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ANALYSIS OF TILTING SIGNATURES OF THE KORADI NADI FOUND IN THE VICINITY OF THE PENGANGA RIVER BASIN.

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Abstract
The morphometric analysis of Koradi Nadi is carried out by tracing and digitizing the toposheet maps of Survey of India. The Koradi Nadi is a part of the Penganga River basin. The Penganga river is partially active with influence of nearby Kinwat and Kaddam faults. The study area has major three meso-watersheds and all of them falls right side with total area 281 Sq. km. of the present Koradi river and a macro-watershed with total area of 352.4 sq. km. The first hand geoprocessing bring out the linear, area, shape aspects and with this further analysis suggest the tilt when applied the geomorphic indices of active tectonics (GIAT).

Keywords: *Tectonics, Geomorphic indices, Morphometry, Geoprocessing, Koradi Nadi*

Introduction

The landscape evolves through series of modification of tectonically produced slopes by erosion, deposition, and the continued growth of structures, then drainage system adapts the changes in surface slopes. Drainages thus have potential to record entire history of evolution of folds, faults and its associated tectonically active structures. In the region of active tectonics, the landscape itself can lead to the existence of active structures mainly because of topography that has been resulted by its associated rates of erosion and deposition.

In recent days, Geographical Information System (GIS) along with Remote Sensing (RS) became very popular in analyzing and understanding the basin areas. The term GIS is defined by Department of Environment (DOE, 1987) as, "A system for capturing, storing, checking, manipulating, analyzing, and displaying data which are spatially referenced to the earth". To analyze recent geological deformation under most of watersheds, researchers nowadays considering the geomorphic indices for active tectonics as a powerful tool to evaluate the relationship between tectonics and development of basin under specified scale.

Generally, most of the landforms are dominated by the fluvial concentration which are sensitive to any activities if occurs. These activities are considered under deformations in ancient and recent times which are reflected in surficial expression in the form of drainage. All these drainage records the changes of deformations in recent times.

This study falls under the vicinity of Penganga river basin, which may be partially active due to nearby Kaddam fault (Sumeet 2021). This can be attributed to the tectonic deformations occurred in concerned areas. The detailed analysis of the current study is due respect to the morphometric analysis and its relation to tilting signatures along with Geomorphic indices.

Study area

The present Koradi Nadi macro watershed is a part of Penganga river which is located towards NW side towards the catchment of the Penganga River (Sumeet 2021). The extent of the Koradi Nadi traced in the four SOI toposheets is as 55d3, 55d7, 55d8 and 55d12. The Koradi Nadi flows from Bhalgaon to Yerandoli with total area of 358.4 sq. km. The perimeter of the basin is of 90.52 km. The area is entirely covered by Deccan basalt (DVB) of Upper cretaceous to lower Eocene age. The black cotton soil is generally found the vicinity which is the product of DVB. The average rainfall in the Buldhana district and the study area is of 764.1mm (IMD 2005) and shows very well developed but shifted main channels of dendritic drainage indicates somewhat tilt in the area (Fig.1).

Methodology

In the present study the SOI toposheets of scale of 1:50000 have been utilized for building the maps. All drainages are traced and vector analysis is followed and UTM projection is used for calculating the datasets.

The methodology adopted here considered the Koradi Nadi as one single macro watershed (Babar 2009) and from the main channel all of its connected meso-watersheds (Babar 2009) have been evaluated. The criteria applied to plot a watershed should have a minimum forth order. Based on such a criterion it has been found that most of its watersheds are falling under meso-watershed category (Babar 2009) which are meeting to the single branch of the Koradi Nadi. The names of each watershed are followed by SOI naming and whereas the names of remaining watersheds are adopted from nearby villages.

The morphometric parameters of the Koradi Nadi meso-watershed are given in Table 1. The remaining area and orders of the present study other than the meso watersheds are tabulated in Table 2.

Result and Discussion

The analysis has been carried out for the total 5 watersheds (Fig.2) with its all aspects in ordered of aerial, linear, shape. The stream ordering suggested by Strahler (1957) is used for the sake of its simplicity in the numbering the drainage networks. The highest stream order found in the Koradi nadi macro watershed is 6^{th} order. The morphometric analysis is applied on the study area and further its prime signatures have been taken under considerations for analysis of tilting. This analysis is further considered for Geomorphic Indices of Active Tectonics using Bifurcation ratio, Drainage Density, Stream frequency, Asymmetry Factor, and Elongation ratio.

