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Remote Sensing and GIS Assessment of Flood Zones: A Case Study of the Bhima River Basin

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Abstract*:* Assessing flood zones represent a paramount challenge in hydrology due to its critical nature. This task is crucial as it plays a pivotal role in mitigating economic and human losses. Real-time flood forecasting is a highly effective non-structural approach in flood management. However, issuing flood warnings to communities involves substantial uncertainty. Throughout history, this uncertainty has predominantly stemmed from the data and models utilized for flood forecasting. Floodplain management employs applied methods where river engineering plays a crucial role in implementing river training practices. Simplifying the complex hydraulic behavior of rivers is essential for this purpose. This study demonstrates the application of these technologies in a flood forecasting context and explores strategies for effectively communicating uncertainties to the public. Modern GIS technology has emerged as a potent instrument for delineating flood risk zones, crucial for planning and managing natural hazards. The Bhīma river basin, a significant hydrological region in India, served as the focal area for this research. Satellite imagery, along with base maps encompassing river basins. The definitive flood zone map is divided into four categories: high, medium, low, and very low. The main conclusion of this study reveals that the upper and central sections of the Bhīma river basin are exposed to considerable too high and medium flood risk. This research intends to assist authorities in formulating development strategies to recognize risks in the Bhīma river basin area.

Keywords: *GIS, flood hazard, flood zone, mapping, remote sensing, weighted overlay analysis*

1. Introduction

Disaster does not cause effect; the effect is what we call a disaster (Wolf Dombrowsky, 1995). This quote emphasizes the consequence rather than the origin, highlighting the necessity to examine the impact of calamities. Natural disasters are inherent in our human habitat (Moradi *et al.*, 2020). Disaster is characterized as a significant disruption in societal functioning, resulting in substantial repercussions on economy, social fabric, financial stability, or environmental integrity that surpass the affected community's ability to cope with using its own existing resources (Plessis, 2002). A disaster arises from risks, insufficient capabilities, or actions aimed at mitigating risk factors (Patel *et al.*, 2018). Natural calamities often result in significant loss of life and extensive socio-economic harm (Jain *et al.*, 2018). Disasters are deemed hazardous when they impact human lives. A hazard is defined as perilous or unsafe conditions or events that are threatening or have the potential to cause harm or damage to human life, property, or the environment (Gabriel *et al.*, 2005). Hazards can stem from natural, human-made, or socio-environmental origins (Leahy *et al.*, 2007). Floods are a natural calamity that impact humans and the environment (Solaimani *et al.*, 2009).

The frequency, concentration, scale and cost of destruction are increasing globally. Flooding is a transient state involving partial, restricted, or total submersion of typically dry areas due to uncommon and rapid runoff accumulation (Govt. of India, CWC). According to the (Kordahari *et al.*, 2011), a flood can be described as "a natural event causing temporary inundation of land that is normally dry." (Borga *et al.*, 2011) similarly defines floods as "the overflowing of water onto land that is not usually submerged." Floods happen when rivers breach their natural boundaries due to intense rainfall, snowfall, or snowmelt, dam break problem etc.

Floods are generally classified in three type that flash flood, river flood and coastal flood (Wang *et al.*, 2011). These are natural disasters that cannot be prevented, resulting in severe consequences such as people being displaced and environmental losses (Francesco *et al.*, 2014). Floods are influenced by factors like deforestation, land development, industrial growth, agriculture, and changes in river flow (Gaurang *et al.*, 2014). Flooding can also result from alterations in the environment and human interventions in natural processes, such as urban expansion in flood-prone lowlands, modifications to natural drainage and river courses, as well as deforestation and climate variability (synthesis report, 2014).

The recurring flooding in certain areas is primarily caused by inadequate land use planning and the construction and location of dams. Poor design and construction of

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hydraulic structures like dams and reservoirs can lead to catastrophic outcomes such as dam failure, flooding of roads, and submersion of bridges (Elsafi *et al.*, 2014). Floods encompass various impacts including structural erosion, contamination of food and water sources, disruption of social and economic activities such as transportation and communication, and damage to life and property (Timbadiya *et al.*, 2014).

Floods account for approximately one-third of all fatalities, including injuries and damage, resulting from natural disasters (Darshan *et al.*, 2015). In India, floods and windstorms contribute to sixty percent of all disasters. A land area of 4 hectares is vulnerable to recurrent flooding (Supriya *et al.*, 2015).

Annually, floods occur in various regions of the country, impacting approximately 78 lakh hectares of land, with an estimated average seasonal cost of 240 crore rupees (Warghat *et al.*, 2012). According to the Planning Commission's flood control program, the total flood-prone area in our country spans about 4.56 lakh square kilometres.

Despite of all this to control flood disaster by using different technology is important. The use of modern technology can make possible to have an early warning for flood and its impact are likely to be caused by flood (Tehrany *et al.*, 2015).

Remote sensing and GIS technology is highly beneficial and robust for flood control (Santos *et al.*, 2017). The challenges associated with flooding in the Bhīma river basin have significantly escalated, necessitating advanced flood modelling to comprehend the issue and reduce its hazardous impact (Gert, 1997). The research integrates satellite and relevant datasets through ArcGIS software to develop and finalize flood risk zones, aiming to safeguard lives, property, and resources from flood damage (Kumar *et al.*, 2014).

