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Morphometric Analysis of Mithmumbri- Malvan Area, Sindhudurg District, West Coast of Maharashtra, India

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Abstract

Morphometric analysis has been carried out from the Mithmumbari to Malvan area, Western part of Maharashtra in Sindhudurg district, India. The morphometric analysis is carried out in fourteen drainage basins, *viz.*, Achra, Pyali, Golvan, Mithmumbari, Katvan, Kamtakhudi, Gavaliwadi, Kunkeshwar, Kandalgaon, Munge, Malvan, Masura, Belachiwadi and Tambalwadi. The morphology of these basins is governed by a number of drivers including tectonic processes mainly the Vijaydurg fault, Mithbav fault, Malvan fault and lineaments, climate and lithology that influence the river system over a range of timescales. The majority of the basins are highly dissected and structurally controlled. The drainage density is low, with moderate to steep slopes within the elongated basin. The Achra, Pyali, Golvan, Gavaliwadi, Kandalgaon, Munge and Malvan basins are structurally controlled. The lower values of length of overland flow in study area reveal that stream erosion is more dominant than sheet erosion. Achra, Pyali, Mithmumbri, Golvan and Malvan basins are higher stream power, which represents higher erosion of the basin indicates high river basin management measures. Achra, Pyali, Golvan, Katvan, Kamthakhudi, Gavaliwadi, Kunkeshwar, Munge, Masura, Belachiwadi and Tambalwadi basins are rapid uplift stage of the basin. The Achra, Pyali, Golvan and Kamthakhudi basins can be inferred as SSW tilting in response to tectonic tilt. The hypsometric analysis shows eight basins (Achra, Pyali, Mithmumbari, Kamtakhudi, Kunkeshwar, Gavaliwadi, Belachiwadi and Tambalwadi) under the mature stage, five basins (Katvan, Munge, Kandalgaon, Malvan and Masura)in the youth stage and one basin (Golvan) under the old stage. The mature stage drainage basins show significant incision and entrenchment as a result of the Late Quaternary upliftment of the study area. The stages of drainage basins development in the western part of Maharashtra thus identify tectonically active and quiescent phases.

Keywords: Morphometric and Hypsometric Analysis, Structural Control Basin, RS-GIS, Sindhudurg District, West Coast of Maharashtra

Introduction

Morphometric and hypsometric analysis are important aspects of planning and sustainable development of management programs of the river basin. The planning and implementation of various development activities such as soil and water conservation and erosion control measures are quite necessary (Bagyaraj and Gurugnanam, 2011). The morphotectonic indices such as asymmetry factor, transverse topographic symmetry factor, stream length gradient index, mountain front sinuosity index and ratio of valley floor width to valley height as a reconnaissance tool in order to determine the relationship between tectonics and the drainage morphology of Rietspruit Sub-basin, South Africa (Rimuka Dzwairo *et al.,* 2024). The geomorphic indices of active tectonics on both sides of the Western Ghat rivers of Maharashtra havebeen uplifted and tectonic deformation from Tertiary to recent times (Kale and Shejwalkar, 2008).The coastal region of Maharashtra was tectonically active during Miocene-Pliocene epoch (Tandale, 1993).

The evolution of the Western coast of India is the rifting events beginning with Late Jurassic-early Cretaceous breakup of Gondwana land and subsequent Late Cretaceous separation of Madagascar (88 Ma) (Storey *et al.,* 1995). The present Indian margin formation was the result of a ridge jump which detached India from the Seychelles at the time of the Deccan volcanism (Norton and Sclater, 1979; Chandrasekharam, 1985). The Western Ghats form the main drainage divide of Peninsular India. The easterly flowing rivers mainly Godavari, Krishna and Bhima originates at the Ghats and debouches to Bay of Bengal, while Konkan rivers mainly Vaitarna, Kundalika, Savitri, Vashishti, Shastri, Vaghotan, Kharda, Achra, Gad and Karli meet the Arabian sea. The asymmetry of continental scale drainage pattern is not unique to Western Ghats, India, comparable examples in southern Brazil (Parana) and southeast Africa (Karoo) (Cox, 1989), contend that the initiation of such drainage pattern was a result of the dynamic plume uplift before continental rifting (Widdowson, 1997). The Panvel Flexure is a regional monocline dipping towards

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the west (2 to 15°) and formed 63-62 Ma (Sheth and Pande, 2014) by rifting India from Seychelles. The Panvel flexure has a post-rift extensional fault comprising of tilted fault block (Desai and Bertrand, 1995).The west coast fault was a passive continental margin active during Triassic-Jurassic and reactivated during the Cretaceous-Early Paleocene (Biswas, 1987). The NNE trending strike-slip fault zone has been confirmed near Koyna region (Gupta *et al.,* 1999). Koyna fault and the West Coast fault follow the Dharwar foliation trend (Gombos *et al.,*1995). Geophysical and remote sensing studies identified faults in the Deccan traps (Harinarayan, *et al.,* 2007, Chandrasekhar *et al.,* 2011). The faults are concentrated in the rifted zone, viz, Narmada rift zone, Cambay rift and west coast passive margin (Kumar *et al.,* 2011).Kurduwadi lineament is a deep crustal shear zone in the sub-trappean Precambrian rocks comprising NW-SE dextral faults (Peshwa and Kale, 1997).The NW-SE/NE-SW minimum compressive stress in the Kalsubai sub-group and Lonavala, Wai and Salsette Subgroups a N-S direction (Mishra *et al.,* 2014). The NE-SW and NW-SE with some N-S strike-slip faults/brittle shear zones, deformation zone as the Western-Deccan Strike-slip zone (Mishra *et al.,* 2014). Srinivasan (2002) demonstrated the westward downthrown of a series of N–S trending faults in Konkan area and inferred that, faulting in these parts is of post-Deccan Trap age and not related to its eruptive history. The recent structural studies in this sector have demonstrated the presence of regional fracture zones that have modified and controlled drainage development in this coastal tract (Kundu and Matam, 2000). The studies in the Koyna-Warna Seismic Zone indicated the presence of a major regional shear zone from the Precambrian basement, namely the Chiplun-Warna Lineament (Kale *et al.,*2014), which extends further inland as key structural elements in this seismic zone (Rajaram *et al.,*2017; Arora *et al.,*2018). The Malvan coastal strip has been faulted in NW-SE direction about a length of 30 km (Hanamgond and Mitra, 2008). All these features suggest that buried structures in the Precambrian basement beneath the Deccan Traps have been reactivated during the Quaternary and have controlled the local landscape evolution in this rocky coastal belt.

Most of the Konkan rivers originated within the Western Ghats escarpment, which are seasonal and fast flowing in their upper reaches due to the gradient difference between the Ghats and the plain areas near the Arabian Sea. The rivers are responsible for carving out the hinterland and their flow is greatly influenced by the gradient and tectonics of the area. All the rivers of the Konkan region of Maharashtra flow from east to west and finally debouch to the Arabian Sea. These westerly flowing rivers have graded course at the origin and estuarine environment towards the mouth. The geomorphological evolution of the Konkan coastal belt and adjoining Sahyadri uplands resulted into episodic cymatogenic uplift during Quaternary period (Powar, 1993).

The development of geomorphic features in relation to the neotectonics and evolutionary model of the Maharashtra coast is based on the geomorphic characteristics and tectonic elements of the coastal tract (Sukhtankar, 1989). The Velas coast, Maharashtra is upliftment due to the neotectonic activity and the change in sea level which is evident in elevated lignite beds (Rajshekhar and Kumaran, 1998). The digital elevation data (SRTM) used and reported the east-facing escarpment is approximately 25 km NW-SE trending Vijaydurg Fault (Gaur and Bilham, 2012).The Western Ghats are a global hotspot and significant biological diversity and many endemic species of flowering plants, fish, amphibians, reptiles, birds, mammals and invertebrates occurred (Selvaraj, 2002). It is also important to domestic plant species such as pepper, cardamom, Alphonso mango and jackfruit. The paleo sea-level evidences through lignite occurrence at Konkan coast. The carbonaceous, grey bluish clay occur sporadically along the Konkan coast, the carbonaceous clays and lignite are highly fossiliferous and yield both micro and megafossils of different ecological complexes ranging from terrestrial to aquatic environments. The pneumatophore associated lignite indicates a higher sea level strand along the west coast of India during Late Neogene (Mio-Pliocene) (Kumaran *et al*., 2004).The quantitative morphometric analysis and prioritization of Upper Shimsha watersheds of Karnataka state, studied soil erosion susceptibility using Fuzzy analytical hierarchy processand compound parameter analysis method (Shantha Kumar *et al.,* 2024). Magesh *et al*. (2011) studied the morphometric evaluation of Papanasam and Manimuthar watersheds of Western Ghat, Tamilnadu and inferred effect of rainfall on the development of stream segments in the watersheds. The morphotectonic studies along the coastal tract between Dabhol and Jaigarh Creek signify geomorphic evolution in relation to neotectonic activity (Herlekar and Sukhtankar, 2011).

