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Manuscript ID:
IJWGAFES-2025-020807
DOI: 10.5281/zenodo.23311978

DOI Link:
https://doi.org/10.5281/zenodo.23311978

Volume: 2

Issue: 8

August

Year: 2025

E-ISSN: 3066-1552

Submitted: *08 July2025*

Revised: *10 July 2025*

Accepted: *05 Aug 2025*

Published: *31 Aug 2025*

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How to cite this article:
Pawar-Patil, V. S. (2025). Geomorphic Assessment of the Tulasi Watershed, Western Ghats (Maharashtra, India), Using Geospatial Technology. International Journal of World Geology, Geography, Agriculture, Forestry and Environment Sciences, 2(8), 34–42. https://doi.org/10.5281/zenodo.23311978

Geomorphic Assessment of the Tulasi Watershed, Western Ghats (Maharashtra, India), Using Geospatial Technology

V. S. Pawar-Patil

Abstract

Understanding the physical template of a watershed is a prerequisite for sound land and water management, particularly in the monsoon-dominated, basalt-capped terrain along the eastern flank of the Western Ghats. This study presents an integrated geomorphic assessment of the Tulasi watershed (163.51 km^2), a fifth-order sub-basin of the Bhogawati River in Kolhapur district, Maharashtra, India. Survey of India toposheets, 30 m SRTM elevation data, LISS-III imagery and published thematic maps of geology, soils and lineaments were processed in ArcGIS, Global Mapper and SAGA to derive geological, physiographic, relief, drainage, terrain-wetness and soil attributes, and these were interpreted alongside gridded rainfall and temperature records for 2000–2013. Deccan basalt flows underlie about 95% of the basin, with thin laterite caps on isolated plateau tops. Hills cover 72.8% of the area, plateaus 12.7% and plains 14.5%; elevation ranges from below 650 m (58.8% of the area) to above 850 m (3.2%), and slopes reach 62.3°. The river, which rises at about 945 m, drains north-eastward at a density of roughly 3 km km^{-2}. Coarse-textured, shallow soils dominate the slopes, whereas deep, fine-textured soils occupy the valley floor and lower plain. Mean annual rainfall of 2,200 mm falls off from 2,652 mm in the south-west to 1,773 mm near the outlet, with about 80% received during the monsoon. The combination of steep, rainfall-rich headwaters and a low-lying, fertile outlet makes the basin prone to runoff-driven soil loss in its upper parts, and the terrain database presented here provides a baseline for watershed prioritisation and conservation planning.

Keywords: *Geomorphology; Watershed characterisation; SRTM DEM; GIS and remote sensing; Topographic wetness index; Western Ghats; Deccan basalt*

Introduction

The shape of the land surface is the outcome of long-term interaction among bedrock, climate, vegetation and running water, and it in turn governs how rainfall is partitioned into runoff, infiltration and erosion. Because the same factors also control the formation and distribution of soils, a physiographic reading of a landscape provides the logical starting point for any attempt to understand its hydrology and land-use potential (Florinsky, 2016; Pike et al., 2009). In small river basins the watershed is the natural planning unit, and a consistent, spatially explicit description of its terrain is therefore needed before conservation, water-harvesting or cropping interventions can be designed.

Digital elevation models (DEMs) and geographic information systems (GIS) have made such descriptions routine. The Shuttle Radar Topography Mission supplies near-global elevation data at 1 arc-second (about 30 m) resolution (Farr et al., 2007), and open-source tools such as SAGA GIS allow slope, aspect, wetness and channel-network attributes to be derived reproducibly (Conrad et al., 2015). These approaches have been applied widely to morphometric and geomorphic characterisation in peninsular India, including the Western Ghats and the Konkan coast (Kamble et al., 2019; Kandekar et al., 2021; Pareta & Pareta, 2011), and they have been used to relate drainage development to rock type and structure in hard-rock terrain (Nag & Chakraborty, 2003).The western margin of the Deccan Volcanic Province, where the Sahyadri escarpment forms the main water divide of peninsular India, is a particularly instructive setting. Uplift, escarpment retreat and basalt stratigraphy have jointly shaped its relief (Gunnell & Radhakrishna, 2001; Kale & Shejwalkar, 2008), and the heavy orographic monsoon rainfall makes the region sensitive to soil loss and flash runoff. The Tulasi River, a tributary of the Bhogawati in Kolhapur district, drains such terrain, yet its geomorphic framework has received limited integrated treatment beyond sub-watershed characterisation and prioritisation (Pawar-Patil & Mali, 2013).

The objective of this study is to provide an integrated geomorphic assessment of the Tulasi watershed using geospatial technology. Specifically, we (i) map and quantify the geological formations and lineaments; (ii) classify the physiographic divisions; (iii) characterise relief through slope, aspect, absolute relief, hillshade and contours; (iv) describe the drainage network, valley depth, channel-

Network base level and compound topographic index; and (v) summarise soil and climatic conditions that condition runoff and land use.