A) Linear Aspects

Each drainage basin has the line segments in terms of stream ordering. The stream ordering is the first step in assessment of the stream which suggest hierarchic ranking of each stream. According to Strahler (1957) stream ordering system, each and every segments of the stream have been evaluated. The linear aspects are stream order (U), Number of Streams (Nu), Stream length(Lu), maximum basin length, bifurcation ratio, length ratio are given in the Table 1 and 4

1. Bifurcation Ratio (Rb)

The bifurcation ratio (Rb) is the ratio in between the branching pattern of the drainage network in the basin area. It is defined by Horton (1945) as, a ratio of a ~~no.~~ number of streams of the next higher order (Nu+1). This provides quantitative information of the stream network evolution (Tejpal et.al 2009). This reflects the degree of the consequences of the drainage network. (Horton 1945).

The formula expressed as,

$$Rb = \frac{N\mu}{N\mu+1}$$ where, Nμ= number of streams of a given order, Nμ+1 number of streams of next higher order.

The values lies between 3.0 and 5.0 (Table 4) shows no geological structure control on drainage development. The bifurcation ratio map of the area is given in (Fig. 3)

B) Aerial Aspects

The aerial aspect has been considered the stretch of the basin with respect to calculation of line as well as the area. The aerial analysis considered here is of Drainage density, stream frequency, asymmetry factor, which is given in Table 1 and Table 4 for macro- and meso-watersheds respectively.

1. *Drainage density (Dd)*

The drainage density is the relationship between total stream length and basin area. This shows the density of the drainages in the particular region. The drainage density is defined by Horton (1945) 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 value of drainage density between 0-2 is low Dd, which indicates highly permeable subsoil, 2.0-4.0 is medium drainage density indicating moderately permeable subsoil, while 4.0-6.0 is high Dd which indicates low permeable subsurface material (Singh 1998). The Dd values in the study region lies between 1.6 and 1.7 Km/Km^2 (Table 4) indicating high permeability of the soil. The drainage density map of the area is given in (Fig. 4)

2. *Stream frequency (Sf)*

The stream frequency is expressed as measure of the sum of total number of the streams and 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 (Singh 1998). The Sf values in the study region lies in 1.6-2.0 $Streams/Km^2$ indicating very poor stream frequency (Table 4). The stream frequency map of the area is given in (Fig. 5)

C) Shape Aspects

The shape aspects of the watershed and sub-basin is considered to be external form or outline of the basin or watershed. This shape aspect has evolved from the tectonic activity which further connected to circular shape to elongated. As more elongation of a shape of the basin suggest more tectonic activity. The shape aspects consider area and line in extent of the longest stretch.

1. *Elongation ratio (Re)*

The elongation ratio is shape and aerial morphometric variable, which gives 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.

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 (Bull and McFadden 1977). The Elongation ratio for the Koradi Macro watershed is 0.62 indicating moderately active, while in the meso watersheds the values range from 0.59 to 0.60 also indicating moderately active (Table 4). The elongation ratio map of the area is given in (Fig. 6)

2. *Asymmetry factor (AF)*

The asymmetry factor is aerial relationship in between left and right of the main 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 map of the study area is represented in Fig. 7.

The asymmetry factor is expressed as,

$$AF = 100\left(\frac{Ar}{At}\right)$$

Ar= area to the right of the trunk stream, At= total basin area

The value lies closer to the 50 suggests stable tectonic setting, whereas more or lesser the values than 50 suggests tilt which indicates active tectonic environments, lithological control, differential erosion (Cox 1994, El Hamdouni et. al. 2008). The value of asymmetry factor in the Koradi Macro watershed is 42.5 – 63.4 indicating the slight tectonic tilt (Fig. 8, Table 4)

Table 1

Koradi macro watershed									
Area Sq. km	358.4	**Rb 1/2**	4.373984	**Dd**	1.672182	**(u) No. of 1o**	537	**Lu 1o**	350.29
area HA	35843.79	**Rb 2/3**	5.347826	**Re**	0.589768	**(u) No. of 2o**	122	**Lu 2o**	135.98
Area RS Sq. km	281.96	**Rb 3/4**	4.6	**Fs**	1.930804	**(u) No. of 3o**	23	**Lu 3o**	58.87
Perimeter Km	90.52	**Rb 4/5**	2.5	**AF**	78.67188	**(u) No. of 4o**	5	**Lu 4o**	20.93
Max length Km	36.23	**Rb 5/6**	2	**∑Nu**	692	**(u) No. of 5o**	2	**Lu 5o**	15.87
				∑Lu	599.31	**(u) No. of 6o**	1	**Lu 6o**	15.37