2. Study Area

Bhīma River originates in India's rain shadow area located in the Western Ghats. The Upper Bhīma basin extends geographically from 73°30'0'' - 75°15'0" E and 18°0'00" - 19°30'00" N, encompassing a total area around 15860 km^2 (Fig. 1). The basin's geography is undulating, with elevations ranging from 499 to 1298 meters above the sea level. The basin's western edge is highly rugged. The central region is characterized by small hills, whereas the eastern region is marked by gently sloping terrain and declining hills (Central Ground Water Board (CGWB), Department of Water Resources). The climate in the basin is tropical monsoon, with maximum and minimum temperatures of roughly 38°C to 11°C in April and the month of January, respectively. The basin receives an average yearly precipitation of 1233 mm, predominantly influenced by the southwest monsoon. The existence of the Western Ghats range of mountains results in over 3000 mm of rainfall in the western section of the basin, which gradually drops to 600 mm at the basin discharge (Pandurang *et al.*, 2023). Considering its close proximity to Western Ghats, the Bhīma River, one of the main tributaries of the river Krishna, discharges a substantial amount of flow. A large portion of the basin is encompassed by wastelands, including open and dense scrub, degraded terrain, barren rocky waste, and stony waste, deemed useless for cultivation because of their thin soil coverage and susceptibility to erosion.

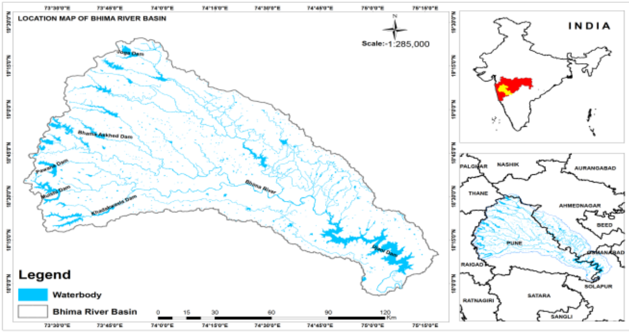

Fig. 1. Location map of Bhīma river basin

3. Methodology

The flood hazard analysis was carried by using multi criteria evaluation (MCE) (Ajin *et al.*, 2013). To execute MCE (Bera *et al.*, 2013) the selected flood factors like geology map, soil map, elevation, slope map, drainage map, LULC map, contour map and rainfall map is used. The detail flow chart is shown in Fig. 2.

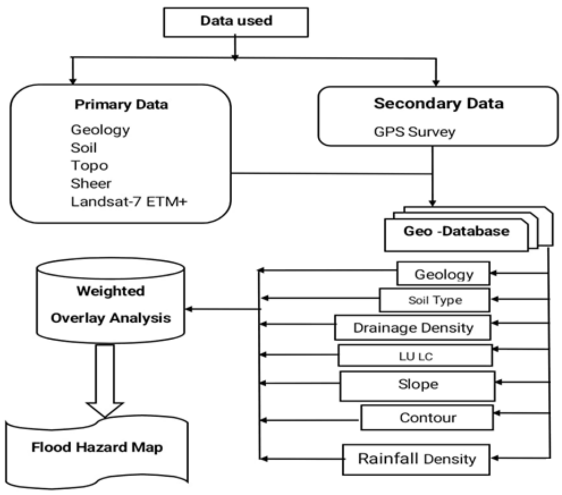

Fig. 2. Flow chart of methodology

3.1. Tools/Data and software employed

The study relies on primary and secondary data gathered from various government offices and official websites. Various software tools were utilized to create the final map, incorporating land use land cover, geology, soil, drainage, slope, contour and rainfall data, which were prepared, developed, and weighted. The weighted overlay technique was applied for analysis using ArcGIS 10.1. The Model Builder within ArcGIS was employed to generate a flood hazard map based on appropriate weighted values.

Table 1. Data collection and software used

Areas	*Tools/Data and software employed*	*Sources of data and versions of software*
The data employed	Topo sheet	Survey of India (SOI) /National Mapping Agency (NMA) https://www.surveyofindia.gov.in/
	Geology	Geological Survey of India (GSI) https://www.gsi.gov.in
	Soil	National Bureau of Soil Survey and Land use
	Landsat	Global Land Cover Facility
	Rainfall	Indian Metrological Department (IMD) https://mausam.imd.gov.in/
The software utilized	Arc GIS	10.1
	ERDAS	9.0
	MS Office	2010

3.2. Preparation of Map (Hendra Pachri et al,, 2013) by using Geographical Information System (GIS)

Geology: The Bhīma river basin geology is characterized by its foundation in the Deccan trap a large igneous province in west central India. The basin predominantly consists of robust, volcanic basalt rock formations from the Deccan Traps. This basalt is of cretaceous to Paleogene age and is known for its thickness which varies from 7 to 45 m in the basin, the terrain and topography is divided into three parts as western part, central part and eastern part. The western part is marked by extremely rugged terrain with deep valley and hill ranges. The high relief in this area led to significant variation in elevation ranging from 499 to 1298 metre above sea level. The central part has smaller hill and large spur that extend from plateaux. The eastern part characterized by rolling topography and low hills which gradually descend into broader valley. The soil depth across the basin varies significantly from as 80 mm to as deep as 1650 mm. The most soil profile in the region is single layer. Fig. 3 shows the details of geology of study area.

Table 2. Lithological Index of Geology

Code	*Lithology*	*Strategic status*	*Nature and characteristics*
1	2 Compound pahoehoe flows (40-50m)	Lower Ratangad Fm	The rock is a dense, dark gray with fine to medium grain, appearing massive and hard, and showing moderate porphyritic texture
2	12-14 the area consists mainly of compound pahoehoe lava flows, with some Aa flows reaching a maximum thickness of 260 meters.	Upper Ratangad Fm	Dark grey, fine to medium, grained, massive, hard, compact and moderately non-porphyritic to porphyritic with olivine phynocrysts
3	Megacryst compound pahoehoe ballistic flow M3 (50-60m)	Upper Ratangad Fm	The rock exhibits a dark gray colour with a medium grain size, appearing massive, hard, and compact, with prominent large