2. Study area

The Tulasi watershed covers 163.51 km^2 in the Radhanagari and Karveer tehsils of Kolhapur district, Maharashtra, and lies between roughly 16°25′–16°39′ N and 73°58′–74°8′ E (Fig. 1). It occupies the eastern flank of the Sahyadri range of the Western Ghats and has an elongated, north-east-trending outline. The Tulasi River rises at about 945 m above mean sea level near Durgmanwad in Radhanagari tehsil and flows from the south-west to the north-east before joining the Bhogawati River near the village of Beed. It is a fifth-order stream with a main-channel length of about 35 km. Originally a seasonal river, it became perennial after the Tulasi irrigation reservoir was built near Dhamod in the upper catchment; a second, smaller dam has been built on Londha Nala, its principal left-bank tributary (Fig. 6a). The climate is of the tropical monsoon type, with a rainy season from June to October, a winter from November to February and a summer from March to May.

Data and methods

1 Data sources

Secondary data comprised Survey of India toposheets, the geology and mineral map of Kolhapur district published by the Geological Survey of India (GSI, 1999), and the soil texture, soil depth and soil productivity maps of the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP, 2005). Elevation was taken from the 30 m SRTM DEM (Farr et al., 2007), and a linearly stretched LISS-III standard false colour composite served as supporting imagery. Bhuvan geomorphology and lineament layers were used as ancillary references, and gridded rainfall and temperature records for 2000–2013 were obtained from an open global weather-data portal (Table 1).

Table 1. Data sets used in the study.

Data set	Source	Use
Toposheets	Survey of India	Base map, drainage digitisation
SRTM DEM (30 m)	USGS EarthExplorer	Relief, slope, aspect, hillshade, drainage, CTI
LISS-III SFCC image	NRSC / Bhuvan	Physiographic interpretation
Geology and mineral map	Geological Survey of India	Geological formations, lineaments
Soil texture and depth maps	NBSS&LUP	Soil characterisation
Rainfall and temperature (2000–2013)	Global weather data portal	Climatic summary

Source: Compiled by the authors.

2 Terrain and drainage processing

Scanned toposheets were georeferenced, mosaicked and clipped to the watershed boundary in ArcGIS 9.3, and both the toposheets and the DEM were re-projected to UTM Zone 43 N. Drainage lines were digitised from the toposheets and attributed. In parallel, the drainage network was extracted automatically from the DEM using the hydrology tools: sinks were filled, flow direction and flow accumulation grids were computed, the accumulation grid was thresholded with a logical function to suppress spurious first-order streams, and stream links, stream order and a raster-to-vector conversion produced the automated network. Slope, aspect, contours and hillshade (cf. Horn, 1981) were generated with the surface-analysis tools, and valley depth and channel-network base level were calculated in SAGA GIS (Conrad et al., 2015) by interpolating stream-bed elevations and subtracting them from the DEM.

3 Geology, soils and compound topographic index

The geology and mineral map was scanned, rectified against the district boundary in Global Mapper 15, and then re-projected and digitised in ArcGIS to delineate formations and lineaments. The soil maps were treated in the same way, and area statistics for each class were computed in the GIS. The compound topographic index (CTI), also called the topographic wetness index, was computed as $CTI = \ln(a / \tan \beta)$, where a is the upslope contributing area per unit contour length and β is the local slope (Beven & Kirkby, 1979; Sørensen et al., 2006). Because the index depends on DEM resolution and flow-routing algorithm (Riihimäki et al., 2021), it is interpreted here as a relative, qualitative indicator of wetness rather than a measured soil-moisture value.

Results and discussion

1 Geological formations and lineaments

The watershed forms part of the Deccan Volcanic Province, whose main phase of basaltic volcanism is concentrated around the Cretaceous–Paleogene boundary (Schoene et al., 2019; Sprain et al., 2019). Geological diversity within the basin is limited (Table 2; Fig. 1a). Two lava-flow formations, the Purandargarh and Mahabaleshwar, are recognised, each about 400 m thick. The Purandargarh Formation consists mainly of simple aa-type flows with a few compound flows and is capped by a 20–25 m megacrystic unit rich in plagioclase phenocrysts, whereas the Mahabaleshwar Formation is made up essentially of aa flows carrying plagioclase phenocrysts. Unclassified basalt flows of the middle and lower reaches cover 74% of the basin. Laterite of Quaternary age occupies only 1.1% of the area, occurring as thin caps, from a few metres to about 30 m thick, on isolated plateau tops in the south-west and on the lower eastern tablelands. Bauxite pockets and lenses within the laterite profile are the principal economic mineral of the region. The mapped lineaments (Fig. 1b) indicate the structural grain that may guide stream alignment and groundwater movement in this hard-rock terrain (Nag & Chakraborty, 2003).

Table 2. Geological formations in the Tulasi watershed.