HA = Hectare, RS = Right Side, Rb = Bifurcation ratio

Table 2

Koradi remaining order except 3 meso watersheds		**stream order**	**Nu**	**Lu**
∑total Area of meso-watershed Sq. km	189.389	**1o**	257	163.51
R A 123 o	169.011	**2o**	58	58.72
Area Total Sq. km	358.4	**3o**	8	15.73

Table 3

W.No.	**meso watershed**	**(u) No. of 1o**	**(u) No. of 2o**	**(u) No. of 3o**	**(u) No. of 4o**	**(u) No. of 5o**	**∑ of (Nu)**	**Area sq km.**	**max watershed length**
1	**Koradi Nala**	44	9	2	1		56	28.13	9.58
2	**Bhogawati**	165	41	9	2	1	218	106.76	19.56

	Nala								
3	**Deulgaon Mali**	72	15	3	1		91	54.49	13.88

W.No.	**meso watershed**	**1o total length**	**2o total length**	**3o total length**	**4o total length**	**5o total length**	**∑ of (Lu) Km**	**Area RS Sq. km**	
1	**Koradi Nala**	26.58	12.08	6.64	0.47		45.79	17.86	
2	**Bhogawati Nala**	109	43.72	21.5	7.44	9.4	191.36	60.03	
3	**Deulgaon Mali**	50.95	23.4	7.24	6.32		87.92	23.18	

Lengths in km

Table 4

Sr. No.	**Koradi Watersheds**	**Drainage Density (Dd)**	**Stream Frequency (Fs)**	**Elongation Ratio (Re)**	**Asymmetry Factor (AF)**	**Rb 1/2**	**Rb 2/3**	**Rb 3/4**	**Rb 4/5**
1	Koradi Nala	1.62	1.99	0.62	63.47	4.88	4.5	2	
2	Bogawati Nala	1.79	2.04	0.59	56.23	4.02	4.55	4.5	2
3	Deulgaon Mali	1.61	1.67	0.6	42.54	4.8	5	3	

Dd unit Km/Km^2 Fs unit $Streams/Km^2$

Conclusions

The map of Koradi nadi clearly depicts the shifted main channel of 6^{th} order stream shown in the location map. The development of the drainages is only due to right of the main channel. The asymmetry map also shows right dominating area of 281.96 sq.km. The development of the meso watershed towards right side also proves the same. The asymmetry factor in the meso watersheds is nearly tilted.

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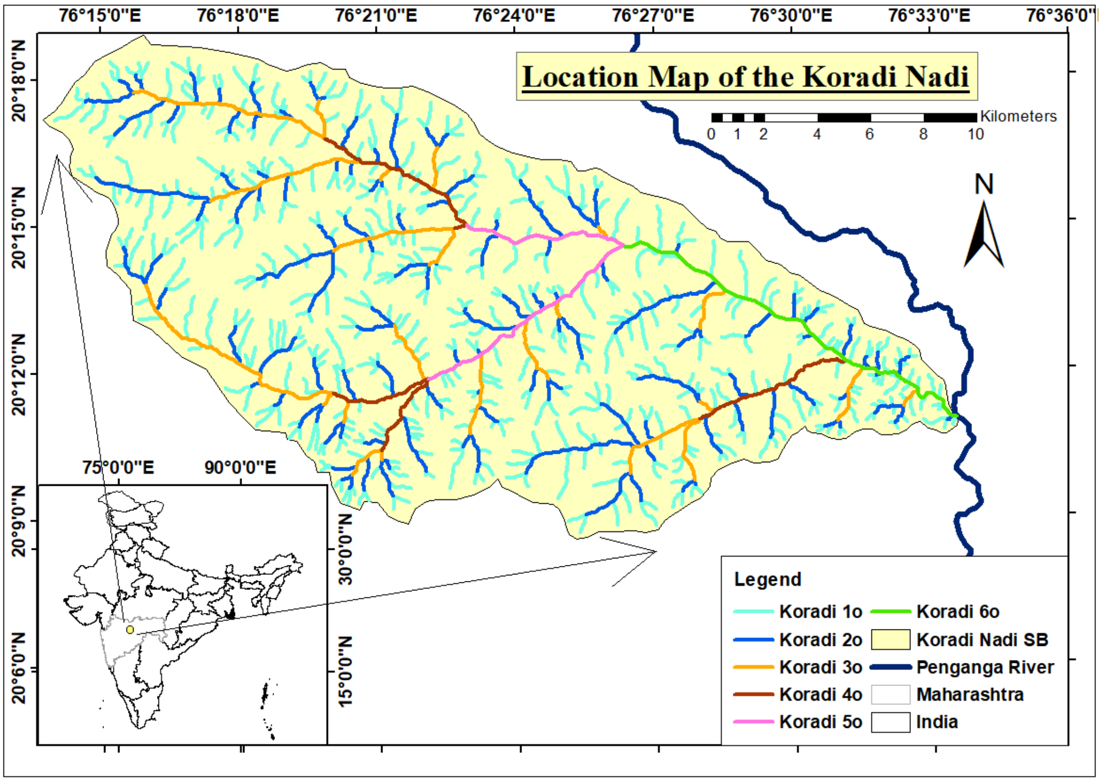