			feldspar phenocrysts.
4	5 Aa and 1 compound pahoehoe balastic lava flows (50-220m)	Indrayani Fmn	The rock is dark gray, with a fine to medium grain size, appearing massive, hard, and compact, displaying moderate variation in porphyritic texture.
5	4-5 compound pahoehoe balastic lav flows (Max. 60m)	Karla Fmn	The rock is dark gray, fine to medium-grained, hard, and compact, with a moderately porphyritic to non-porphyritic texture.
6	3-15 Aa and simple balastic lava flows (50-350m)	Dive ghat Fmn	The rock is dark gray, fine to medium-grained, hard, and compact, with a sparsely to highly porphyritic texture.
7	11-16 aa and simple balastic lava flows (100-300m)	Purandar Formation	The rock is dark gray, fine to medium-grained, hard, compact, and exhibits a porphyritic nature.
8	Megaphenocryst aa flow M4 (50-70 m)	Purandar Formation	Dark grey, medium grained, massive and compact, moderately to highly porphyritic with larg plagoclase laths up to 5 cm in length

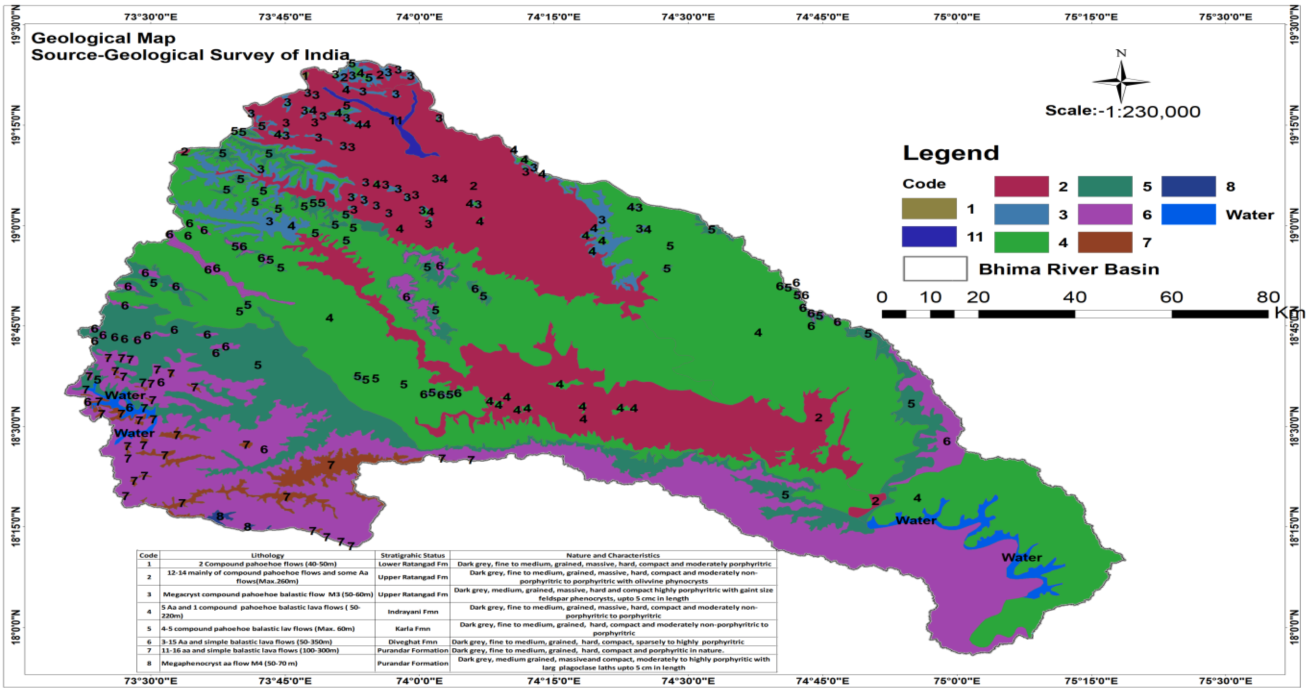

Fig. 3. Geological Map of Bhīma river basin

3.3. Soil

Soil area exhibits a diverse range of soil types influenced by its varied geology and topography. Soil characteristics play a crucial role in determining the agricultural potential, water retention capacity, and overall land use of a region. The Bhīma river basin presents a complex soil profile primarily due to its geological foundation in the Deccan trap and the varying topographical feature from the western ghat to the eastern plain. The depth of soil in the Bhīma river basin varies significantly ranging from 80 mm to 1650 mm. The variability of soil depth is influenced by factor such as topography, erosion, and deposition process. In the high-relief western region, shallow soils are more prevalent due to steep slopes and substantial erosion. Conversely, deeper soils are found in the central and eastern parts of the basin. Most soil profile in the Bhīma river basin are single lathered which affect the soil's water retention capacity and fertility. The single layer nature of the soil is primarily due to the underlying hard basalt rock of the Deccan trap. In the central part of the basin soil depth increasing as the terrain become less rugged. The soil here supports a mix of agricultural and sparse vegetation cover, significantly from as 80mm to as deep as 1650 mm. Most soil profile in the region is single layered. In In the dry period the soil volume shrink and forms deep wide cracks. The soil volume then expands as it gets up. This soil has the slow infiltration rate compared to other soil type because water is moving very slowly through the small pores and it possess high water retaining capacity because it contains very small tightly packed particle that do not allow water to percolate. The details of soil are shown in Fig. 4 and Table 3.