Geological formation	Area (km^2)	Area (%)
Unclassified basalt flows	120.40	74
Laterite	1.87	1
Mainly aa simple flows	5.82	4
Essentially aa simple flows	27.14	17
Megacryst flows	8.29	5
Total	**163.51**	**100**

Source: Computed by the authors from the geological map of the Geological Survey of India.

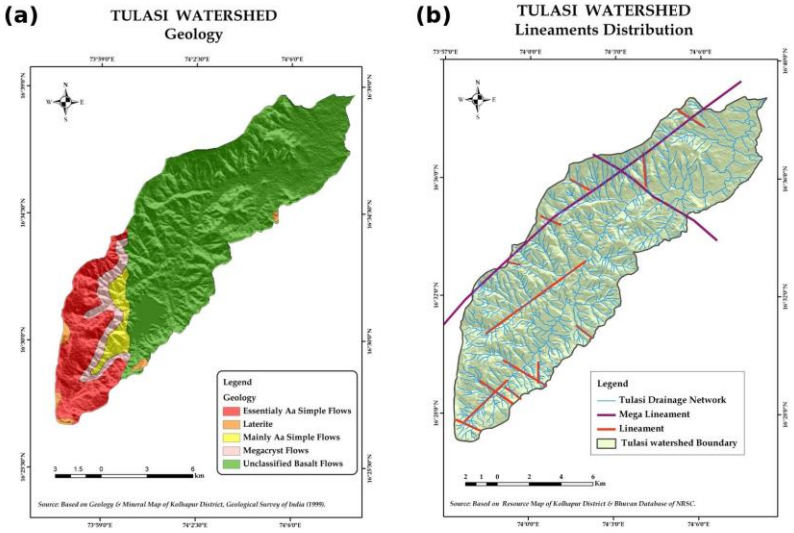

Fig. 1. (a) Geology and (b) lineament distribution of the Tulasi watershed.

2 Physiographic divisions

Interpretation of LISS-III bands, the SRTM DEM and the toposheets (Fig. 2a) resolved three landforms: hills, plateaus and plains (Fig. 2b; Table 3). Off-shoots of the Sahyadri, running south-west to north-east, form the water divides and the most conspicuous physiographic feature, with summits above 700 m. Together the western and eastern undulating hills occupy 72.8% of the basin. The western flank is steeper and more dissected, with interlocking spurs and incised valleys, than the eastern flank. Small patches of wasteland with sparse scrub occur on these hills. Plateaus on the hill tops and in the south-western and north-western off-shoots, with gentler gradients and elevations of 600 to more than 900 m, account for 12.7% of the area. The plain lies in the lower reaches (14.5%), is nearly level to gently sloping with deep, fine-grained soil, and is the zone best suited to cultivation; agricultural development is concentrated here.

Table 3. Physiographic divisions of the Tulasi watershed.

Physiographic division	Area (km^2)	Area (%)
Plain	23.671	14.48
Plateau	20.805	12.72
Western undulating hills	81.418	49.79
Eastern undulating hills	37.615	23.00
Total	**163.510**	**100.00**

Source: Computed by the authors from GIS analysis.

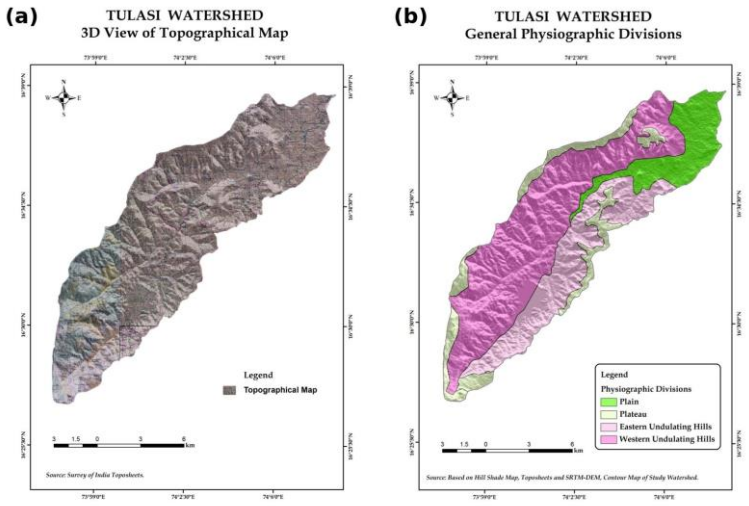

Fig. 2. (a) Topographic map and (b) physiographic divisions of the Tulasi watershed.

3 Relief characteristics

Relief expresses the vertical variation of the land surface and reflects the combined action of geomorphic and climatic processes; it is commonly described through absolute and relative relief, dissection, slope and drainage density (Singh & Sinha, 1996). Slope in the watershed ranges from 0° to 62.34° (Fig. 3a). The south-western, western and eastern hill flanks have steep to strong slopes, while the lower plain and plateau tops have moderate to low relief.