Morphometric parameters as a reconnaissance tool in order to determine watershed prioritization for soil erosion risk in Upper Jhelum catchment, India may help in sustainable management of natural resources (Rayees Ali, *et al.,* 2024). Morphometric studies of Jog River Basin and its geomorphic evolution are controlled by neo-tectonic activity that affected the Jog basin, West Coast of Maharashtra (Herlekar and Wavare, 2014). The morphometric and morphotectonic analysis with the field study within the Wan river sub-basin of Amravati district, Maharashtra revealed a significant role of active tectonics (Masurkar *et al*., 2019).The morphometric analysis of Harnai to Kolthare watersheds along the Ratnagiri district exhibits the majority of drainage basins are structurally controlled (Kamble *et al*., 2019). The morphometric analysis of WGKD sub-watershed in Sati Watershed, Wainganga catchment of the Godavari basin exhibits moderate to low infiltration rate and high runoff conditions with high erosion activity (Kale and Deshmukh, 2020). In many parts of India as well as in the world of micro, mega and sub-watershed studies have been of broad significance for groundwater exploration (Choudhari *et al.*, 2018; Lamsoge *et al*., 2019). The morphometric and hypsometric analysis has been carried out in the Markandeya River basin significant erosional stages and structural control (Herlekar *et. al*., 2020).

The main objectives of this work is a detailed morphometric and hypsometric analysis for the fourteen drainage basins of the coastal region Sindhudurg district, Maharashtra and discuss their characteristic features using remote sensing (RS) and GIS approach.

Study Area

The area selected for the present study extends from Mithmumbari to Malvan, Sindhudurg district, western part of Maharashtra, India (Lat. 16°, 05' 21.22" to 16°, 21' 53.65" N, Long. 73° 22' 16" to 73° 43' 21.44"E). The study area is part of the Survey of India topographic sheet numbers 47H/7,47H/8, 47H/11 and 47 H/12 (scale 1: 50,000) (Fig. 1). A variety of fluvial landforms have been developed and identified in the study area to represent erosional and depositional features. The ground truth has been carried out after studying the topographic sheets and satellite

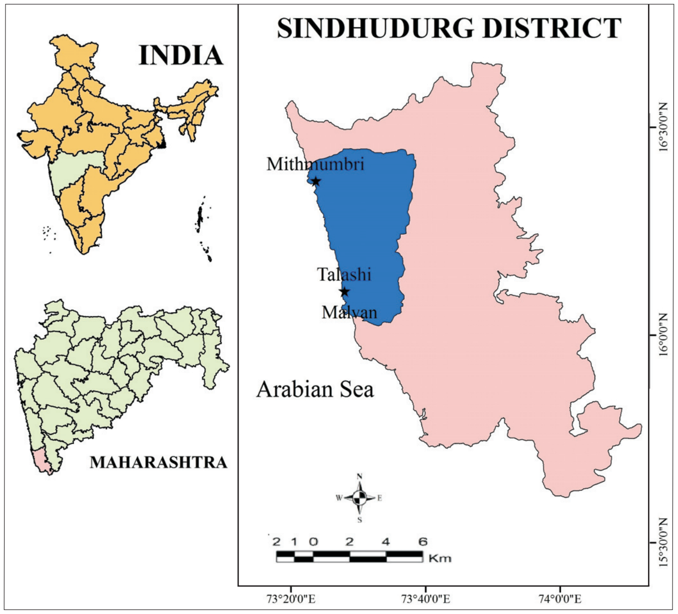


Fig.1. Location map of Mithmumbri to Malvan Area

imagery (IRS-R2) that revealed the study area has rugged topography. The drainage pattern of the study area is mainly dendritic, parallel, reticulate and rectangular pattern.

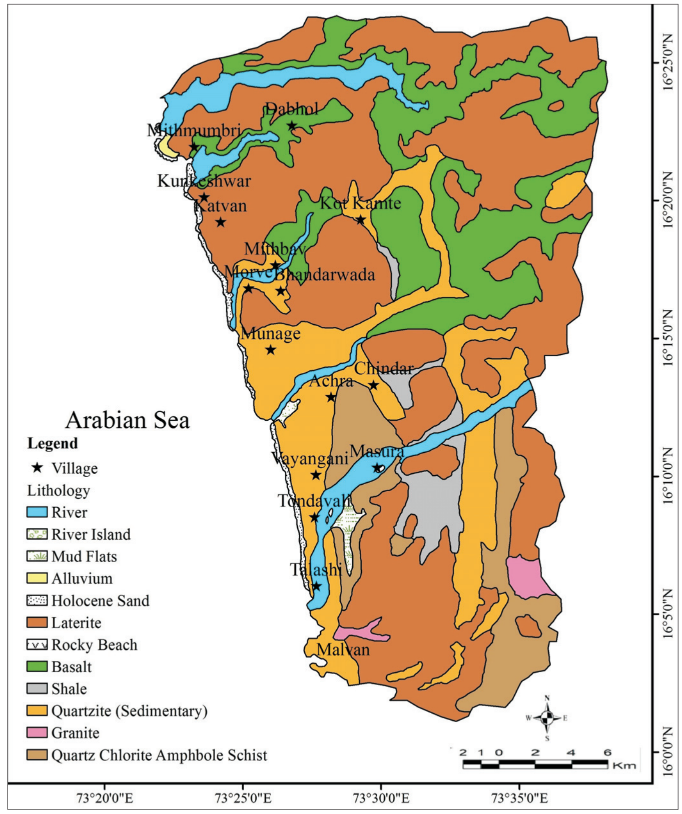


Fig.2. Geological map of Mithmumbri to Malvan Area.

Geological Setting

The geological constituents of the study area are mainly Archean to Recent in age. Wilkinson (1871) was the first to carry out geological fieldwork in this area. The Kaladgi Supergroup of rocks are scattered all over the study area and are represented by quartzites, shales, sandstones and conglomerates. They are characteristically found as inliers since they are separated from one another by the Deccan traps (Sarkar and Soman, 1983). The Deccan trap basalts are seen to overlay Archean and the Kaladgis are exposed along a few isolated patches atMithmumbri, Pyali, Achra and Golvan basins (Fig. 2). The Deccan traps basalt and other formations, at all other places, are covered by thick beds of laterites. The Kaladgi quartzite is exposed at Mithbav, Achra and Morve, which exhibit large fluctuations in dip intensity and direction. These rocks are bounded on the east by a major NNW-SSE trending Mithbav fault zone (GSI, 2001).

The metaconglomerate - quartzites are exposed from North of Malvan more than 10 km along the coast. Near Nivti the rock exposures are found to be 70°-80° steeply bedded in SW or NE directions. At Malvan, the same exposures exhibit a dip of around 20° towards NNE. A major NNW-SSE trending fault zone binds these sections towards the east (Sarkar and Soman, 2010). Along the coast of Malvan, well developed close spaced fractures and slickenside surfaces are observed. The Kaladgi quartzites are exposed about two km along the coast parallel from Mithbav in the north to Bhandarwada in the south. Near Mithbav in the west, the exposures are found to be steeply bedded to around 60° to 70° in the NE direction. A major NNW-SSE trending fault zone, along these quartzites, shows crushing, granulation, recrystallization and emplacement of quartz veins (Fig. 3; Fig. 4A-F). The study area also contains metasediments belonging to Dharwar Supergroup and Pleistocene to recent sediments. In the southern part of the study area, Dharwar Supergroup is mainly represented by mica-gneiss, garnetiferous mica gneiss, hornblende gneiss, quartz chlorite and amphibole schist, quartzites and granites which are exposed in Golvan Basin (Sarkar and Soman, 1983). The deep gorge of the main westward flowing Pyali River, deep entrenchment and knick points indicate a relative fall in base level in the Late Quaternary period. The base-level fall and streams adjust the profile from sea level to upstream (Fig. 5A-B). The Deccan trap basalt flows belonging to Upper Cretaceous to lower Eocene age and the recent Pleistocene Formations (laterite, sand, soils and alluvium) occur along the coastal tract.