Fig. 1. Drainage and Location map of study area

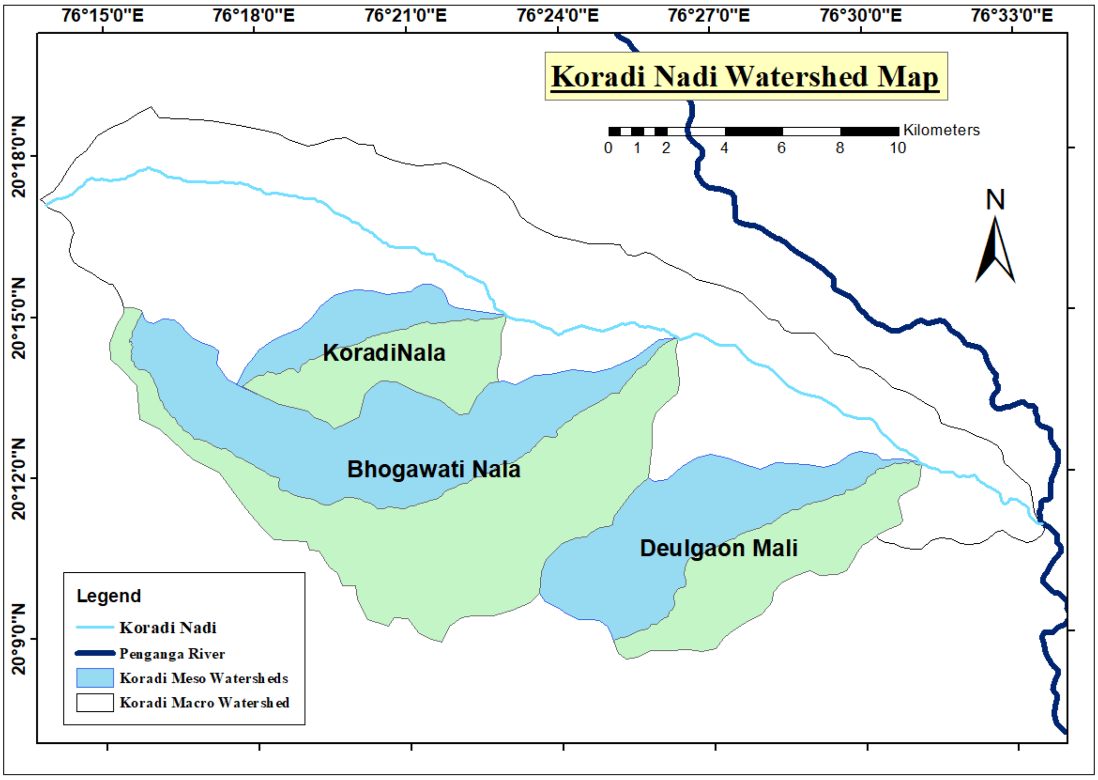

Fig. 2. Watershed map of the Koradi Nadi sub-basin