Absolute relief, defined here as elevation above mean sea level, indicates the intensity of denudation acting on a surface and the height–area relationship of the basin. The reclassified SRTM DEM yields four classes (Table 4; Fig. 4). Elevation falls below 650 m near the confluence in the north and exceeds 850 m on the south-western and western hills. About 58.8% of the watershed lies below 650 m, and only 3.2% above 850 m.

Table 4. Absolute relief in the Tulasi watershed.

Absolute relief (m)	**Area (km^2)**	**Area (%)**
Low (< 650)	96.11	58.78
Moderate (650–750)	40.75	24.92
High (750–850)	21.46	13.13
Very high (> 850)	5.19	3.17
Total	**163.51**	**100.00**

Source: Based on SRTM DEM (30 m) and GIS analysis.

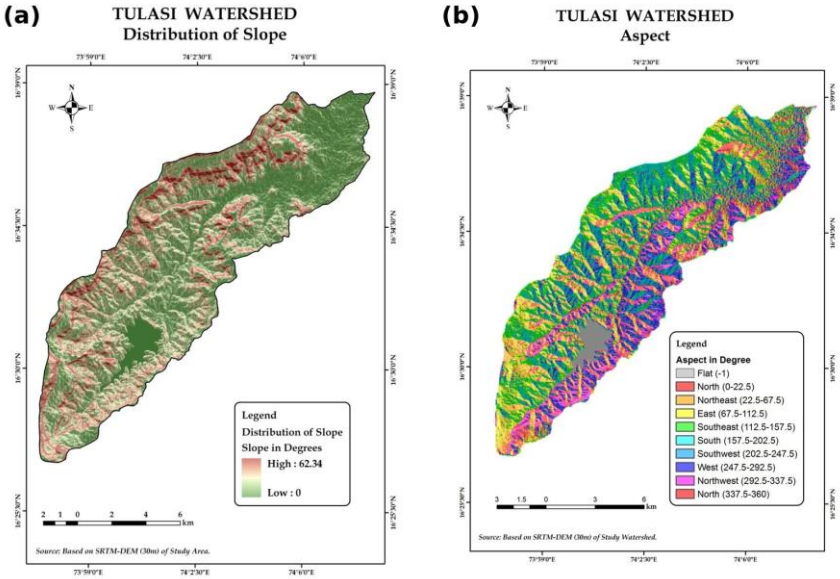

Fig. 3. (a) Slope and (b) slope aspect of the Tulasi watershed (SRTM DEM, 30 m).

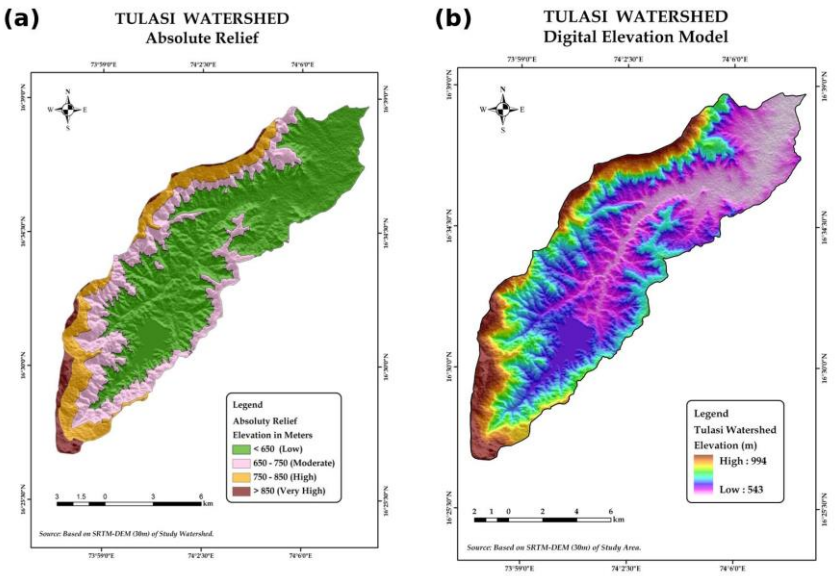

Fig. 4. (a) Absolute relief classes and (b) SRTM digital elevation model of the Tulasi watershed.

Slope aspect gives the compass direction of the steepest downslope gradient and therefore also the direction of overland flow. Measured clockwise from north (0°/360°; east 90°, south 180°, west 270°), north-westerly, south-easterly and southerly aspects predominate (Fig. 3b), which is consistent with the north-east-trending ridge-and-valley grain of the basin.

The hillshade surface (Fig. 5a) conveys the undulation of the terrain and supports the physiographic interpretation: elevated hills with dissected valleys characterise the south-western, western and eastern parts, whereas the lower reaches are conspicuously plain. Contours in the basin range from 550 to 950 m (Fig. 5b). Widely spaced 550–650 m contours in the lower reaches signal low to moderate gradients, whereas closely spaced 800–950 m contours on the hills of the upper and middle reaches mark steep gradients.