Materials and Methods

The data generation for the basin analysis of the Mithmumbri to Malvan area has been carried out using Shuttle Radar Topographic Mission (SRTM) data with 90m resolution downloaded. The drainage network has been generated by hydrological and spatial analyst tools in ARC GIS-10.3 software and registered to Survey of India (SOI) toposheets number 47H/7, 47H/8, 47H/11 and 47H/12 (1:50,000). The various morphometric parameters of drainage basin have been carried out using various formulas (Table 1). The basin has been generated using SRTM through basin tool in spatial analyst (Rai *et al.,* 2017). The study area has been subdivided into fourteen basins, based on the stream arrangement and minimum third order basins considered for quantitative analysis. The SRTM data has been used for extracting drainage and delineating the basin. GIS software was used for topology construction of the drainage layer and calculation of drainage density, stream frequency, bifurcation ratio, circularity ratio, form factor, elongation ratio, length of overland flow and

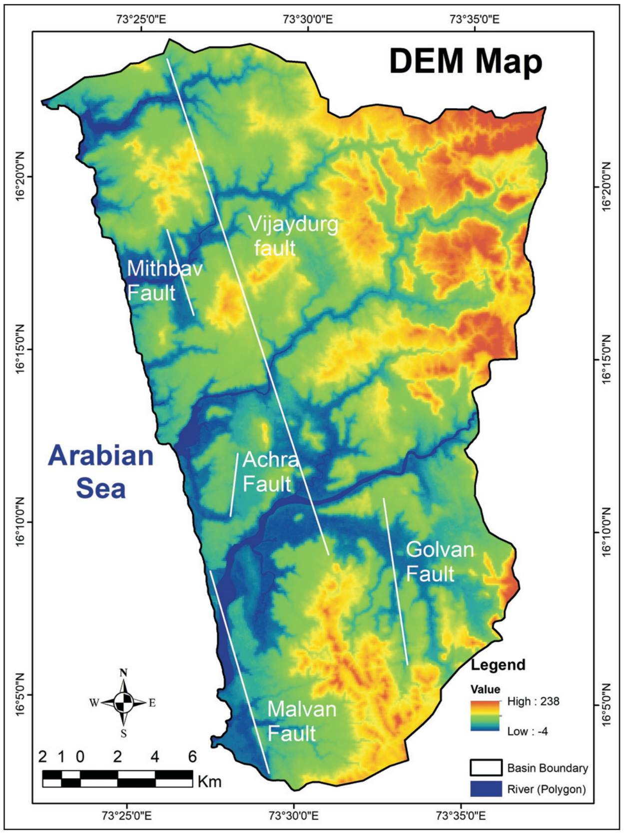


Fig.3. Physiographic map showing Mithbav, Malvan, Achra and Vijaydurg fault of Mithmumbri to Malvan Area.

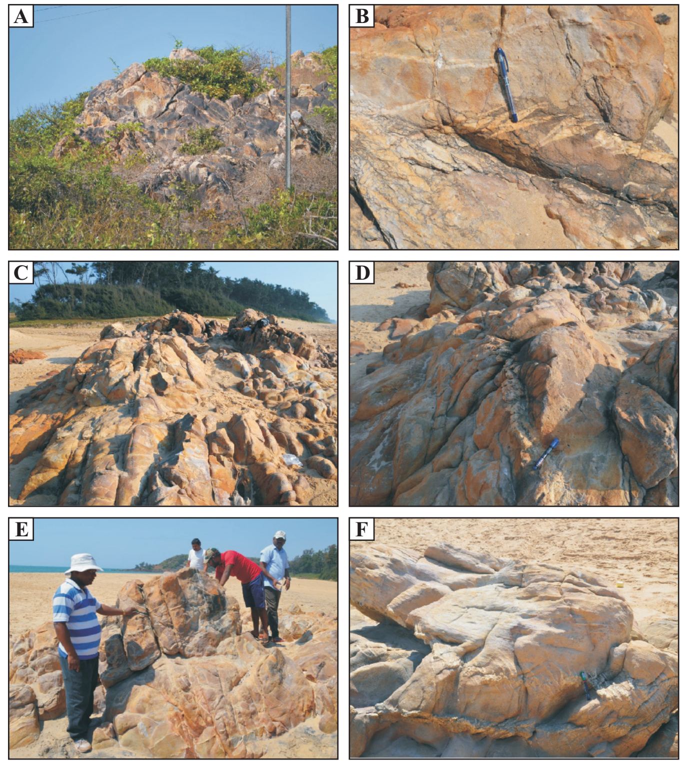


Fig.4. Field photographs, A) Kaladgi quartzites near Mithbhav exhibiting steep dips of 60 to 70°, B) Emplacement of quartz veins along N-S trending, C) Closely spaced joints in Kaladgi quartzites along N-S trend, D) Emplacement of Silica veins along N-S trend, E) Closely spaced fractures in Kaladgi quartzite along N-S trend, F) Emplacement of quartz veins along N-S trend.

Table 1: Morphometric parameters of drainage network and their mathematical expressions

Sr. No.	Morphometric parameters	Formulae	References
1	Stream order (U)	Hierarchical rank	Strahler (1964)
2	Stream Number (Nu)	Nu=N1+N2+…. Nu	Strahler (1964)
3	Stream Length (Lu) Kms	Lu=L1+L2+…Lu	Horton (1945)
4	Bifurcation ratio (Rb)	Rb=Nu/Nu+1 Nu=Stream Number Nu+1= number of the segments of the higher order	Horton (1945)
5	Drainage density (Dd)	Dd=Lu/A, Where, Lu=Stream length, A= Basin area	Horton (1932,1945)
6	Stream frequency (Fs)	Fs=Nu/A, Where, Nu=Stream Number, A= Basin area	Horton (1932,1945)
7	Drainage Texture (T)	T=Dd*Fs, Where, Dd= Drainage density and Fs= Stream frequency	Smith (1950)
8	Elongation ratio (Re)	Re=(2/Lb) $(A/\delta)^{0.5}$; Where, Lb= Basin length A= Basin area	Schumm (1956)
9	Circulatory ratio (Rc)	Rc=$4\Pi A/P^2$Where, A= Basin area, P= basin perimeter	Miller (1953)
10	Form factor (Ff)	Ff= A/Lb^2, Where, A= Basin area, Lb= Basin length	Horton (1932)
11	Length of Overland flow (Lg)	Lg=1/2Dd, Where, Dd= Drainage density	Horton (1945)
12	Constant of channel maintenance (C)	C= 1/Dd, Where, Dd= Drainage density	Schumm (1956)
13	Basin relief (R)	R=H-h	Hadley and Schumm (1961)
14	Relief ratio (Rr)	Rr=R/Lb, Where, R= Basin relief Lb= Basin length	Schumm (1956)
15	Sinuosity Index (Si)	Si=Cl/Vl, Where, Cl= Channel Length Vl= Valley length	Mueller (1968)
16	Hypsometric Integrals (Hi)	Hi= Sbm-h/H-h ; Where, sbm=Mean slope of the basin	Strahler (1952)
17	Dissection Index	Dis = R/ Ra ; Ra= Absolute Relief	Singh and Dubey (1994)
18	Stream Power Index (SPI)	SPI=$A_s \tan\beta$; Where, As= the specific catchment area, β= Slope gradient in radians	Moore *et al.* (1993)
19	Ratio of Valley Floor Width to Height	VF=2Vfw/(Eld-Esc)+(Erd-Esc) ; Where Vfw=width of valley floor, Eld and Erd= elevations of the left and right valley divides respectively, Esc=elevation of the valley floor	Bull and Mcfadden, (1977)
20	Asymmetry Factor	AF=100(Ar/At) ; Where, Ar=area of the basin to the right of the trunk stream, At=total area of the drainage basin	Hare and Gardner (1985)
21	Transverse Topographic Symmetry Factor (T)	T= Da/Dd ; Where, Da= the distance from the midline of the drainage basin to the Midline of the active meander belt, Dd= the distance from the basin midline to the basin divide	Cox (1994)
22	Stream Length- Gradient Index (SL)	SL=(ΔH/ΔL).L ; Where, ΔH/ΔL= Channel Slope or gradient of the reach, L= Total channel length from the highest point on the channel	Hack (1973)

