Morphotectonic Analysis of Zuari River Basin, Goa (India)

Ms. Arati Panshekar
Govt. College of Arts, Science and Commerce Sanquelim Goa
Email- panshekar.arti@gmail.com

Abstract

In this study an attempt is made to evaluate and analyse morphotectonic, topographical and hydrological aspects of Zuari River Basin by using Remote Sensing and GIS. Morphotectonic indices such as Channel Sinuosity (S), the ratio of the width of valley floor to valley height (Vf), Asymmetry Factor (AS), Transverse Topographic Symmetry Factor (TTSF) Mountain-front Sinuosity (Smf) and Drainage basin shape (Bs) are assessed for ten sub watersheds of Zuari River basin. The study indicates that the drainage basin has insignificant tectonic influence on landscape evolution.

Keywords: Morphotectonics, Remote Sensing and GIS

Introduction

Landscape evolves and constantly modified by exogenetic and endogenetic forces of the Earth. Exogenetic forces are the external forces responsible for the weathering and erosional processes. Endogenetic forces involve tectonic movement of the Earth surface that modifies the fluvial systems. Tectonic Geomorphology deals with impact of tectonic base level fall of fluvial system (Dutta and Sarma, 2011). It describes the relationship between tectonic and ground surface processes that results in evolution of landscape (Burbank and Anderson, 2001). Sinuosity analysis helps us to know the impact of topography on flow pattern of the streams (Krishanu and Gopinath, 2015).

Morphotectonic analysis is a paramount tool to study landscape processes on the Earth surface (S. Boras et al, 2010). Morphotectonic refers to the study of landforms produced by tectonic activities. The extent of tectonic activities in the region is studied from several indices that help in assessing the tectonic influence thousand years ago. Papanikolaou et al. (1988) made first attempt to study morphotectonic indices for Asopos Basin by analysing drainage network and slope morphology with outcome that the basin has active tectonic control (S. Boras et al, 2010). The morphotectonic evaluation provides data for the seismic hazard assessment (Toudeshki and Arian, 2010). Although Zuari River basin is a part of shield zone with lesser or no tectonic activities, the attempt is being made to apply the morphotectonic indices to test the results.

Study area

The study area forms a part of Goa state in India which comprises Western Ghats, plateau region and alluvial plains. The latitudinal extent of the region is $15^0$00'00'' to $15^0$30'00'' north and longitudinal spread is from $73^0$45'00'' to $74^0$15'00'' east. It covers approximately 26% total area of Goa. The total length of the river is 69 km and it flow towards west attaining dendritic pattern. It originates in Barcem region of Western Ghats and drains it water in the Arabian Sea near Mormugoa. The region forms Dharwar group of Archaean to Proterozoic age consisting Vageri, Bicholim, Savordem and Barcem formation. Lithology of Vageri comprises metabasalt, Bicholim with banded ferruginous quartzite, maganiferous chert, breccias with pink ferruginous phyllite, limestone, quartz-chlorite-amphibole schist, Savordem with argillite, quartzite, tilloid, metagreywacke and Barcem with metagabbro, peridotite, talc-chlorite schist, variegated phyllite, quartz-chlorite schist, quartz-sericite schist etc.