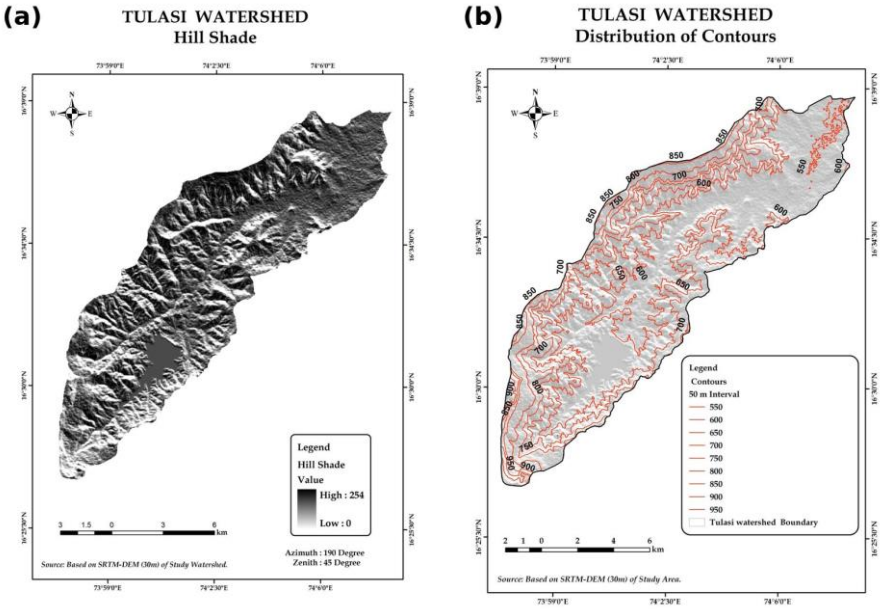

Fig. 5. (a) Hillshade and (b) contour distribution of the Tulasi watershed.

4.4 Drainage, terrain wetness and valley incision

The Tulasi River is a fifth-order stream whose elongated basin has a drainage density of about 3 km km^{-2}, a fine drainage texture and a coarse drainage intensity (Fig. 6a). The combination of high density and steep headwater slopes indicates efficient conversion of monsoon rainfall into channel flow, as reported for other Western Ghats basins (Kamble et al., 2019; Kandekar et al., 2021).

The CTI map (Fig. 6b) shows higher wetness values along the main streams and in the lower reaches, and lower values on the ridges flanking the river and in the dry upper reaches. Such a pattern is expected because the index increases with upslope contributing area and decreases with slope (Beven & Kirkby, 1979; Sørensen et al., 2006). Given the coarse 30 m grid, the map is best used to distinguish broad zones of likely saturation, rather than to estimate soil moisture quantitatively (Riihimäki et al., 2021).

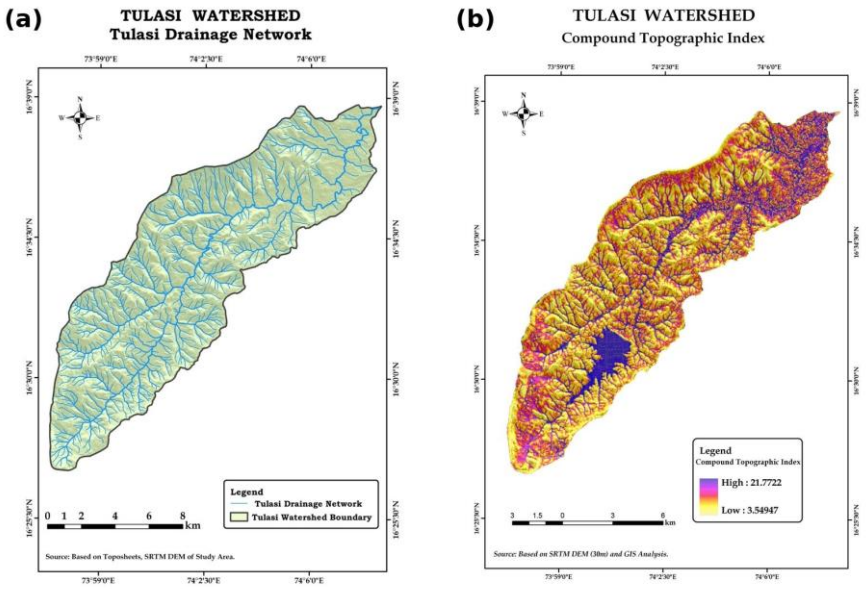

Fig. 6. (a) Drainage network and (b) compound topographic index of the Tulasi watershed.