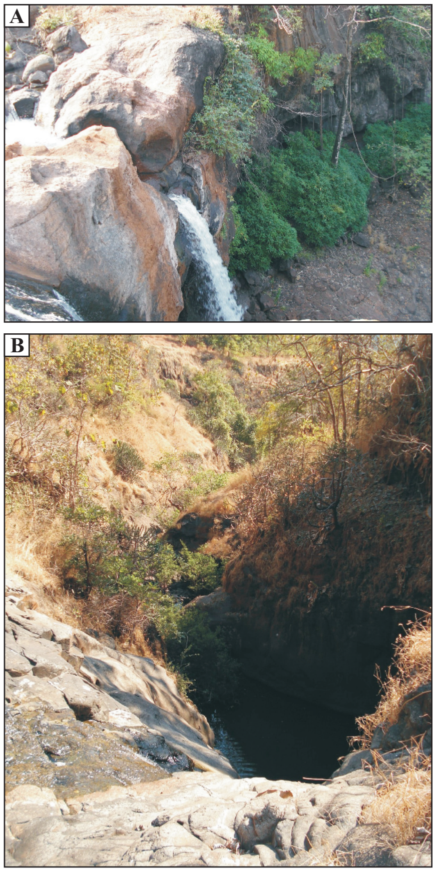


Fig.5. Photographs showing, A) Knick points in Pyali river indicate a relative fall in base level, B) Deep meandering gorges of the Pyali river, bottle neck valley

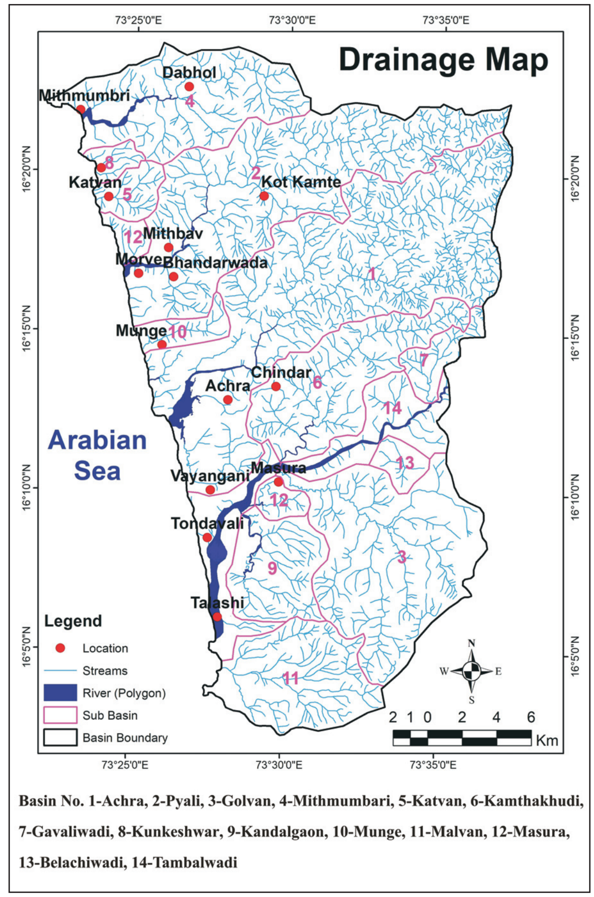


Fig.6. Drainage map of Mithmumbri to Malvan Area.

constant of channel maintenance *etc* (Table 1). The linear aspects were calculated by using the methods of Horton (1945) and Strahler (1964).The areal aspectsuse those of Schumm (1956), Strahler (1964), Miller (1953), Horton (1932) and the relief aspects used the techniques of Schumm (1956) and Strahler (1964) (Table 1). For detailed morphometric analysis of the drainage basin from Mithmumbri to Malvan area; the third, fourth and fifth order basins are delineated from the toposheet after assigning 'stream order' to all the segments following the Strahler (1964) method. The fourteen drainage basins are delineated following the surface water divide (Fig. 6).

Results and Discussion

Linear aspects

The drainage basin is seen to transfer water and sediments, eroded within a basin, through a channel that is marked as the highest order of a basin.

Stream Order (U)

Stream order is the first stage of morphometric analysis. In study area, fourteen basins are present. The Achra, Pyali and Golvan basins are fifth order basins, Mithmumbri, Katvan, Kamthakudi, and Gavaliwadi, Kandalgaon and Malvan basins are fourth order basinsand Kunkeshwar, Munge, Masura, Belachiwadi and Tambalwadi basins are third order basins (Fig. 6).

Stream Number (Nu)

The number of streams of each order in a given basin is known as stream number. In the study area, all the third, fourth and fifth-order basin is counted and tabulated for the morphometric analysis (Table 2). The total number of stream segments is found to decrease as the stream order increases in all the basins. The Achra River has a total number of streams are 929. The Pyali and Golvan basin has a total number of streams are 356 and 197, respectively. The Mithmumbari Basin has a total number of streams are 116 while the Katvan Basin has 33 streams (Table 2). The maximum number of 1st order streams exhibits that the basin is subjected to erosional activity of PGW-1 Watershed of Ghatanji Area, Yavatmal District (Gupta *et al*., 2020).

Stream Length (Lu)

The total length of individual stream segments of each order is the stream length of that order. The total stream length of the Achra Basin is 673 km, while the Pyali Basin has a 261 km. The total stream length of the Golvan Basin is 134 km, while the Mithmumbari Basin is 70.5 km (Table 2).

Bifurcation Ratio (Rb)

This is a dimensionless parameter that express the ratio of the number of streams of any given order to the number in the next lower order (Nu+1) (Horton, 1945). The bifurcation ratio (Rb)

Table 2: Linear Aspects of Mithmumbri to Malvan area

Name of the sub-basin	Stream order (u) in number					Total No.	Stream Length Lu (km)					T (km)	Bifurcation Ratio (Rb)			
	N1	N2	N3	N4	N5		L1	L2	L3	L4	L5		Rb1	Rb2	Rb3	Rb4
Achra	711	171	37	9	1	929	405	128	70	22	48	673	4.15	4.62	4.11	9
Pyali	278	56	19	2	1	356	173	47	26	10	5	261	4.96	2.94	9.5	2
Golvan	147	36	11	2	1	197	57.5	27.5	22	17	10	134	4.1	3.27	5.5	2
Mithmumbari	87	23	5	1	-	116	39	18.5	8	5		70.5	3.7	4.6	5	
Katvan	23	7	2	1	-	33	7.5	4	2	1		14.5	3.3	3.5	2	
Kamthakhudi	33	9	2	1	-	45	19	6	3	2.5		30.5	3.6	4.5	2	
Gavaliwadi	19	4	2	1	-	26	22.5	8.5	6.5	4.5		42	4.8	5.5	2	
Kunkeshwar	8	3	1	-	-	12	5.5	2.5	1.5			9.5	2.7	3		
Kandalgaon	54	10	4	1		69	33	12	10	4		59	5.4	2.5	4	
Munge	19	3	1			23	9.5	4	0.5			14	6.3	3		
Malvan	81	15	6	1		103	36	27	4	2		69	5.4	2.5	6	
Masura	10	3	1			14	8.5	3	2			13.5	3.33	3		
Belachiwadi	8	2	1			11	4.5	2.0	1.0			7.5	4.0	2.0		
Tambalwadi	11	2	1			14	6.5	4.5	2			13	4.8	4		

T-Total Stream Length

ranges from two for flat topography, 3 or 4 mountainous or highly dissected drainage basin and greater than 5 indicates structurally controlled basin (Strahler, 1964).Mithmumbri, Katvan, Kamthakhudi, Kunkeshwar, Tambalwadi, Belachiwadi and Masura basin shows a mountainous or highly dissected drainage basin. Achra, Pyali, Golvan, Gavaliwadi, Kandalgaon, Munge and Malvan basins are lithological and structurally controlled basins (Table 2).

Areal Aspect

The areal aspect is the two-dimensional property of a basin. It is possible to delineate the area of the basin which contributes water to each stream segment.

Drainage Density (Dd)

The drainage density (Dd) is an important parameter of the landform elements in stream eroded topography (Horton, 1932). It is the ratio of total stream length cumulated for all orders within a basin to the basin area, which is expressed in terms of km/km^2 (Horton, 1945). In all the basins, 'Dd' values range between 1.15 and 4.07 km/km^2 (Table 3). 'Dd' reflects the prevailing condition of climate, soil texture, landuse and tectonics as well as their interactions that result in observed landforms (Moglen *et al.*, 1998).The Golvan, Mithmumbri, Kunkeshwar, Munge and Malvan basins have low 'Dd', which indicates dense vegetation cover, most rainfall infiltrates the ground and low relief (Thomas *et al.*, 2010). The Achra, Pyali, Katvan, Kamthakhudi, Kandalgaon, Masura, Belachiwadi and Tambalwadi basins have moderate 'Dd', indicates gentle to steep slopes, less permeable with thick vegetation cover. Gavaliwadi Basin has high drainage density linked to hydrologic processes including infiltration, soil saturation, sheet erosion, overland flow and their interactions that control the production of runoff and sediments (Moglen *et al.*, 1998).

