2(2), May-August, pp.141-149.

7. Strahler, A. N. (1957). #Quantitative analysis of watershed geomorphology.# *Trans. America Geophy. Union,* 38, pp. 913-920.

8. Keller E.A. amd Pinter N. (2002). #Active tectonics, Earthquakes, Uplift and Landscape.# New Jersey, Prentice Hall, U.S.A. 432 p.

9. Horton, R.E. (1945). #Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology.# *Geological Society of America Bulletin*. 56, 275-370.

10. Tejpal S. and Vikrant J. (2009). #Tectonic constraints on watershed development on frontal ridges: Mohand Ridge, NW Himalaya, India.# *Geomorphology*, 106, 231–241.

11. Singh S. (1998). #Geomorphology.# *Prayag pustak bhavan, Allahabad.*, 11-372.

12. Gurav Chandrakant, Babar M. and Asode Ajaykumar (2019). #Morphometric Analysis of Yelganga- Shivbhadra-Kohilla River Basins in Aurangabad District Maharashtra India-Using GIS Techniques.# *International Journal of Research and Analytical Reviews*, 6(1), 250-257.

13. Avijit Mahala (2020). #The significance of morphometric analysis to understand the hydrological and morphological characteristics in two different morphoclimatic settings.# Applied Water Science (2020) 10:33.https://doi.org/10.1007/s13201-019-1118-2.

14. Gaurav Kumar, Pratibha Warwade, Gulab Mukund, Nitish Dhaked and Shailesh Suman (2020). #Morphometric Analysis and Prioritization of Sub-Watersheds in Watershed of Nashik, Maharashtra of Godavari River Basin using Remote Sensing and GIS as a Tool.# *International Journal of Innovative Technology and Exploring Engineering*, 9(4), 1553-1559.

15. Shruti Verma, Dhiraj Khalkho and Lov Kumar Gupta (2020). #Morphometric Analysis of a Drainage Basin using Remote Sensing and Geographical Information System (GIS).# *Int. J. Current Microbiology Applied Science*, 9(4), 1950-1959.

16. Chougule V.A. and Sapkale J.B. (2020). #Prioritization of watersheds based on morphometric characteristics of Achara basin, India using AHP technique.# *Disaster Advances*, 13(5), 62-70.

17. Schumm, S.A. (1956). #Evolution of drainage system and slope in Badlands at Perth Amoboy, New Jersey.# *Geological Society of America, Bulletin*, 67, 597-646.

18. Bull W. and McFadden L. (1977). #Tectonic geomorphology north and south of the Garlock Fault California.# In: *Geomorphology in Arid regions* (ed.) Doehring D O, Binghamton: State University of New York, 115–138.

19. Cox R. T. (1994). #Analysis of drainage-basin symmetry as a rapid technique to identify areas of possible quaternary tilt-block tectonics: an example from the Mississippi embayment.# *Geol Soc Am Bull*, 106, 571–581.