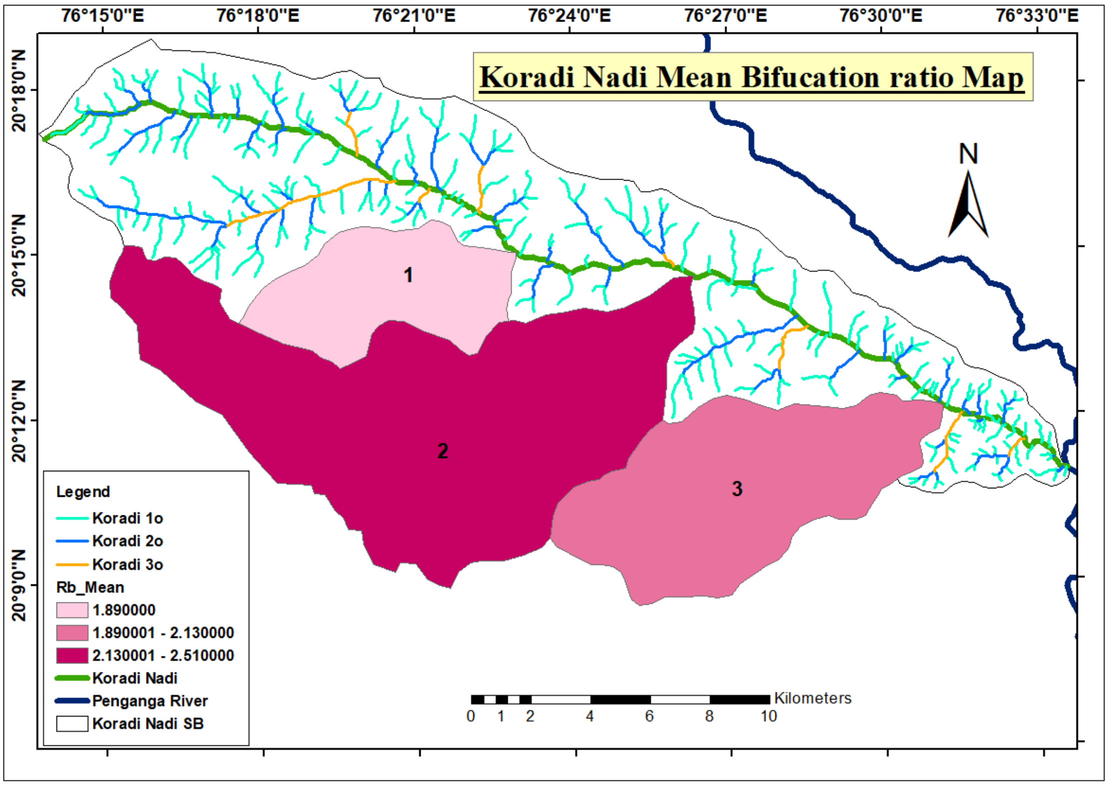

Fig. 3. Mean bifurcation ratio map of the Koradi Nadi sub-basin

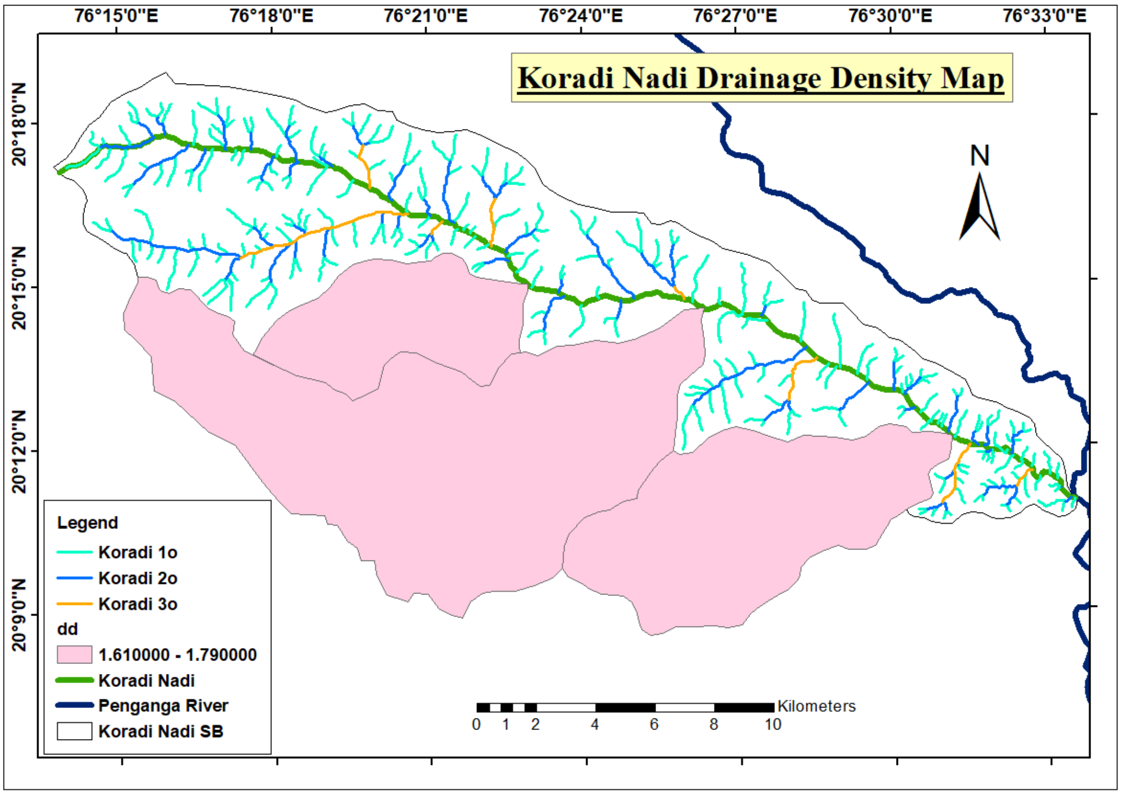