Stream Frequency (Fs)

Stream frequency (Fs) may be directly related to the lithological characteristics of the basin (Horton, 1945). The 'Fs' of Achra, Golvan, Mithmumbri, Kamthakhudi, Kunkeshawar, Munge, Malvan, Masura, and Tambalwadi basin ranges between 1.46 to 3.65/km^2 indicates low stream frequency. The low 'Fs' indicates high permeable character. The Pyali, Katvan and Belachiwadi basins ranges between 4.44 and 5.0 /km^2, which indicates moderate stream frequency (Table 3).

Drainage Texture (Rt)

Drainage texture (Rt) is based on the underlying lithology, infiltration capacity and relief aspect of the terrain. According to Smith (1950), drainage texture is a measure of relative channel spacing in a fluvial-dissected terrain, which is influenced by

Table 3: Areal Aspects of Mithmumbri to Malvan area

Sr. No.	Name of the basin	Dd	Fs	DT	Re	Rc	Rf	Lg	C	SI
1	Achra	2.64	3.65	9.64	0.27	0.22	0.59	1.32	0.38	0.77
2	Pyali	2.20	4.65	10.23	0.74	0.67	0.87	0.22	0.45	0.61
3	Golvan	1.93	3.2	6.17	0.61	0.52	0.44	0.26	0.51	1.3
4	Mithmumbari	1.84	3.03	5.57	0.34	0.39	0.16	0.27	0.54	1.0
5	Katvan	2.19	5.0	10.94	0.18	0.68	0.32	0.22	0.45	0.88
6	Kamthakhudi	2.1	3.09	6.48	0.65	0.81	0.78	0.24	0.47	0.90
7	Gavaliwadi	4.07	2.52	10.25	0.96	0.95	0.73	0.12	0.24	1.26
8	Kunkeshwar	1.15	1.46	1.67	0.23	0.25	0.55	0.43	0.86	0.9
9	Kandalgaon	2.0	2.29	4.58	0.61	0.68	0.83	0.25	0.5	0.6
10	Munge	1.68	2.77	4.65	0.63	0.46	0.28	0.30	0.59	1.48
11	Malvan	1.50	1.49	2.23	1.02	0.32	0.82	0.33	0.66	0.87
12	Masura	2.7	2.8	7.56	1.0	0.98	0.8	0.18	0.37	0.89
13	Belachiwadi	2.48	4.44	11.01	0.19	0.52	0.37	0.20	0.40	0.94
14	Tambalwadi	2.88	3.11	8.95	0.68	0.97	0.84	0.17	0.34	1.17

Dd-Drainage density, Fs-Stream frequency, Lg-Length of overland flow, Dt-Drainage texture, Re-Elongation ratio, Rc-Circulatory ratio, Rf-Form factor, C-Constant of channel maintenance and SI-Sinuosity Index climate, vegetation, lithology, soil type, relief and stages of development of watershed. Smith (1950) identified five different texture classes *viz.,* very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). The Kunkeshwar and Malvan basins are coarse to very coarse texture, while Mithmumbari, Kandalgaon and Munge basins are moderate texture. The Golvan, Kamthakhudi and Masura basins are a fine texture that shows greater permeability and potential for groundwater recharge. Achra, Pyali, Katvan, Gavaliwadi, Belachiwadi and Tambalwadi basins are of very fine texture (Table 3).The massive and resistant lithology causes coarse texture, whereas soft or weak rocks unprotected by vegetation produce a fine texture (Sreedevi *et al.*, 2009).

Basin shape

The shape of the basin mainly governs the rate at which the water is supplied to the main channel. The main indices used to analyze basin shape and relief is the elongation and relief ratios.

Elongation Ratio (Re)

According to Schumm (1956), elongation ratio (Re) is defined as, 'the ratio of diameter of a circle of the same area as the basin to a maximum basin length'. The value of 'Re' varies from 0 (highly elongated shape) to unity *i.e*., 1.0 (circular shape). Thus, higher the value of the elongation ratio more circular shape of the basin and vice-versa. These values can be grouped as <0.7-elongated, 0.8-0.7-less elongated, 0.9-0.8 oval and > 0.9 circular (Strahler, 1964). The 'Re' value of the study area varies between 0.18 to 1.02. Achra, Pyali, Golvan, Mithmumbri, Katvan, Kunkeshwar, Kamtakhudi, Munge, Kandalgaon, Belachiwadiand Tambalwadi basins show elongated to less elongated shape, high relief and moderate slope (Table 3). Gavaliwadi, Malvan,and Masura basins are a high value of 'Re' indicates circular shape basins. High 'Re' values indicate that; the areas are high infiltration capacity and low runoff. The low 'Re' values are susceptible to high erosion and high sedimentation load (Sreedevi *et al*., 2009).

Circularity Ratio (Rc)

According to Miller (1953), a circularity ratio is defined as the ratio of the basin area to the area of a circle having the same circumference perimeter as the basin, which is dimensionless and expresses the degree of circularity of the basin. The 'Rc'value for basins ranges between 0.22 and 0.98. The 'Rc' of the Achra river basin is 0.22, whereas the Pyali Basin is 0.67 indicating an elongated shape. In the study area, majority of the basins are elongated and highly permeable character (Table 3).The Malvan, Masura and Gavaliwadi basins are oval to circular shape. The 'Rc' is influenced by slope, geologic structure, land use and land cover in the basin.

Form Factor (Ff)

The form factor (Ff) values of all the basins ranges between 0.16 to 0.87; itindicates an elongated shape of the basins (Table 3). Golvan, Mithmumbari, Katvan, Kunkeshwar, Munge, and Belachiwadi basins are a low value of 'Ff' indicates flatter peak flow for a longer duration. Achra, Pyali, Kamtakhudi, Kandalgaon, Malvan, Tambalwadi and Masura basins are a high value of 'Ff' indicates high flow for shorter duration, high erosion and high sediment transport capacities. The form factor is used to predict the flow intensity in the basin (Horton, 1945).

Length of Overland Flow (Lg)

According to Horton (1945), the length of overland flow (Lg) is the length of runoff over the ground before it gets submerged into the main trunk stream. The 'Lg' is affected by rainfall intensity, infiltration rate, soil and vegetation covers. In the study area, 'Lg' value ranges between 0.17 and 1.32 km. Most of the basins reveal relatively low 'Lg' values, which characterize the moderate sloping terrain and lower length of sheet flow. The length of overland flow is the flow of precipitated water which moves over the land surface leading to the stream channels, whereas the channel flow reaching to the outlet of watershed is referred to as the surface runoff (Sreedevi *et al.,* 2009).

Constant of Channel Maintenance (C)

The constant of channel maintenance (C) indicates the relative size of the landform unit in a drainage basin and has a specific genetic association (Strahler, 1957).The 'C' depends on the climate, permeability, lithology, vegetation cover and erosion (Arulbalaji and Padmalal, 2020). A higher 'C' indicates higher permeability of the rocks of the basin and vice versa. The 'C' values in the study area range between 0.24 and 0.86 km^2/km (Table 3).The higher value of constant of channel maintenance reveals strong control of lithology with a surface of high permeability.

Sinuosity Index (SI)

In the study area, sinuosity index(SI) values ofAchra, Pyali, Mithmumbri, Katvan, Kamthakhudi, Kunkeshwar, Kandalgaon, Malvan, Masura and Belachiwadi basins ranges between 0.61 and 1.0, indicates straight channel. Sinuosity index signify the topographic influence on sinuosity and hydraulic influence or relatively unstable and easily translocate sediment deposits within the river channel (Mueller, 1968). The Golvan, Gavaliwadi, Munge and Tambalwadi basins 'SI' values ranges between 1.17 and 1.48, indicating a sinuous channel (Table 3).

Relief Aspects

It is an important parameter of drainage basin evolution and has a great impact on the climate, geology and geomorphology.

Basin Relief (R)

Basin relief (R) is a parameter that shows the elevation difference between the highest and lowest point in the basin (Hadley and Schumm, 1961). Basin relief (R) is an important parameter in understanding the denudational characteristics of the basin. It plays an important role in drainage development, surface and subsurface water flow (Magesh *et al*., 2011).The basin relief value ranges from 40 to 240 m. The low value of 'R'indicates low runoff conditions and a high infiltration rate (Table 4).The Achra, Pyali and Tambalwadi basins are steep slope, indicates high surface runoff conditionsand less infiltration rate.Golvan, Mithmumbri, Katvan, Kamthakhudi, Gavaliwadi, Kunkeshwar, Kandalgaon, Munge, Malvan, Masura

Table 4: Relief Aspects of Mithmumbri to Malvan area

Sr. No.	Name of the basin	R	Rh	HI	DI	SPI
1	Achra	222	0.34	0.44	0.84	56610
2	Pyali	240	0.24	0.54	0.49	28320
3	Golvan	80	0.04	0.34	0.6	7137
4	Mithmumbari	147	0.01	0.52	1.0	9186
5	Katvan	153	0.03	0.66	1.0	1530
6	Kamthakhudi	40	0.02	0.56	0.4	2120
7	Gavaliwadi	80	0.03	0.50	0.5	825
8	Kunkeshwar	142	0.04	0.56	1.0	710
9	Kandalgaon	90	0.05	0.66	1.0	2700
10	Munge	40	0.01	0.68	0.66	360
11	Malvan	140	0.04	0.66	0.5	6477
12	Masura	60	0.03	0.58	0.6	293
13	Belachiwadi	60	0.06	0.56	0.4	403
14	Tambalwadi	180	0.02	0.66	0.5	2160

R-Basin relief, Rh-Relief ratio, HI-Hypsometric Integral, DI-Dissection index, SPI-Stream power index

and Belachiwadi basins are low value indicates low runoff conditions and high infiltration rate (Table 4).