Valley depth, the vertical distance to the stream base level, shows how strongly streams have incised the surface and how far topography controls fluvial dynamics. In Tulasi it is relatively high in the lower reaches and in the incised western hill tract, and low elsewhere (Fig. 7a). Channel-network base level, obtained by interpolating stream elevations and subtracting them from the DEM, is high near the south-western source area and along the prominent western ridges, and declines towards the confluence with the Bhogawati (Fig. 7b).

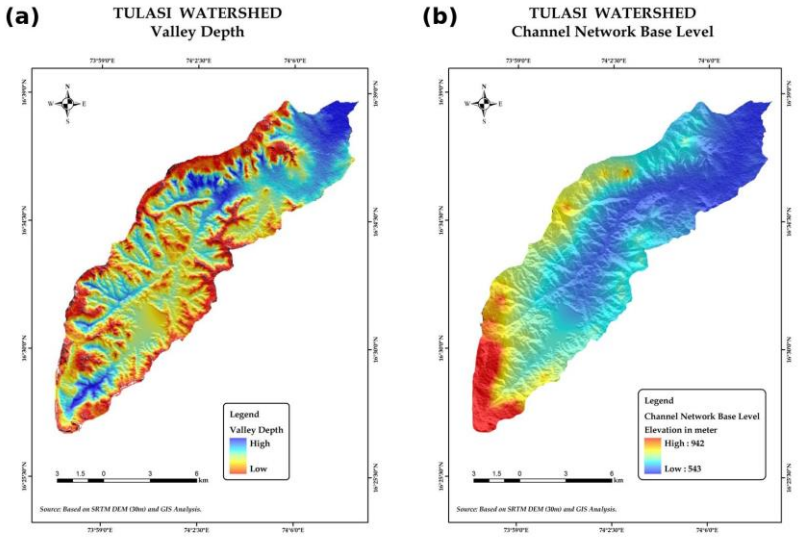

Fig. 7. (a) Valley depth and (b) channel-network base level of the Tulasi watershed (SAGA GIS).

5 Soil characteristics

Soil information underpins watershed management and conservation planning, and soil texture and depth strongly influence land suitability and limitations. Coarse-textured soils cover 45.4% of the basin, medium-textured soils 28.6% and fine-textured soils 26.0% (Table 5). Clay-loam to silty-loam textures predominate along the river, whereas sandy to coarse sandy loam is found on the hill tops and slopes (Fig. 8b). Soil depth is greatest on both sides of the main channel in the middle and lower reaches and decreases towards the hill slopes (Fig. 8a); deep soils account for 32.3% of the area and shallow soils for 21.6% (Table 5). Rock outcrops are frequent on hill slopes and tops, while the low-lying areas are only slightly stony.

Table 5. Soil texture and soil depth in the Tulasi watershed.

Soil class	**Area (km^2)**	**Area (%)**
Soil texture		
Fine	42.58	26.04
Medium	46.72	28.57
Coarse	74.21	45.38
Soil depth		

Soil class	**Area (km²)**	**Area (%)**
Deep	52.77	32.27
Moderately deep	33.93	20.75
Moderate	41.54	25.41
Shallow	35.27	21.57
Total (each attribute)	**163.51**	**100.00**

Source: Based on NBSS&LUP soil texture and soil depth maps and GIS analysis.

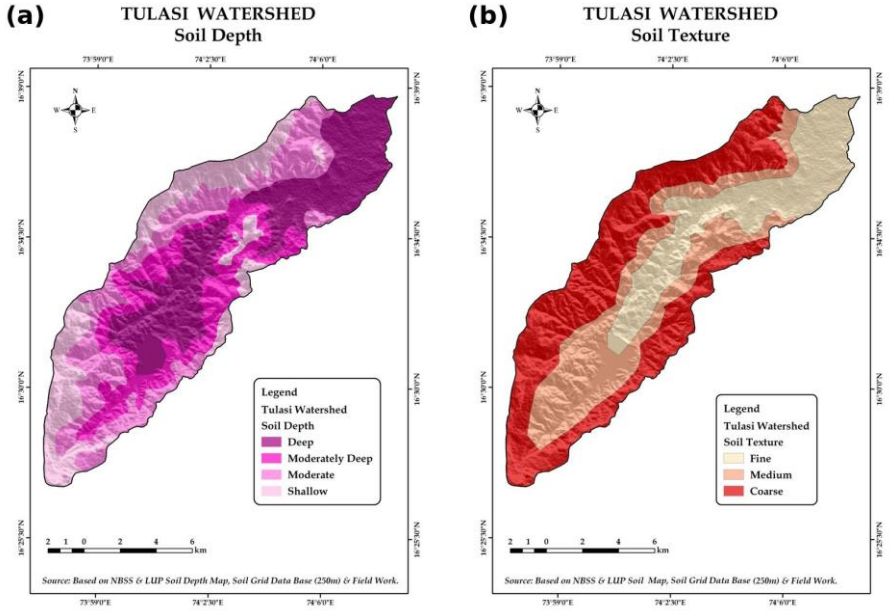

Fig. 8. (a) Soil depth and (b) soil texture of the Tulasi watershed.