Fig. 4. Drainage density map of the Koradi Nadi sub-basin

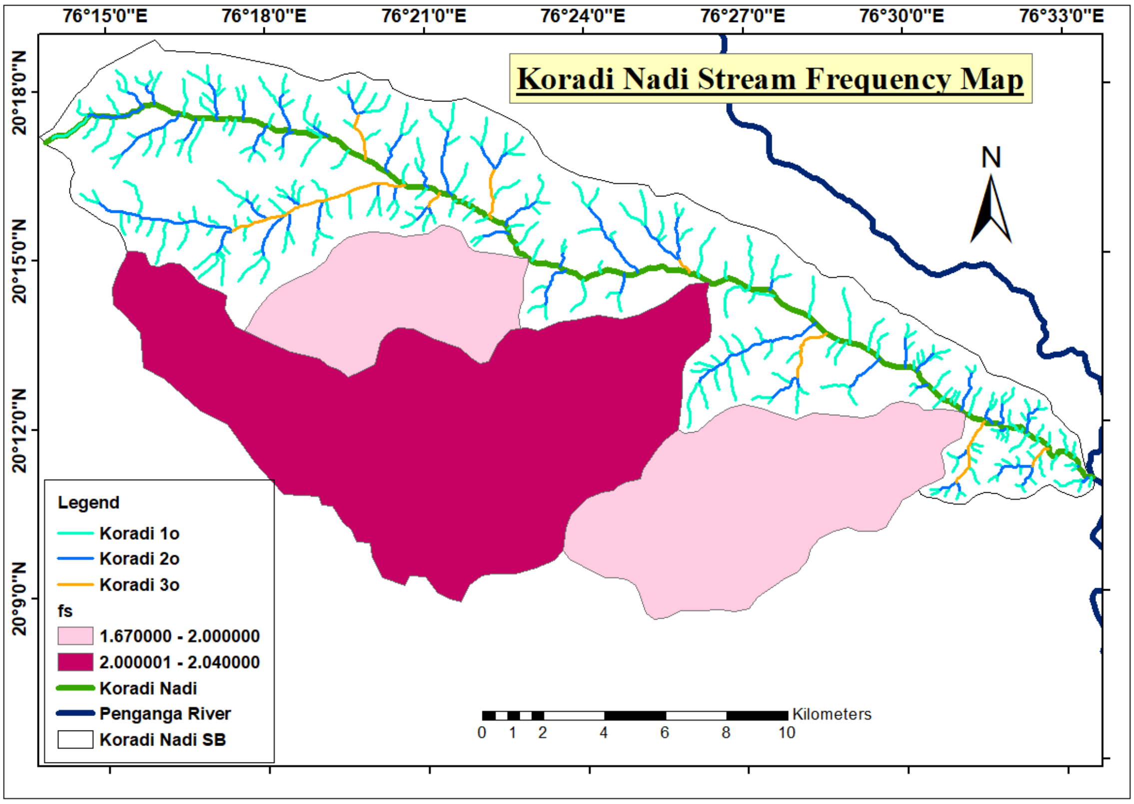

Fig. 5. Stream frequency map of the Koradi Nadi sub-basin