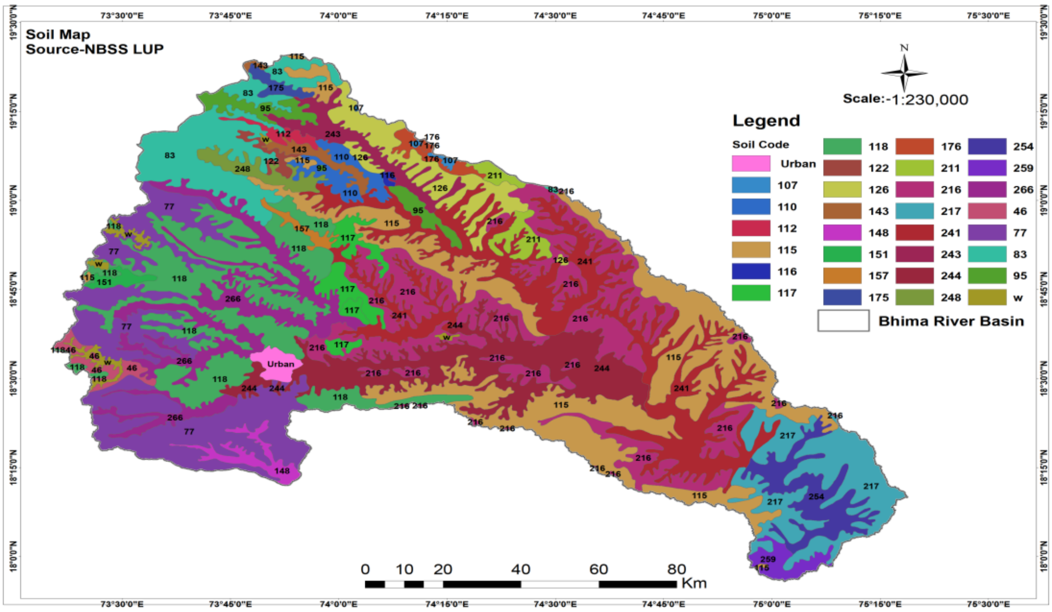

Fig. 4. Soil map of Bhīma river basin

Table 3. Soil code with description

Sr. No.	***Soil Code***	***Description***
1	46	Very deep well drained loamy soil on gently sloping narrow valley with moderate erosion associated with shallow well drained loamy soil on moderately sloping hill slopes and narrow valleys with very severe erosion and moderate stoniness.
2	77	Very shallow excessively drained loamy soils moderately steeply sloping highly dissected hill ranges with escarpments and narrow valleys with very severe erosion.
3	83	Shallow, well drained clayey coils on moderately sloping highly dissected hill ranges on north Sahyadri with moderate erosion; associated with slightly deep moderately well drained clayey soils with moderate erosion.
4	95	Very shallow well drained loamy soil on gently summits/spurs of upper plateau with moderate well drained loamy soils with moderate erosion.
5	107	Shallow, well drained, clayey, calcareous soils, on very gently sloping summits/spurs with moderate erosion, associated with slightly deep, well drained, fine, calcareous soils with moderate erosion.

6	112	Very shallow, excessively drained loamy soils moderately sloping undulating lands with severe erosion and strong stoniness, associated with very shallow, well drained, loamy calcareous soils with moderate erosion.
7	115	Very shallow, well drained, loamy, calcareous soils on gently sloping undulating lands with moderate erosion, associated with very shallow, well drained, loamy, calcareous soils with severe erosion and moderate stoniness.
8	116	Very shallow, well drained, loamy, calcareous soils on gently sloping lands with moderate erosion, associated with very shallow, well drained, loamy, calcareous soils with severe erosion.
9	117	Very shallow, excessively drained loamy soils moderately steep undulating lands severe erosion, moderate and stoniness, associated with very shallow.
10	118	Very shallow, well drained to somewhat excessively drained loamy soils on gently sloping undulating lands, with moderate erosion, associated with very shallow, well drained to somewhat excessively drained, loamy soils with moderate erosion and moderate stoniness.
11	122	Shallow, well drained, loamy soils on gently sloping undulating lands with moderate erosion, associated with moderately deep, moderately well drained, loamy soils with moderate erosion.
12	126	Slightly deep, somewhat excessively drained, loamy soils on gently sloping undulating lands with severe erosion, associated with slightly deep, well drained, fine, calcareous soils with moderate erosion.
13	143	Shallow, well drained, loamy, calcareous soils on very gently sloping plain with moderate erosion, associated with very shallow, well drained, loamy, calcareous soils with moderate erosion.
14	148	Moderately deep, well drained, fine soils on gently sloping narrow valleys with slight erosion, associated with very shallow, well drained clayey soils with slight erosion.
15	151	Shallow, well drained, clayey soils on gently sloping lands with moderate erosion, associated with deep, moderately well drained, fine calcareous soils with moderate erosion.
16	157	Deep, moderately well drained clayey soils on gently sloping plain with slight erosion, associated with deep, well drained, clayey soils with moderate erosion.
17	175	Very shallow, somewhat excessively drained, loamy, calcareous soils on gently sloping undulating lands with mesas and buttes with severe erosion, associated with very shallow excessively drained, loamy soils with very severe erosion and moderate stoniness
18	176	Slightly deep, well drained, fine, calcareous soils, on very gently sloping lands with mesas and buttes with moderate erosion, associated with slightly deep, well drained, fine, calcareous soils with moderate erosion.
19	211	Slightly deep, well drained, fine, moderately calcareous soils, on very gently sloping lands deep, well drained, fine soils with moderate erosion.
20	216	Shallow, well drained, clayey moderately calcareous soils on gently sloping lamds with moderate erosion and moderate stoniness; associated with slightly deep, well drained, fine, moderately calcareous soils with moderate