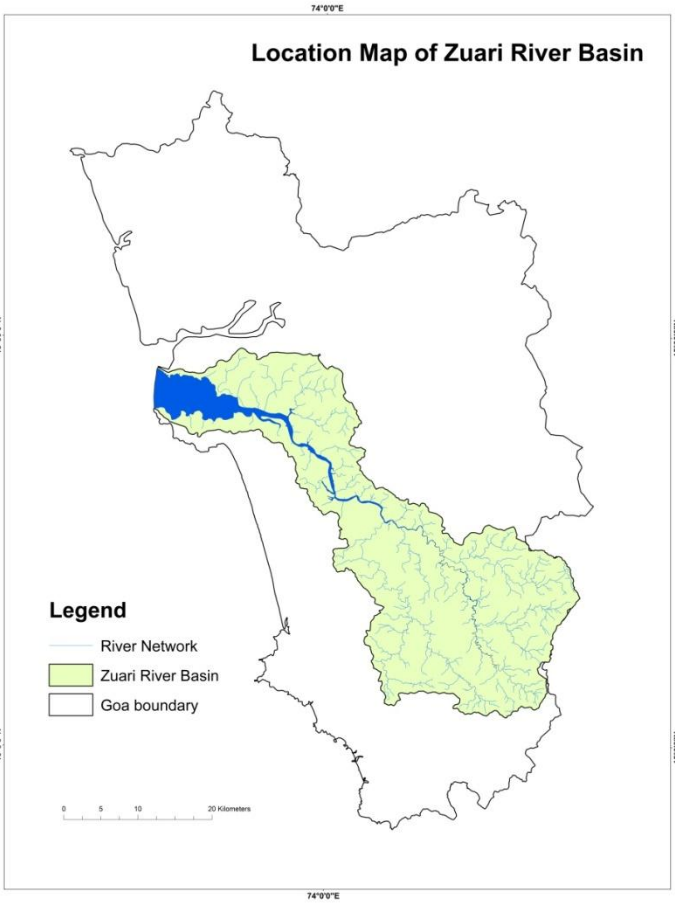

Fig 1

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Data and Methods

For the detail morphotectonic analysis topographical maps (48E/15, 48I/3, 48I/7, 48I/8, and 48I/4) with 1:50000 scales are processed in Arc GIS. These toposheets are rectified and mosaiced to get proper coordinates. All the streams are digitized and sub watersheds are delineated based on pattern and flow of the streams. The SRTM DEM with 30 meter resolution is also used to acquire elevation. Morphotectonic parameters are computed based on mathematical equations proposed by scholars.

Result and Discussion

The indices associated with the drainage basin such as Channel Sinuosity (S), the ratio of the width of valley floor to valley height (Vf), Asymmetry Factor (AS), Transverse Topographic Symmetry Factor (TTSF) Mountain-front Sinuosity (Smf) and Drainage basin shape (Bs) are calculated for the sub watersheds of the Zuari river basin. These indices are evaluated in order to understand relative variations and tectonic influence in the study area.

Table 1. Morphotectonic Analysis for Zuari River sub watersheds

SW/MI	S	Vf	AF	TTSF	Lmf	Ls	Smf	Bs
1	1.31	308	72.92	0.64	8.10	3.86	2.09	1.02
2	1.47	39.2	57.60	0.23	13.75	7.13	1.92	1.61
3	1.23	8.48	48.43	0.26	5.37	2.96	1.81	0.96
4	1.24	7.2	49.63	0.12	19.10	10.88	1.75	0.19
5	1.23	109.6	54.97	0.42	19.26	9.89	1.94	2.33
6	1.26	115.6	68.69	0.70	19.51	8.56	2.27	1.64
7	1.22	70.56	51.47	0.14	16.75	7.41	2.26	1.57
8	1.20	20.88	49.52	0.38	8.999	4.70	1.91	3.13
9	1.31	162.4	29.58	0.41	30.52	14.84	2.05	2.79
10	1.36	5.04	59.72	0.17	19.15	5.56	3.44	1.5

Sources: Calculated by author

*Sub watersheds (SW), Morphotectonic Indicators (MI), Channel Sinuosity (S), the ratio of the width of valley floor to valley height (Vf), Asymmetry Factor (AF), Transverse Topographic Symmetry Factor (TTSF), Length of Mountain Front (Lmf) , Straight Line Length(Ls), Mountain-front Sinuosity (Smf) and Drainage basin shape (Bs)