6 Climate

Climate controls water availability and hence watershed development. The basin lies on the eastern flank of the Western Ghats and has a monsoon climate, with about 80% of annual rainfall received in the rainy season (June–October). The long-term (2000–2013) mean annual rainfall is 2,199.88 mm, declining from 2,652.41 mm in the south-western hill flank to 1,772.56 mm near the north-eastern confluence (Fig. 9a). Mean annual temperature is about 24.5 °C, with mean annual minimum and maximum temperatures of 18.58 °C and 30.43 °C, respectively; summer maxima occasionally reach 38 °C. The delineated sub-watersheds (Fig. 9b) provide the units for the prioritisation of conservation measures (Pawar-Patil & Mali, 2013; Thakur & Sharma, 2014).

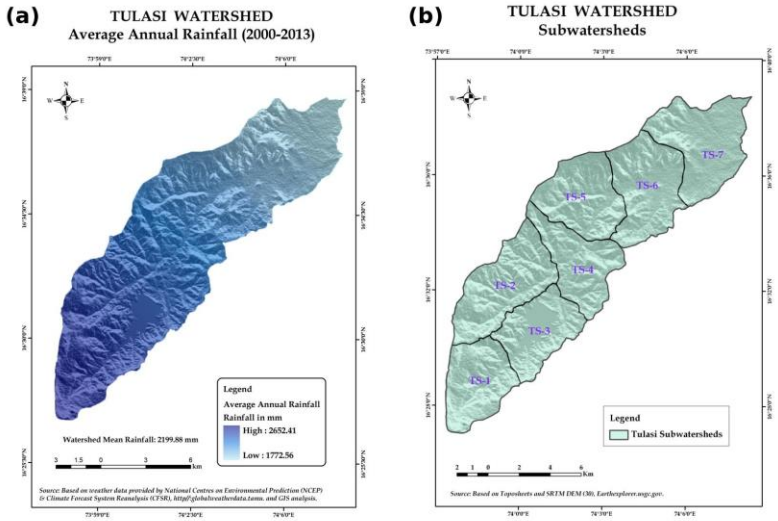

Fig. 9. (a) Rainfall distribution (2000–2013) and (b) delineated sub-watersheds of the Tulasi watershed.

7 Integrated interpretation

Taken together, the layers describe a coherent geomorphic system. Steep, rainfall-rich, shallow-soiled hill flanks on basalt in the south-west, west and east generate rapid runoff and are the zones most exposed to soil loss, and the steep upper tributaries feed a deeply incised trunk valley. Moving downstream, slope and relief decline, soils deepen and become finer, and terrain wetness rises, so that the plain at the outlet accumulates both water and fertile material. This contrast supports an

upland-to-lowland management logic: erosion control, contour-based water-harvesting structures and vegetative cover on the hills, and efficient irrigation and drainage management on the plain. The conclusions rest on 30 m data and on published regional thematic maps, and field validation, finer-resolution DEMs, and quantitative morphometric and erosion modelling would strengthen them.

Conclusions

The Tulasi watershed is a basalt-floored, elongated, fifth-order basin on the eastern flank of the Western Ghats. Its upper and middle parts are rugged and dissected: hills occupy 72.8% of the area, slopes reach 62.3° and south-western rainfall exceeds 2,600 mm per year, conditions that favour rapid surface runoff and soil loss during the monsoon. Dissected plateaus occur in the middle and lower reaches, and the lower confluence zone is a plain of deep, fine-textured, fertile soil that supports agriculture. The terrain, soil and climate database assembled here offers a baseline for sub-watershed prioritisation, soil and water conservation planning and further hydrological modelling in this part of the Western Ghats.

Acknowledgement

The author expresses sincere gratitude to all those who provided valuable support and guidance during the completion of this research work entitled “Geomorphic Assessment of the Tulasi Watershed, Western Ghats (Maharashtra, India), Using Geospatial Technology.”

The author is thankful to the concerned academic institutions, departments, and research organizations for providing the necessary academic environment, facilities, and support required for conducting this study. The availability of geospatial datasets, remote sensing imagery, topographic information, and GIS-based resources greatly contributed to the successful analysis and interpretation of the geomorphic characteristics of the Tulasi Watershed

Financial support and sponsorship

Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of thesis paper.