		erosion and moderate salinity.
21	217	Shallow, well drained, clayey soils on gently sloping lands with moderate erosion and moderate stoniness; associated with slightly deep, moderately well drained, fine, calcareous soils with moderate erosion.
22	241	Deep well drained, fine soil on gently sloping plains and valleys with slight erosion; associated with shallow, somewhat excessively drained, clayey soils with moderate erosion.
23	243	Moderately deep, moderately well drained, clayey soils on very gently sloping plains and valleys with moderate erosion and slight salinity; associated with deep, moderately well drained, clayey soils with moderate erosion.
24	244	Slightly deep, moderately well drained, fine soils on very gently sloping plains and valleys with moderate erosion and moderate salinity; associated with moderately, well drained, clayey, calcareous soils with moderate erosion.
25	248	Shallow, moderately well drained, clayey soils on gently sloping plains and valleys with moderates erosion; associated with moderately shallow, moderately well drained, fine soils with moderate erosion.
26	254	Deep, moderately well drained, fine, calcareous soils on very gently sloping plains and valleys with moderate erosion; associated with shallow, well drained, clayey soils with moderate erosion.
27	259	Deep, moderately well drained, fine, calcareous soils on very gently sloping plains with moderate erosion; associated with moderately deep, moderately well drained, fine, calcareous soils with moderate erosion.
28	266	Deep, moderately well drained, strongly calcareous, fine soils on gently sloping plains and valleys with moderate erosion; associated with moderately deep, moderately well drained, fine strongly calcareous soils with moderate erosion.

3.4. Drainage

The Bhīma river basin features a complex drainage system shaped by its geological and topographical characteristics. Comprehending the drainage pattern within a river basin is crucial for efficient water resource management, flood control, and sustainable development. The Bhīma River serves as the main drainage artery collecting water from numerous tributaries and smaller streams. The Mula and Mutha river system is a major tributary of the Bhīma River, merging with it from the south. This river coverage near the city of Pune before merging with the Bhīma River. This river system plays a crucial role in draining the central part of basin and supporting agricultural and urban areas. Bhīma River is the river running from west to east. The majority of the smallest streams originate in the northwest and southwest corners of the river basin. The basin broadly shows dendritic type of drainage pattern (Fig. 5). A branch-like pattern can emerge on uniform rock, resembling the branching of a tree or the veins of a leaf. This pattern is irregular and represents the most frequent type of drainage system. In this arrangement, numerous smaller streams converge to form tributaries that feed into the main river. Such patterns typically develop where the river course follows the natural slope of the terrain. Dendritic patterns form in V-shaped valleys, necessitating impervious and non-porous rock types (NBSSLUP, 1996, soil survey report). The western part of basin is characterized by a dendritic drainage pattern due to its rugged terrain and high relief. Numerous small streams and rivulets originate from the hill ranges flowing through deep valleys and converging into larger tributaries. The steep slope and heavy monsoon rain in this region contribute to rapid runoff and significant stream flow variability. (Jain, 2009).

Stream classification follows the Strahler method, where all links without tributaries are designated as order 1, or first order. Subsequent orders increase when streams of the same order intersect. Thus, the confluence of two first-order links forms a second-order link, and the convergence of two second-order links generates a third-order link. It is continuing in this manner.

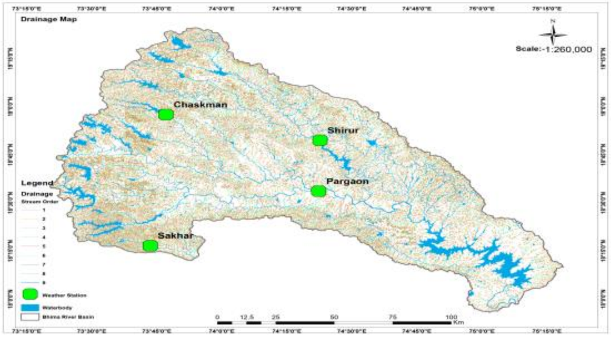

Fig. 5. Drainage Map of Bhīma river basin

3.5. Contour Map

A contour map is created using a Digital Elevation Model (DEM) map. The contour map prepared by considering contour interval of 20 m. The western part of the Bhīma river basin represent closely spaced contour which indicate a steep slope with the highest contour value of 880 m whereas the eastern part of basin represents distant contours which indicate a shallow slope with the lowest contour value. The river flows downhill from higher to lower elevation perpendicular to the contour line above it. The study area contour map is shown in Fig. 6.

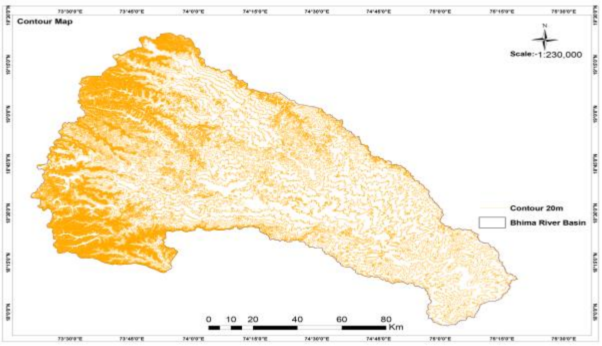

Fig. 6. Contour map of Bhīma river basin

3.6. Digital Elevation Map (DEM)

A Digital Elevation Model (DEM) depicts the digital representation of the topography of the Earth's surface. It is specialized data base that represent surface of point of known elevation. By interpolation method and known elevation data like ground survey and photogrammetric data the details is captured rectangular digital elevation model. Based on the DEM depicted in Fig. 7, the elevation map has been categorized into eight primary classes. The western section of the Bhīma river basin exhibits the highest altitude at 1473 m within the mountainous range, while the eastern part of the basin shows the lowest elevation at approximately 304 meters in the low-lying region. During the rainy season, runoff flows from higher elevations to lower elevations, causing flooding in the low-lying areas.