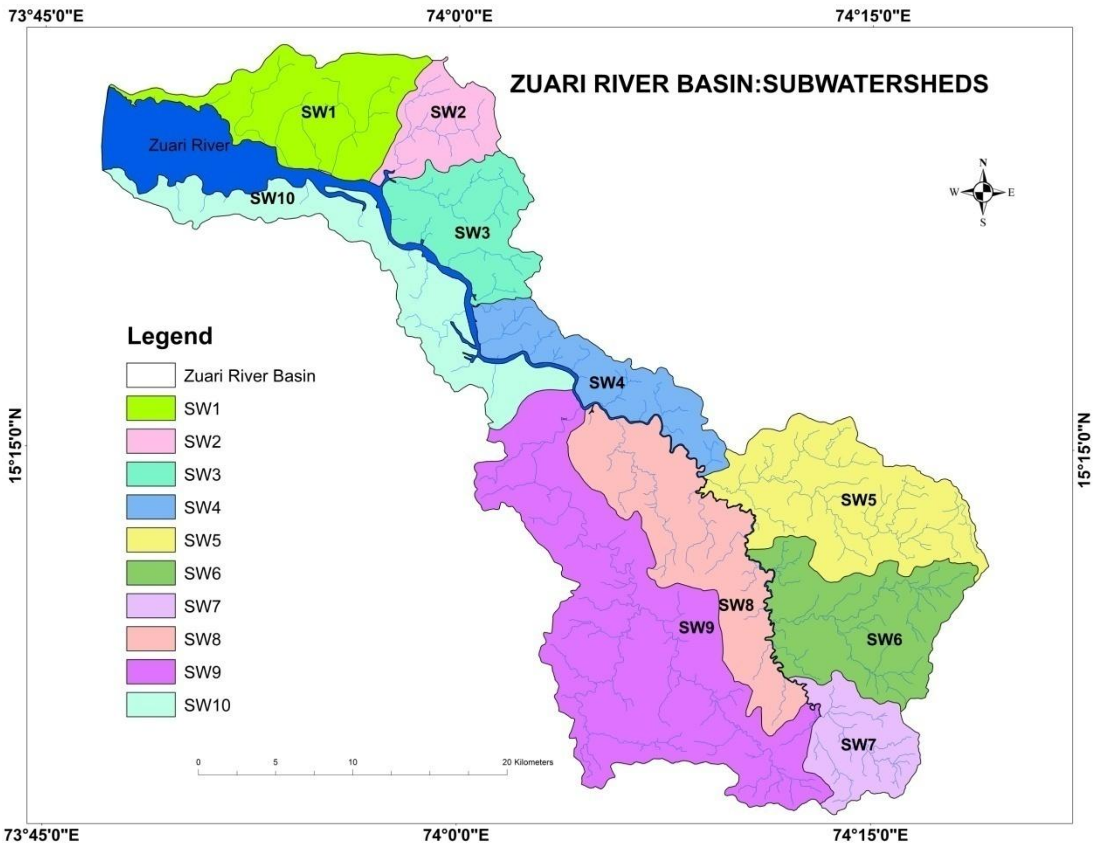

Fig. 2

1. Channel Sinuosity (S)

Channel Sinuosity is suggested by Muller (1968) is used to identify tectonic influence in the region. Rivers do not follow straight path due to geographical and hydrological factors. It helps in understanding impact of landscape characteristics on river course (Acharjee at el, 2017). This is calculated by;

$$S = SL/VL$$

Wherein, S is channel sinuosity, SL is stream length and VL is valley length

The value of S is 1 for straight course, between 1 to 1.5 sinuous course and more than 1.5 represents meandering course. The Sinuosity values for sub watersheds in the Zuari River basin vary from 1.20 to 1.47 which indicates that the channels of the streams are sinuous in nature which is due to lesser tectonic influence and few physical barriers along the course of the river.

2. The ratio of the width of valley floor to valley height (Vf)

The ratio of the width of valley floor to valley height (Vf) evaluates the degree of adaptation of drainage system into the landscape. It helps in understanding expansion and contraction of drainage on the ground surface along with the impact of tectonics. Higher values of the ratio of the width of valley floor to valley height indicates higher rate of uplift that causes streams to incise their valleys in order to keep pace with relative drop in base level. Lower values are the indication of base level stability for longer period that results in widening of valley floor with smaller valley height.

It is computed by;

$$Vf = 2Vfw/[(Eld - Esc) + (Erd - Esc)]$$

Wherein, Vf is width of valley floor to valley height, Vfw is the width of valley floor, Eld and Erd are the elevations of the left and right valley respectively and Esc is the elevation of the valley floor (Bull and McFadden, 1977).

The ratio of the width of valley floor to valley height (Vf) is calculated for 10 sub watersheds of Zuari River basin varies from 308 to 5.04. Higher value is attained for SW1 and SW9 that indicates broad valley with lower rate of upliftment and incision. The lower values are calculated for SW3. SW4, SW8 and SW10 which represents narrow valleys and active incision. Rest of the sub watersheds have moderate valley floor to valley height ratio.