Relief Ratio (Rh)

Relief ratio (Rh) is a ratio between basin relief and basin length (Schumm, 1956). Relief ratio (Rh) is an effective measure of gradient aspects of basin (Schumm, 1956). The values of 'Rh' ranges between 0.01 and 0.34 indicating moderate relief (Table 4).The relief ratio is directly proportional to the surface run-off and intensity of erosion. The high values of 'Rh' indicate a steep slope and high relief. Run-off is generally faster in steeper basins, producing more peak discharges and greater erosive power.

Aspect Map

A visual comparison of the aspect map of Achra, Pyali, Mithmumbri, Katvan, Tambalwadi, Kunkeshwar, Munge, Kamtakhudi, Gavaliwadi, Masura and Malvan basins, in that SW (15.27%), S(13.32%), W(16.17%), and SE (11%) slope are dominant. Golvan, Kandalgaon and Belachiwadi basin in that N (10.19%), NE (9.51%), NW (14%) and E (10%) (Fig.7). The Achra, Pyali, Mithmumbri, Katvan, Kunkeshwar, Munge, Kamtakhudi, Gavaliwadi, Masura, Malvan and Tambalwadi basins are West, Southwest, South facing slopes receive high amount of insolation, influencing high productivity of soil.

Slope Map

Slope map provides data for planning, settlement, agriculture, planning of engineering structures, and morpho-conservation structures (Sreedevi *et al.,* 2005). In the study area, slope values vary from 0° to 25°. The gentle slope (0-2°) is observed in Kunkeshwar, Katvan, Munge and Malvan basins, the total percentage of gentle slope is 36.47% (234.54sq.km). The 2-4° of slope observed in Kandalgaon and Belachiwadi basins and the total percentage is 29.5% (189.73sq. km.). The moderate gentle slope areas (4-8°) are found in the Mithmumbari, Kamthkhudi and Gavaliwadi basins and the total percentage is 17% (109.59 sq. km.). Moderately steep slope areas (8-12°) are found in Belachiwadi and Tambalwadi basins and the total percentage is 11.7% (75.24sq. km.) (Fig. 8). The steep slope (12-25°) is associated with dissected plateau, and structural hills found in the upper part in Achra, Pyali and Golvan basins (5.33%). The Achra and Pyali rivers erode the

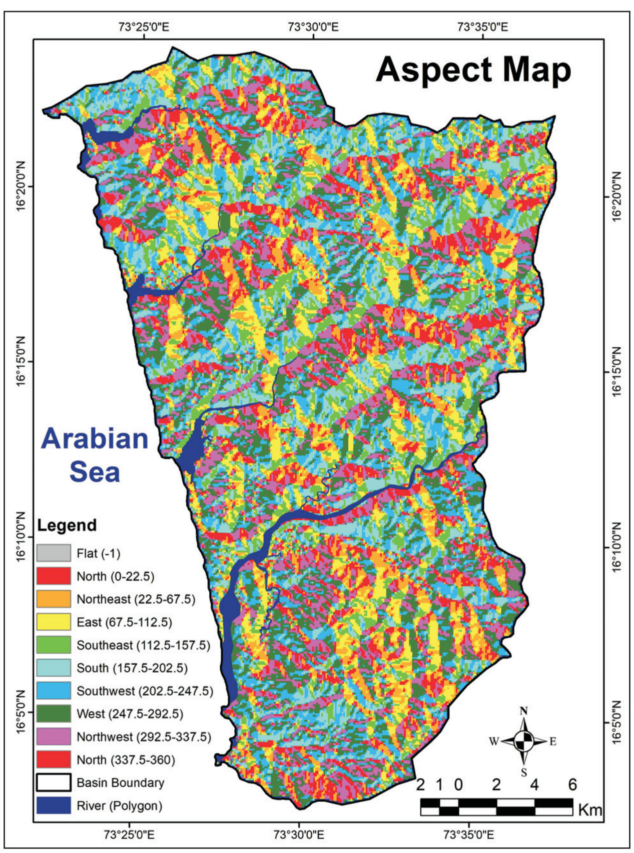


Fig.7. Aspect map of Mithmumbri to Malvan Area.

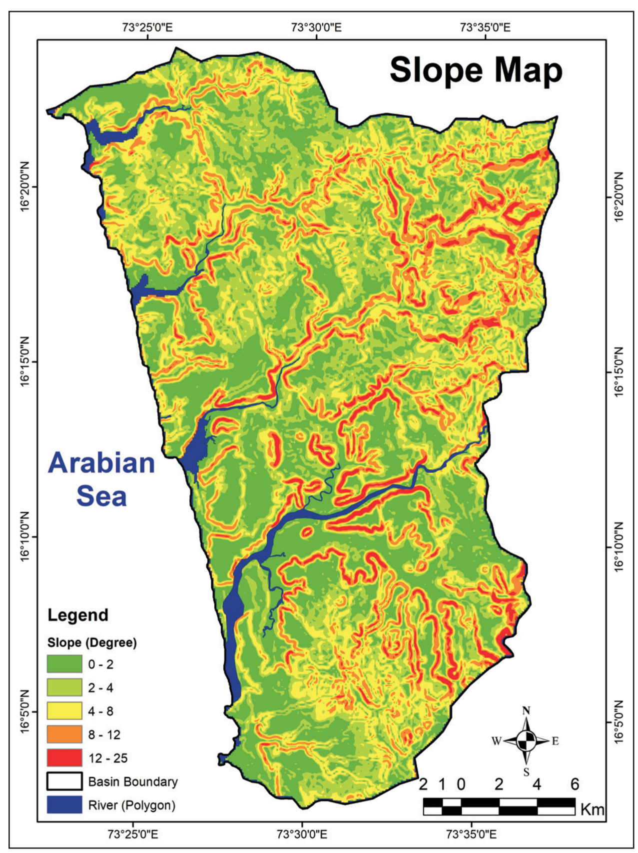


Fig.8. Slope map of Mithmumbri to Malvan Area.

material through hillslope processes and the bedrock channel incision that has eventually transported in the form of dissolved and suspended sediments.

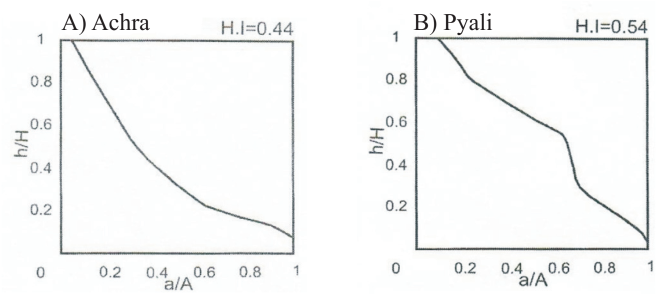
Hypsometric Integral (HI)

In the study area, three fifth order, six fourth order and five third order basins are present and illustrated in the form of the hypsometric curves for these basins (Fig.9) and the hypsometric integral values for basins are given in Table 4. On the basis of the hypsometric curve and the integral values, Strahler (1952) has distinguished three stages of development of basins, namely inequilibrium (>60%, Youth), equilibrium (35% to 60%, Mature) and Monadnock (<35%, Old) stage of development. The typical hill slope profile-convex at the top transitioning to concave–up towards the valley bottom, can be qualitatively matched using a range of different erosion and mass movement processes (Willgoose *et al.*, 1991).