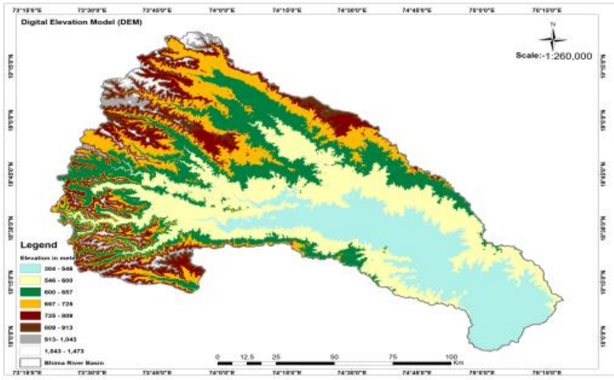

Fig. 7. Digital elevation map of Bhīma river basin

3.7. Slope

The slope tool assesses the gradient at each cell of a raster image. Lower slope values indicate flatter terrain, while higher values indicate steeper terrain. The output slope raster can be calculated in degrees or percent. The CartoDEM, sourced from the National Digital Elevation Model on the Bhuvan Data portal (NRSC, ISRO), was used to generate a slope map of the area using ArcGIS's slope extension tool under data management analysis. The DEM is provided in GeoTIFF format with a geographic projection, later projected to Universal Transverse Mercator (UTM) WGS 84, Zone 43.

In this map there is a colorized representation of slope. The degree of slope steepness is depicted in the range of dark to light colors. Level terrain is depicted in dark green, gentle slopes in light green, moderate slopes in yellow and steep slopes in orange-red on the slope map. The western region exhibits higher slope degrees, indicating steep terrain with mountainous or hilly features. The degree of slope decreases towards east which indicates flatter terrain. The slope value ranges from 2 to 77 .The slope map details shown in Fig. 8.

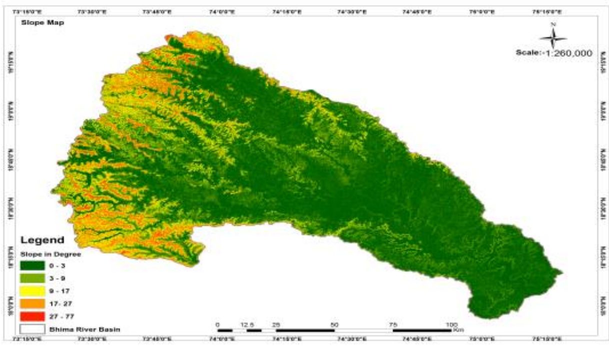

Fig. 8. Slope map of Bhīma river basin

3.8. Land Use and Land Cover (LULC)

The land use and land cover (LULC) data characterize vegetation, natural surfaces, and cultural features on the land. The LULC map was generated using Landsat satellite imagery and ERDAS software (Fig. 8). The unsupervised classification method was applied for creation of LULC of the study area. The LULC is divided into five different classes, agriculture, forest, water body, settlement and barren land. As per LULC analysis for the year 2000 and 2023 there is a gradual increase in settlement as well as barren land. Whereas agricultural land is present on the bank of river, water bodies are located in the southern and western part. The river and its main tributaries run eastward. The northeastern part of the study area has dense urban development. Agricultural land and settlements are severely impacted by flood hazards. Forested areas, however, are less susceptible to these hazards and play a crucial role in flood control. The LULC map details shown in Fig. 9.