3. Asymmetry Factor (Af)

This morphotectonic index, determined by Keller and Pinter (2002), provide quantitative results for the development of river basin under the influence of tectonic processes. It is assessed to determine the tectonic tilt of the basin. It is useful to examine the lateral tilt of the basin from its main course of the river. It is calculated by using following formula;

$$Af = 100\ (Ar / At)$$

Where; *Ar* is the area of a part of a drainage basin on the right side of main stream (looking downstream) and *At* is the total area of the drainage basin.

The normal AF value is 50 when the basin is not tilted that shows stable part of the earth surface. When the value is more than 50 it shows leftward tilt and below 50 represents rightward tilt of the basin.

All computed values of Af for ten sub watersheds shows considerable or slight deviation from the normal value that shows the tilt and asymmetric nature of the basin. Sub watersheds SW1 and SW2 have value more than 50 which indicate that the tilt is towards the left side and SW9 specifies the tilt towards right side of the basin. Rest of the sub watersheds have Af value closer to 50 indicating minor variation in tilt and symmetry.

4. Transverse Topographic Symmetry Factor (TTSF)

This quantitative index assesses the asymmetry of the basin, formulated by (Keller and Pinter, 2002). The main river forms a perfect symmetric basin and all streams flows uniformly from both the sides of the main stream if there is no tectonic influence with TTSF value 0 (S. Boras et al, 2010). The value from 0 to 1 represents intensity of the tectonic influence. The value approaching closer to 1 represents asymmetric nature of drainage basin (Jaan, et al, 2015). It is defined by;

$$\text{TTSF}=Da/Dd$$

Where; Da is the distance from the midline of the drainage basin to the midline of the active meander belt and Dd is the distance from the basin midline to the basin divide (Keller and Pinter, 2002)

SW1 and SW6 have TTSF value more than 0.5 that represents asymmetric nature of the sub watersheds. Rest of the sub watersheds have computed TTSF value less than 0.5.As most of the sub watersheds have lesser TTSF value, it can be inferred from the evaluation that the drainage basin is not influenced by tectonic activities.

5. Mountain-front Sinuosity (Smf)

This index is significant for the areas with higher mountain ranges especially with limestone region (S. Boras et al, 2010). It symbolizes the balance between erosional and tectonic impact (Keller and Pinter, 2002). Tectonically active mountain fronts are straight where tectonic activities are more prominent than erosion. Mountain front is highly tectonically active if Smf value is from 1 to 1.6, 1.6 to 3 represents less active zone and above 3 shows inactive section of the mountain front and old tectonic event (Pavlides, 2003). It is computed by;

$$\text{Smf} = \text{Lmf}/\text{Ls}$$

Wherein, Smf is the mountain front sinuosity, Lmf is the length of the mountain front along the bottom of the mountain and Ls is the straight line length of the mountain front (Keller and Pinter, 2002).

The computed values of Smf for all the sub watersheds are more than 1.6 which indicates that the basin in inactive in terms of tectonic activities.

6. Drainage basin shape (Bs)

Drainage basin shape represents hydrological behaviour of the basin. High Bs index represents active tectonic zone and lesser value indicates dormant tectonic activities.

It is calculated by;

$$Bs = Bl / Bw$$

Wherein, Bs is drainage basin shape, Bl is the length of the basin, measured from its outline to the most distal point in the drainage divide, and Bw is the width of the basin.

All the sub watersheds have lower Bs value that shows lesser impact of tectonic activities in the basin.

Conclusion

The study demonstrates the applications of Remote Sensing and GIS in delineating river sub watersheds and evaluation of morphotectonic parameters. Based on calculated parameters it is clear that the Zuari River basin has a lesser tectonic influence on its drainage system. Channel Sinuosity (S) shows that all the streams in the ten sub watersheds are sinuous in nature with lesser incision and meandering course. The ratio of the width of valley floor to valley height (Vf) proves that SW1 and SW9 have broader valleys with lower rate of incision and uplift. Rest of the sub watersheds have narrow valleys with possibility of higher incision.

Asymmetry Factor (Af) clearly symbolize that all the sub watersheds are not symmetric in nature as the Af value deviates from the 50. TTSF values for all the sub watersheds evidently signify the lesser impact of tectonic activities in the basin. Smf and Bs values for sub watersheds noticeably indicate inactive basin in terms of tectonic activity.

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