Out of five third-order basins, three basins, *viz.,* Kunkeshwar, Tambalwadi and Belachiwadireveal hypsometric integral (HI) values between 0.56 and 0.58, indicating a mature geomorphic stage of development, which are underlain by Kaladgi quartzites, shale and laterites (Fig. 9H, L,M). Munge and Masura basins 'HI' values are between 0.66 and 0.68, indicating youth stage of development (Fig. 9J, N). In the fourth order, Katvan, Kandalgaon and Malvan basin hypsometric integral value is 0.66 (Fig. 9E,I,K), indicative of the youthful geomorphic stage, whereas Mithmumbri, Kamthakhudi and Gavaliwadi basins 'HI' values are from 0.50 to 0.56, indicating mature stage (Fig. 9D,F,G). These basins are underlain by Kaladgi sandstone, shale, Deccan traps basalt, laterites and alluvium. Fifth-order, Achra and Pyali basins have hypsometric integral values ranges between 0.44 and 0.54 suggests a mature stage of basins (Fig. 9A-B). These basins are underlain by Kaladgi sandstone, shale, Deccan traps basalt and laterites. Golvan basins 'HI' value is 0.34, indicating an old or monadnock stage underlain by hornblende gneiss, mica gneiss, Kaladgi sandstone, shale and laterites (Fig. 9C). The discharge increases downstream and the ability to transport eroded sediment is greatest in the larger streams, lower part of the drainage basin eroded more rapidly than the distal parts until an equilibrium of slope is achieved. This is because of concave upward from of drainage systems (Hack, 1973).

Dissection Index (DI)

Dissection index (DI) is the ratio between relative relief and absolute relief (Schumm, 1956). It is an important parameter of drainage basin dynamics as well as the stage of basin development.



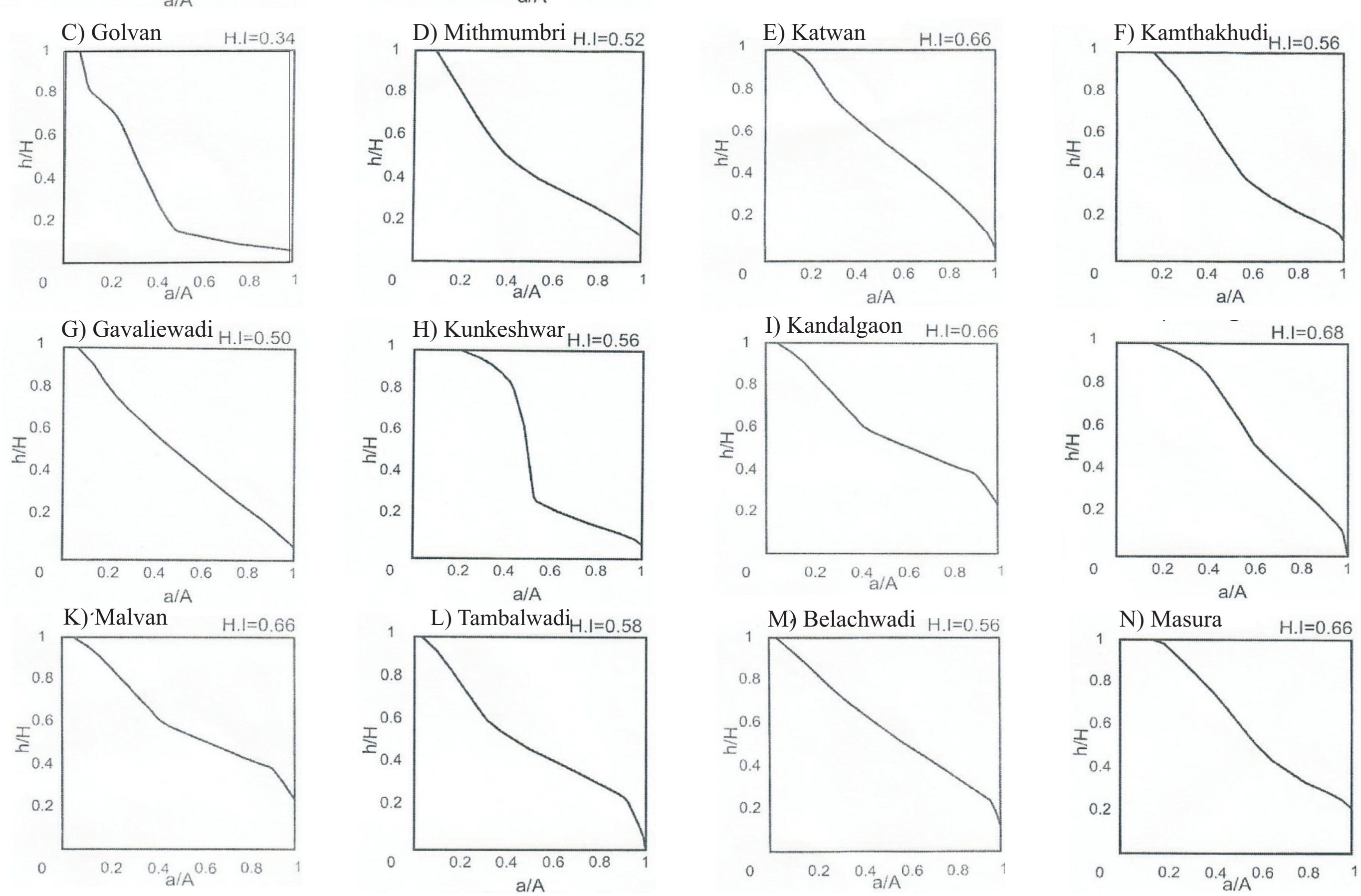


Fig.9. Hypsometric curve showing, Achara, Pyali, Golvan, Mithmumbri, Katvan, Kamthakhudi, Gavaliwadi, Kunkeshwar, Kandalgaon, Munge, Malvan, Tambalwadi, Belachiwadi and Masura basin of study area.

The varying degree of erosional potential, due to differences in aspects like lithology, slope, basin relief, vegetation growth and rainfall distribution is the main cause for the spatial variations of dissection in the basin (Singh and Dubey, 1994). In the study area, 'DI' value ranges between 0.4 and 1.0 (Table 4). The Achra, Pyali, Golvan, Mithmumbri, Katvan, Kunkeshwar, Kandalgaon, Munge, Masura and Tambalwadi basins are highly dissected basins.

Stream Power Index (SPI)

The SPI varies between 292.8 and 56610 (Table 4). The higher SPI of Achra, Pyali, Mithmumbri, Golvan and Malvan basins is an indication of higher stream power, which is result of the steeply sloping terrain and high channel gradient. The higher SPI represents higher erosion of the basin indicates high river basin management measures (Moore *et al.,* 1993). The soil conservation measures are essential in this basin. The moderate SPI of Katvan, Kamthakhudi, Gavaliwadi, Kandalgaon, Kunkeshwar and Tambalwadi basin is an indication of moderate stream power, which is a result of moderate slope and moderate channel gradient. The low SPI of Munge, Masura and Belachiwadi basin is low stream power which is a low slope area.

Ratio of Valley Floor Width to Valley Height (Vf)

High values of 'Vf' are associated with low uplift rates, so that streams cut broad valley floors. Low values of 'Vf' reflect deep valleys with stream that are actively incising, commonly associated with relatively rapid uplift (Bull and Mcfadden, 1977). The 'Vf' values in study area range from 0.16 to 1.56 (Table 5). Lower values are associated with Achra, Pyali, Golvan, Katvan, Kamthakhudi, Gavaliwadi, Kunkeshwar, Munge, Masura, Belachiwadi and Tambalwadi basins where deep valleys with stream that are actively incising, commonly associated with relatively rapid uplift.

Asymmetry Factor (Af)

The asymmetric factor (AF) and the transverse topographic symmetry factor (t) are the morphometric indices, which are useful to measure the degree of drainage basin asymmetry and to locate the tilt-down direction, caused by active tectonic deformation. According to Hare and Gardner (1985), AF values of about '50' indicate that stream network is in a stable region whereas that of lower or higher than 50 suggests a tilt. Hence AF=50, the drainage basin is perfectly symmetric, while values greater or less than 50 belong to asymmetric basins.

The average values of AF of Achra (32), Pyali (30), Golvan (45), Mithmumbri (30), Katvan (28), Kamthakhudi (15), Gavaliwadi (39), Kunkeshwar (29), Munge (28), Malvan (35), Masura (30), Belachiwadi (30), and Tambalwadi basins (19) have low values consistent with tilting towards SSW of the basins. The asymmetry factor (AF) displays a wide range of values in the study area (Table 5). The asymmetry factor (AF) is developed to detect tectonic tilting at drainage-basin scales or on larger scales (Hare and Gardner, 1985).