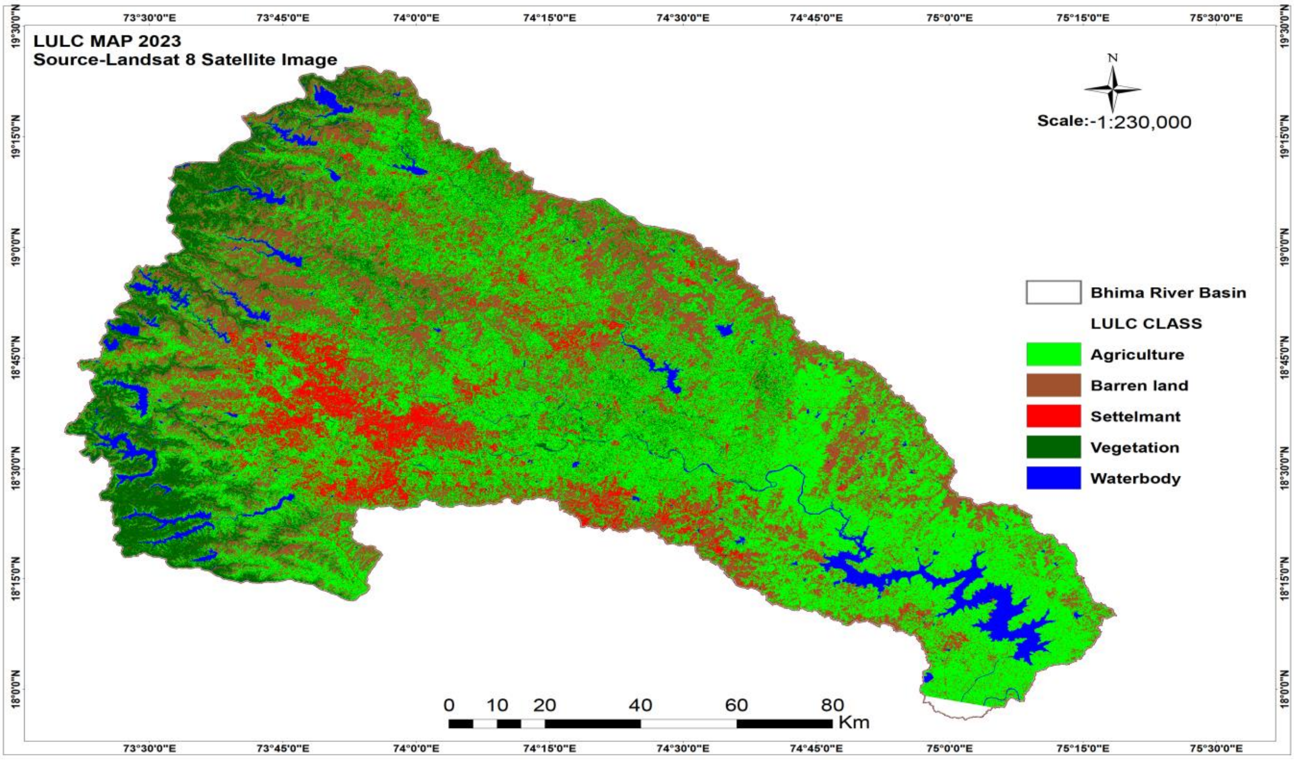

Fig. 9. LULC map of Bhīma river basin

3.9. Rainfall

Precipitation is a critical factor contributing to flooding in the Bhīma River basin. A rainfall grid map was employed for analysis and extracted specifically for the study area using ArcGIS 10.2.2. The following rainfall map was prepared using the PERSIANN-CSS grid format data. The data obtained was yearly average rainfall for the years 2001 and 2022 respectively. The map prepared in a grid format with resolution of 4 km x 4 km (Fig. 10). The lowest average yearly rainfall according to the data in 2001 was 530 mm and highest was 1250 mm. In 2022 the lowest average rainfall was 488 mm and highest rainfall was 1856 mm. This indicates that the rainfall has increased over the years. The precipitation in the region determines the total water availability during the monsoon season. The western part of the basin receives more rainfall due to the Sahyadri mountain range. The maximum average annual rainfall recorded was 1700 mm in both 2001 and 2022.

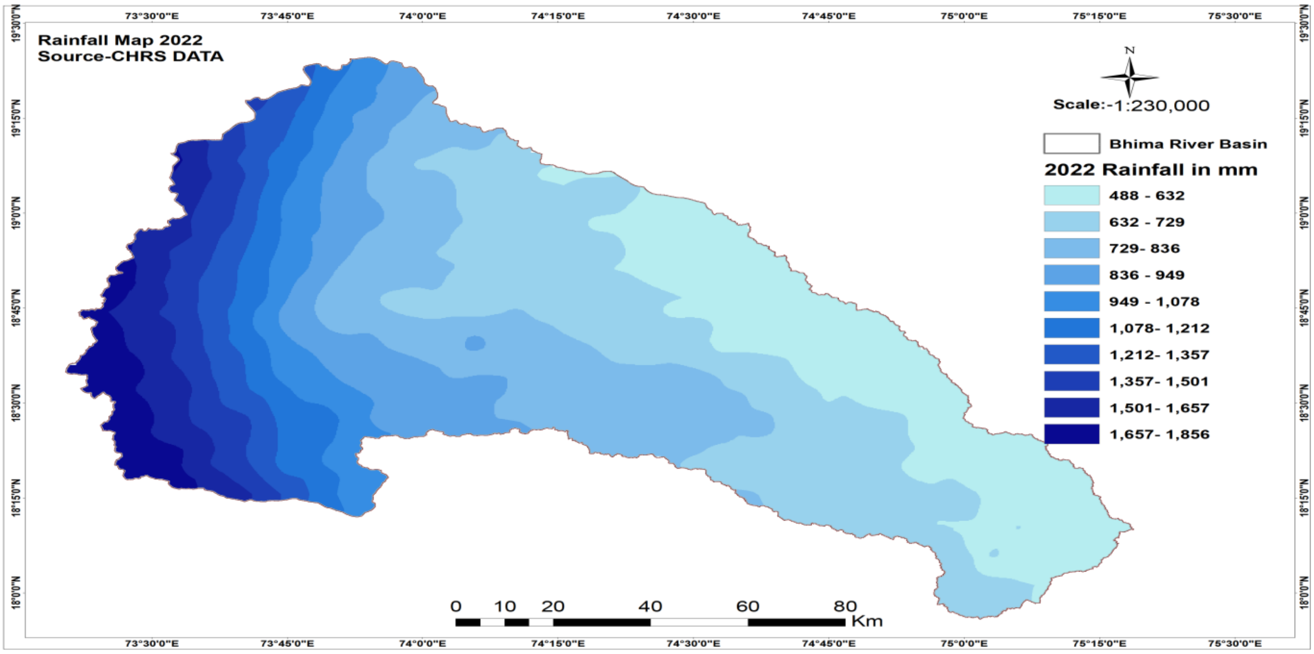

Fig. 10. Magnetization as a function of applied field

3.10. Weighted Overlay Analysis (WOA)

All datasets underwent preprocessing that included geo-referencing, resampling, and standardization to a common scale to ensure compatibility and precision. Each dataset was given a weight according to its relative significance in contributing to flood risk, determined through a mix of field studies and a review of existing literature (Alharbi, 2024). The weighted datasets (Table 4) were subsequently combined using ArcGIS to produce a composite flood risk map, which outlined the flooding zones in the Bhīma River basin with low, medium, high, and very high susceptibility to flooding. This methodology employed advanced geospatial techniques and a multi-criteria approach to thoroughly evaluate flood risk in urban environments (Vahdettin *et al.*, 2016). The results of this study are anticipated to offer valuable insights for policymakers, urban planners, and disaster management authorities.