References

1. Beven, K. J., & Kirkby, M. J. (1979). A physically based, variable contributing area model of basin hydrology. *Hydrological Sciences Bulletin*, *24*(1), 43–69. https://doi.org/10.1080/02626667909491834
2. Conrad, O., Bechtel, B., Bock, M., Dietrich, H., Fischer, E., Gerlitz, L., Wehberg, J., Wichmann, V., & Böhner, J. (2015). System for Automated Geoscientific Analyses (SAGA) v. 2.1.4. *Geoscientific Model Development*, *8*(7), 1991–2007. https://doi.org/10.5194/gmd-8-1991-2015
3. Farr, T. G., Rosen, P. A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, M., Oskin, M., Burbank, D., & Alsdorf, D. (2007). The Shuttle Radar Topography Mission. *Reviews of Geophysics*, *45*(2), RG2004. https://doi.org/10.1029/2005RG000183
4. Florinsky, I. V. (2016). *Digital terrain analysis in soil science and geology* (2nd ed.). Academic Press.
5. Geological Survey of India. (1999). *Geology and mineral resources map of Kolhapur district, Maharashtra* [Map]. Geological Survey of India.
6. Gunnell, Y., & Radhakrishna, B. P. (Eds.). (2001). *Sahyadri: The great escarpment of the Indian subcontinent* (Memoir 47). Geological Society of India.
7. Hjerdt, K. N., McDonnell, J. J., Seibert, J., & Rodhe, A. (2004). A new topographic index to quantify downslope controls on local drainage. *Water Resources Research*, *40*(5), W05602. https://doi.org/10.1029/2004WR003130
8. Horn, B. K. P. (1981). Hill shading and the reflectance map. *Proceedings of the IEEE*, *69*(1), 14–47.
9. Kale, V. S., & Shejwalkar, N. (2008). Uplift along the western margin of the Deccan Basalt Province: Is there any geomorphic evidence? *Journal of Earth System Science*, *117*(6), 959–971.
10. Kamble, P. B., Shinde, J. U., Herlekar, M. A., Gawali, P. B., Umrikar, B. N., Varade, A. M., & Aher, S. (2019). Morphometric analysis of Ratnagiri coast, western Maharashtra, using remote sensing and GIS techniques. *Journal of Geosciences Research*, *4*(2).
11. Kandekar, V. U., Gavit, B. K., Atre, A. A., Bansod, R. D., & Nimbalkar, C. A. (2021). Morphometric analysis of Agadgaon watershed using remote sensing and geographic information system. *Journal of Pharmacognosy and Phytochemistry*, *10*(2), 450–460. https://doi.org/10.22271/phyto.2021.v10.i2f.13839
12. Nag, S. K., & Chakraborty, S. (2003). Influence of rock types and structures in the development of drainage network in hard rock area. *Journal of the Indian Society of Remote Sensing*, *31*(1), 25–35.
13. National Bureau of Soil Survey and Land Use Planning. (2005). *Soil resource mapping project*. NBSS&LUP and Department of Space.
14. Pareta, K., & Pareta, U. (2011). Quantitative morphometric analysis of a watershed of Yamuna basin, India using ASTER (DEM) data and GIS. *International Journal of Geomatics and Geosciences*, *2*(1), 248–269.
15. Pawar-Patil, V. S., & Mali, S. (2013). Watershed characterization and prioritization of Tulasi sub-watersheds: A geospatial approach. *International Journal of Innovative Research in Science, Engineering and Technology*, *2*(6), 2182–2189.
16. Pike, R. J., Evans, I. S., & Hengl, T. (2009). Geomorphometry: A brief guide. In T. Hengl & H. I. Reuter (Eds.), *Geomorphometry: Concepts, software, applications* (Developments in Soil Science, Vol. 33, pp. 3–30). Elsevier.

17. Riihimäki, H., Kemppinen, J., Kopecký, M., & Luoto, M. (2021). Topographic wetness index as a proxy for soil moisture: The importance of flow-routing algorithm and grid resolution. *Water Resources Research, 57*(10), e2021WR029871. https://doi.org/10.1029/2021WR029871
18. Schoene, B., Eddy, M. P., Samperton, K. M., Keller, C. B., Keller, G., Adatte, T., & Khadri, S. F. R. (2019). U-Pb constraints on pulsed eruption of the Deccan Traps across the end-Cretaceous mass extinction. *Science, 363*(6429), 862–866. https://doi.org/10.1126/science.aau2422
19. Singh, C. P., & Sinha, N. K. P. (1996). Analysis of the relief of South Mirzapur upland, U.P., India. *National Geographical Journal of India, 42*(3–4), 267–280.
20. Sørensen, R., Zinko, U., & Seibert, J. (2006). On the calculation of the topographic wetness index: Evaluation of different methods based on field observations. *Hydrology and Earth System Sciences, 10*(1), 101–112. https://doi.org/10.5194/hess-10-101-2006
21. Sprain, C. J., Renne, P. R., Vanderkluysen, L., Pande, K., Self, S., & Mittal, T. (2019). The eruptive tempo of Deccan volcanism in relation to the Cretaceous–Paleogene boundary. *Science, 363*(6429), 866–870. https://doi.org/10.1126/science.aav1446
22. Thakur, B. R., & Sharma, D. D. (2014). *Characterization and prioritization of Giri watershed: An integrated approach* [Major research project report]. University Grants Commission.