Table 5: Geomorphic Indices of Mithmumbri to Malvan area

Sr. No.	Basin Name	Af	Vf	T	SL
1	Achra	32	0.72	0.47	427
2	Pyali	30	0.78	0.58	582
3	Golvan	45	0.16	0.42	328
4	Mithmumbri	30	0.70	0.61	450
5	Katvan	28	0.65	0.26	280
6	Kamthakhudi	15	0.58	0.29	360
7	Gavaliwadi	39	0.23	0.56	218
8	Kunkeshwar	29	0.7	0.24	260
9	Kandalgaon	75	1.23	0.57	250
10	Munge	28	0.22	0.41	350
11	Malvan	35	1.56	0.54	240
12	Masura	30	0.28	0.36	140
13	Belachiwadi	30	0.17	0.25	380
14	Tambalwadi	19	0.24	0.38	142

Af-Asymmetry Factor, Vf-Ratio of Valley Floor Width to Valley Height, T-Transverse Topographic Symmetry factor, SL-Stream Length Gradient index

Transverse Topographic Symmetry Factor (T)

Transverse Topographic Symmetry Factor (T) values range from 0 to 1. Zero value represents a perfectly symmetric basin, while a value up to 1 indicates an asymmetric basin (Cox, 1994). Transverse topographic symmetry factor (T) values have been calculated for fourteen different basins and the average T value is determined for each segment. The T values ranges from 0.24 to 0.61. The T values for the Achra, Pyali, Mithmumbri, Kamthakhudi, Golvan, Kandalgaon, Gavaliwadi, Belachiwadi and Tambalwadi are in the range of 0.24 to 0.61 (Table 5). The Achra, Pyali and Mithmumbri rivers have a high value (T=0.47, 0.58 and 0.61) and these rivers have migrated uniformly and largely to the southwest. This evidence a direct influence of external forces (tectonics/ climate), as fluvial processes respond by the migration of the river (Beaty, 1962; Cox, 1994). The Achra, Pyali, Golvan and Kamthakhudi, basins therefore can be inferred as SSW tilting of the basins in response to tectonic tilt.

Stream Length-Gradient Index (SL)

Stream Length-Gradient Index(SL) correlates to stream power, which is proportional to slope and discharge and sensitive to changes in the channel slope as a function of tectonics, rock resistance and/or topography (Hack, 1973). An anomalous value of SL indicates tectonic activity. There is a large variation in SL values as seen near Achra (427), Pyali (582), Golvan (328), Mithmumbri (450), Kamthakhudi (360), Munge (350) and Belachiwadi (380) (Table 5).Abrupt changes in slope and SL index evaluate the ongoing processes of uplift of the underlying structures (Seeber and Gornitz,1983).

Discussion

Morphometric parameters and climatic factors are an important role in the river ecosystem at the basin scale. The fourteen drainage basins analyses are carried out from Mithmumbri to Malvan area. The Katvan, Kamthakhudi, Kunkeshwar, Gavaliwadi, Belachiwadi and Tambalwadi basins are mountainous or highly dissected basins. The Achra, Pyali, Golvan, Gavaliwadi, Munge, Kandalgaon and Malvan basins are structural control basins. The majority of the basins has low to moderate Dd, indicating the region is highly resistant and permeable to subsurface with dense vegetation cover, low runoff and high infiltration rate. Golvan, Mithmumbri, Kamthakhudi, Kunkeshwar, Munge, Tambalwadi and Malvan basins are low 'Sf' value suggests higher infiltration rate and low relief. The Pyali and Belachiwadi basins are moderate 'Sf' indicates moderate relief. The 'Dt' of the Achara, Pyali, Katvan, Gavaliwadi, and Belachiwadi, Tambalwadi basins show very fine texture, while Golvan, Kamthakhudi and Tambalwadi basins are fine texture indicates high drainage development. The Kamthakudi, Gavaliwadi and Munge basins shows high 'Re' values indicate high infiltration capacity and low runoff. Achra, Pyali, Golvan, Mithmumbri, Katvan, Kunkeshwar, Kamtakhudi, Munge, Kandalgaon, Belachiwadi and Tambalwadi basins shows elongated to less elongated, and moderate slope. As elongated basins favor a minimized floods because tributaries flow into the main stream at greater intervals of time and space. The circularity ratio is influenced by geologic structure, relief, land use and land cover, climate and slope of the basin. When rainfall intensity is more than the soil infiltration capacity the excess water flows over the land surface as overland flow (Suresh, 2005). This factor depends on geology, climate, vegetation cover, relief and duration of erosion (Schumm, 1956).

The Achra, Pyali, and Tambalwadi basins are a moderate value of basin relief while, the remaining basins are low value. Basin relief is a significant parameter for stream gradient and influences flood patterns and sediments material can be transported in a basin. Katvan, Munge, Kandalgaon, Masura, Gavaliwadi and Malvan basins are youth stages of basin, while Achra, Pyali, Mithmumbari, Kamtakhudi, Kunkeshwar, Tambalwadi and Belachiwadi basins are the mature stage of basins. The Golvan Basin is an old or monadnock stage of the basin. The Achra, Golvan, Mithmumbri, Katvan, Kunkeshwar, Munge and Tambalwadi basins are highly dissected basins while the remaining basins are moderately dissected. The gentle slopes are found in Mithmumbari, Kunkeshwar, Katvan and Munge basins while, moderate slopes occur in Kamthakhudi and Gavaliwadi basins. The Achra, Pyali, Golvan, Belachiwadi and Tambalwadi basins are moderately steep slopes.

In Konkan, there are two distinct episodes of deposition during the Holocene, 1) Late Holocene (1000-700 yrs. BP) (Kale and Rajaguru, 1988), 2) Early Holocene period (Guzder, 1980). During Late Quaternary, when the sea fell by more than 150m, the Konkan rivers responded by intensively incising their channel (Kale and Rajaguru, 1986). In Konkan area, stream deepening and stream fillings associated with deposition of fluvio-marine sediments suggests four lower and higher sea level stands during the period from Middle Miocene to Late Pleistocene (Tiwari, 2001). As a result of the lowering of sea level during the early Holocene period, the base level might have gone down. It indicates resulted in the rejuvenation of the river system, causing river deepening due to the erosion of channel lag deposits. The valley aggradation and dissection of aggraded valleys may be related to sea level oscillations of Mid Holocene. The Holocene (Flandrian) transgression caused the drowning of the older coastline features, and a landward extension of the mudflats over the coastal alluvium and formation of Mithmumbri estuary, Pyali estuary, Achara river estuary and Gad river estuarine creek. Golvan Basin is well graded form might have been attained during post Pleistocene period as indicated by prominent erosional lateritic surfaces around 100m msl (Sarkar and Soman, 1983). The streams having narrow, deep water courses, the development of valley in valley profiles steep valley side's slopes. In the Golvan Basin, under study rejuvenation of the faults during different period is evidenced from the observed brecciated quartzite fragments (Sarkar and Soman, 1983).

Lower values of ratio of valley floor width to valley height are associated with Achra, Pyali,Golvan, Katvan, Kamthakhudi, Gavaliwadi, Kunkeshwar, Munge, Masura, Belachiwadi and Tambalwadi basins where deep valleys with stream that are actively incising, commonly associated with relatively rapid uplift during Late Quaternary. Asymmetry factor of Achara, Pyali, Golvan, Mithmumbri, Katvan, Kamthakhudi, Gavaliwadi, Kunkeshwar, Munge, Malvan, Masura, Belachiwadi, and Tambalwadi basins have low values consistent with tilting towards SSW direction of the basins. The Achara, Pyali, Mithmumbri, Golvan and Kamthakhudi, basin therefore can be inferred as SSW tilting of the basin in response to tectonic tilt.

Conclusions

The morphometric and hypsometrically analysis has been carried out from Mithmumbari to Malvan area, Western Coast of Maharashtra. The Achra, Pyali, Golvan, Gavaliwadi and Munge basins are structural control basins. All the basins show that, the low to moderate drainage density indicates suitable for the construction of recharge structures. Most of the basins are of fine to very fine texture, linear and sinuous channels with an elongated shape of basins. The elongated basins indicate a lower vulnerability to flash floods and hence easier flood management. The overland flow in the study area dominantly streams erosion rather than sheet erosion. The GIS and remote sensing data helped to understand various types of landforms and their processes and drainage basins for planning and management. The present study is important for the ecosystem management of drainage basins in Western Ghat region of Maharashtra.

Authors' Contributions

MH: Investigation, Conceptualization, Writing Original Draft, Methodology, Supervision, Visualization, Validation. **PK:** Visualization, Formal Analysis, Data Curation, Software, Formatting, Reviewing and Editing. **AC:** Formal Analysis, Data Curation, Methodology, Software. **RRN:** Satellite Image Interpretation, GIS Mapping, Analysis, Preparation of Base Maps.

Conflict of Interest:

The authors declare no conflict of interest.

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