Table 4. Parameter and weight

Parameter	*Overall Weight (Percentage)*	*Classes*	*Weight*
Slope (degrees)	25	0-3	2
		03-Sep	4
		Sep-17	6
		17-27	8
		27-77	10
Precipitation (mm)	25	529-602	2
		602-649	4
		649-710	6
		710-791	8
		791-875	10
		875-962	12
		962-1053	14
		1053-1150	16
		1150-1251	18

		2 Compound pahoehoe flows (40-50 m)	14
		12-14 mainly of compound pahoehoe flows and some Aa flows(Max. 260 m)	2
		Megacryst compound pahoehoe balastic flow M3 (50-60 m)	12
Geology	10	5 Aa and 1 compound pahoehoe balastic lava flows (50-220 m)	8
		4-5 compound pahoehoe balastic lav flows (Max. 60 m)	12
		3-15 Aa and simple balastic lava flows (50-350 m)	4
		11-16 aa and simple balastic lava flows (100-300 m)	6
		Megaphenocryst aa flow M4 (50-70 m)	10
		Water	0
Soil	15	Urban	0
		Calcareous	2
		Claye	4

		Fine	3
		loamy	1
		water	0
LULC	25	Agriculture	4
		Barren land	6
		Built	4
		Veg	2
		water	0

4. Result and Discussion

The research utilized a weighted overlay analysis to evaluate the potential flood hazard across the Bhima River Basin, displaying the findings through data that highlighted varying levels of vulnerability in different regions of the basin. The integrated flood risk map was produced by combining datasets that included land use and land cover (LULC), rainfall patterns, geology, soil, and slope. Before the overlay analysis, the layers were categorized, weighted, and scored on a scale. (Details are given in Table 4)

GIS technology was employed to create a flood hazard map (Fig. 11) of the Bhima river basin using the Multi-Criteria Evaluation technique. A flood hazard model was developed using diverse datasets in ArcGIS 10.1's Model Builder tool. The weighted overlay analysis method was utilized to generate the flood hazard map, employing various weighted values for different classes. The upper reaches of the Bhima river basin exhibit low flood hazard, along with some parts in the west, east, and Maval taluka. Medium and high flood hazard zones are identified in parts of the eastern and western regions. Areas characterized by low elevation, high rainfall, and substantial runoff are classified under the high flood hazard zone.

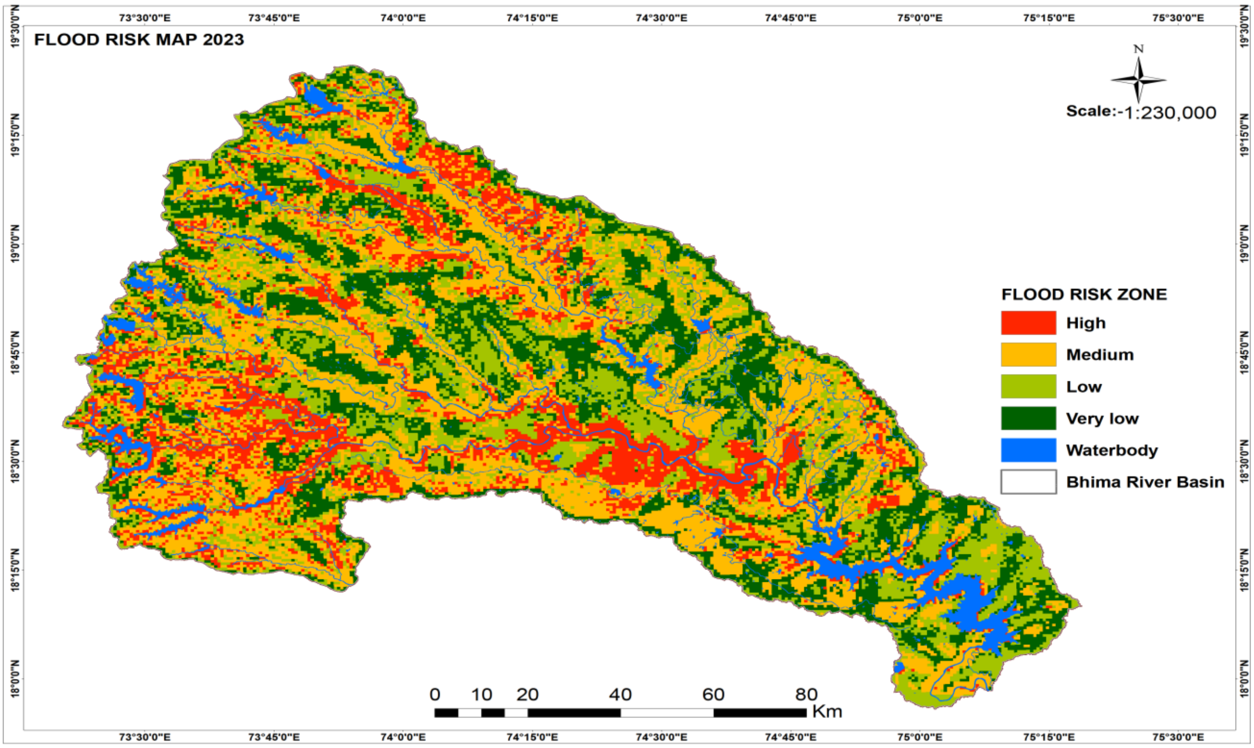

Fig 11. Flood risk map of Bhīma river basin

5. Conclusion

This study demonstrates an effective approach to mapping flood hazard zones in the Bhīma River basin using GIS and remote sensing (RS) technologies. The research effectively pinpointed potential flood zones in the Bhīma River Basin by employing a weighted overlay analysis. This analysis integrated various datasets, including digital elevation models, lithology, rainfall patterns, slope, and drainage density. The outcome of the analysis classified the risk zones into high, medium, low, and very low categories. The study area covers 15859 km² of this total area, 23.98 percent is at very low risk of flooding, while 22.28, 36.14, and 16.60 percent of the area are at low, medium, and high risk of flooding, respectively. It aims to regulate flood hazard zoning to mitigate anticipated damages from flooding. The research identifies agriculture land, vegetation, and urban areas as the most vulnerable to floods. It is conducted for future planning, development, and resource protection. Additionally, the findings will assist local authorities in mitigating flood risks.

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Author contributions

Mahesh Waghmare: Conceptualization, Methodology, Investigation, Writing- Original draft preparation **Shrishail Shahapure:** Data curation, Writing-Reviewing, and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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