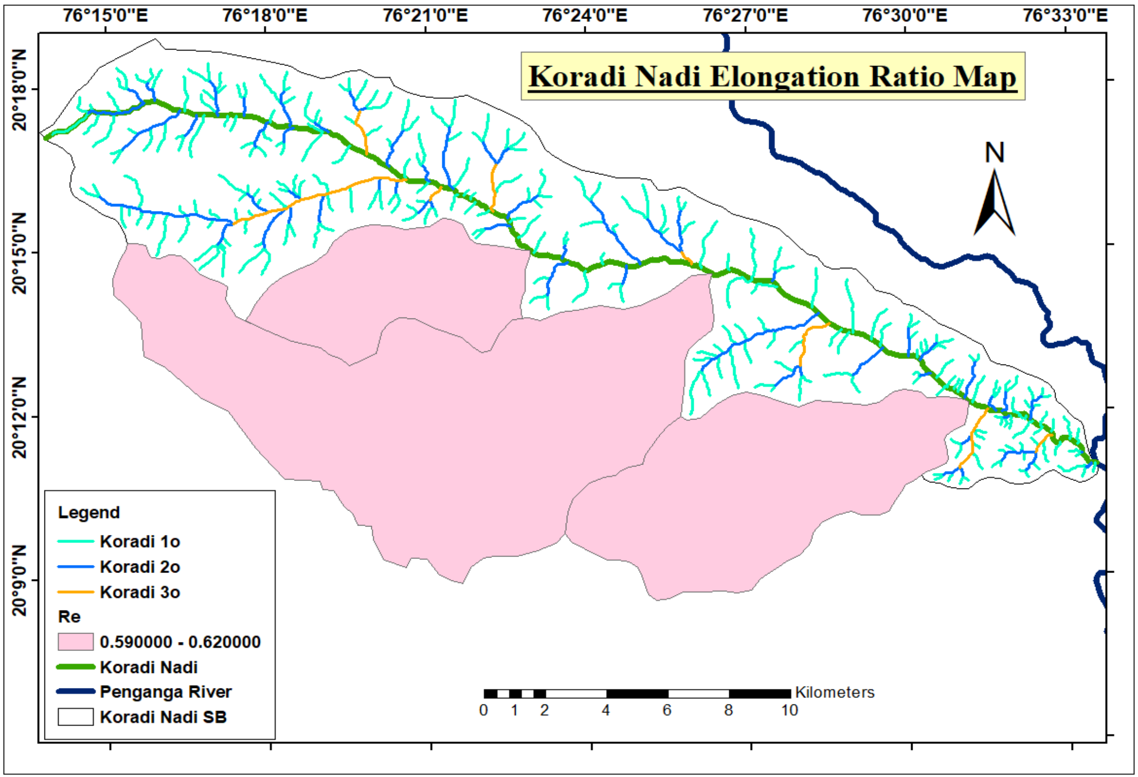

Fig. 6. Elongation ratio map of the Koradi Nadi sub-basin

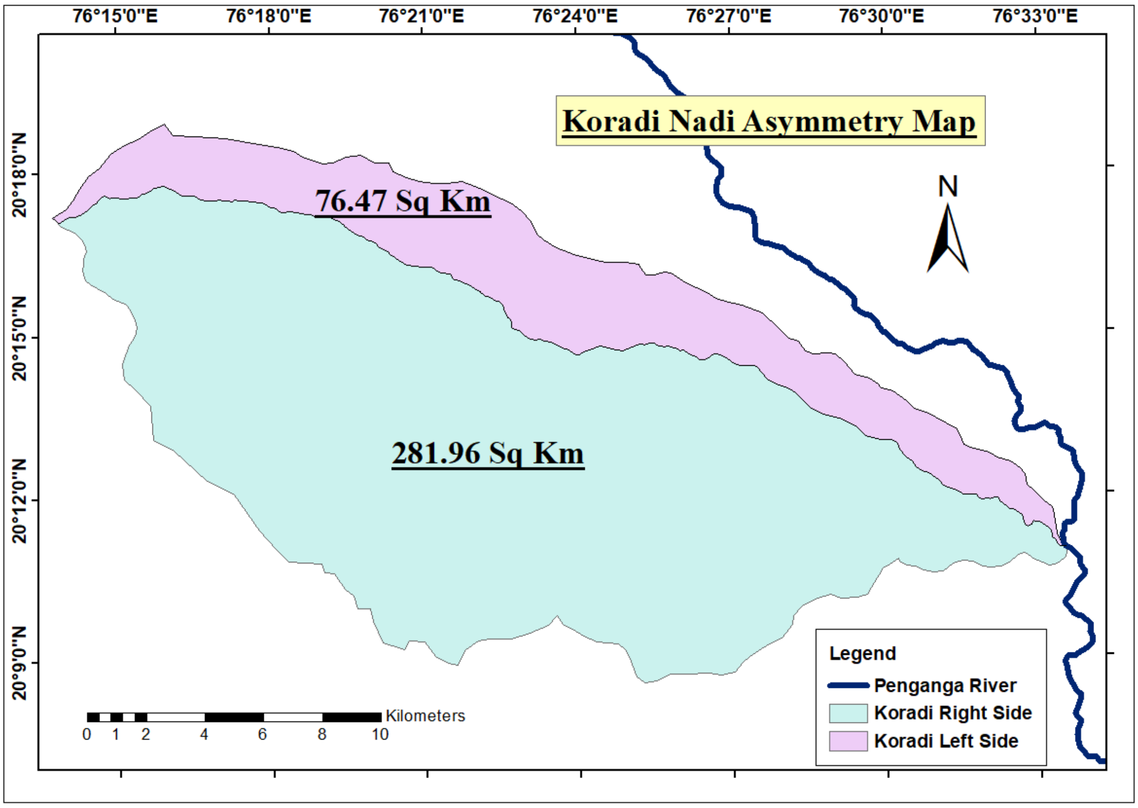

Fig. 7. Asymmetry map of the Koradi Nadi sub-basin

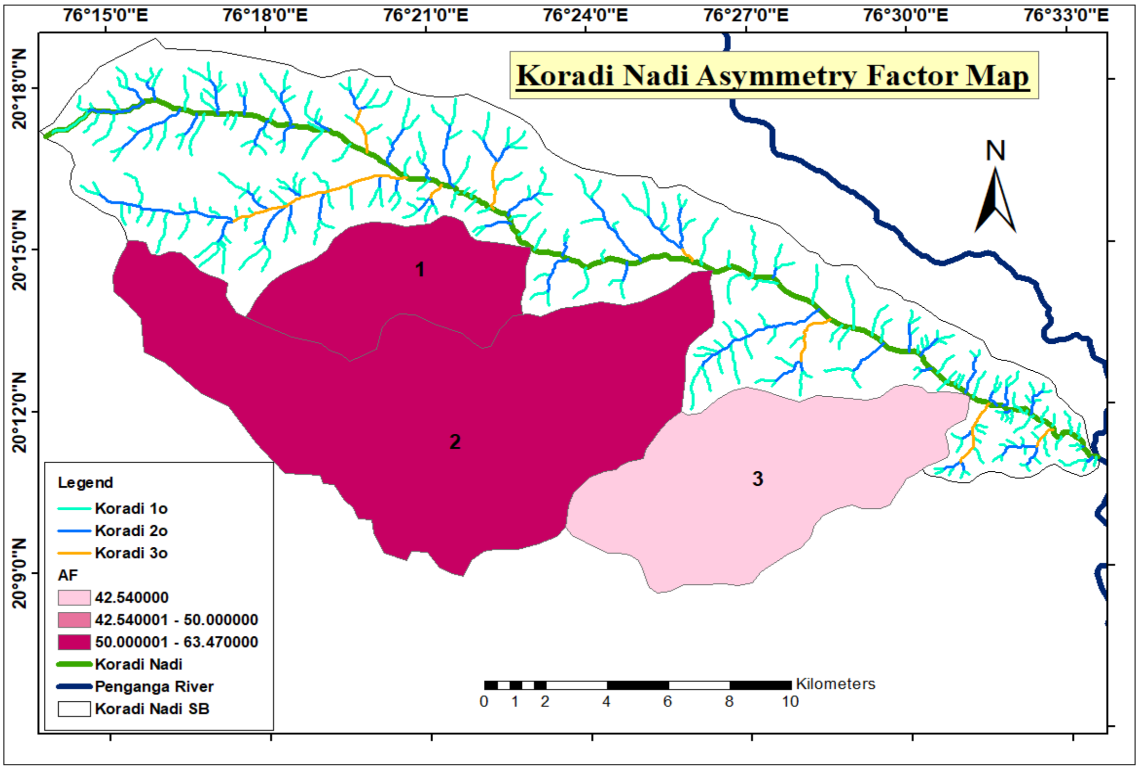

Fig. 8. Asymmetry factor map of the watersheds of Koradi Nadi sub-basins