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Assessment of Flood Hazard Zone Using Remote Sensing & GIS – A Case Study of Panchganga River Basin, Kolhapur District, Maharashtra

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Abstract:
A flood is a natural hazard on our planet that occurs when water overtops a stream's natural or manmade banks. Floodplains are generally affected by overtopped banks, which often cause problems for residents, crops, and vegetation. Although flood hazards cannot be controlled, we can safeguard and save lives, property, and other resources if we are aware of the threat with the help and advancement of recent technology. GIS is an influential tool that can be used to identify flood risk zone essential for planning and management against this natural hazard. Panchganga river basin is one of the main river basins in southwest Maharashtra. Using satellite (Sentinel 2 & DEM) images, associated base maps (Geology, Soil, River basin, & Toposheet), along with taluka wise rainfall data, the flood hazard map was prepared in the GIS environment with the aid of Arc GIS. The weighted overlay analysis method was followed to prepare the final flood hazard map using suitable feature class weighted values. This map is divided into five classes: Very High, High, Moderate, Low, and Very Low. Key findings of this study suggest that the downstream portion of the Panchganga river basin towards the eastern region is categorized into high to very high flood hazard risk zone which includes parts of Karvir, Hatkanangale, and Shirol taluka. The western region including parts of Bavda, Radhanagari, Panhala, and Shahuwadi lies under a moderate to high flood hazard zone. This study will thus help concerned authorities to formulate their development strategies according to the areas at risk.

Keywords: *Flood Hazard, Sentinel 2, DEM, River Basin, Remote Sensing, GIS, Weighted Overlay*

1. INTRODUCTION

Flooding is a natural threat that occurs as a result of natural factors such as high rainfall, as well as urbanization, and deforestation. Asia, which covers roughly one-fifth of the Earth's surface area, is home to more than half of the world's inhabitants. The Asian region continues to be affected by a disproportionate number of hazard events, resulting in loss of lives, infrastructure, stability, and economic progress due to the intensification and severity of the natural disasters around the world (Arambepola et al, 2009 and Uddin. K, et al. 2013). Major components of the flood hazard include structure, erosion, and degradation, contamination of food and water, interruption of socio-economic activity, including transportation and communication, as well as loss of life and property (Hewitt and Burton, 1971; Muhammad and Saanyol, 2013). Fewer developed areas that are influenced by climate risks have significant development hurdles in the future. While it has proven challenging to improve development levels in underdeveloped nations, (Collier, 2007; UNDP, 1990 to 2014; World Bank, 2002), extreme weather imposes additional restrictions on development in certain areas. (Adger, N.W, et al., 2003, 2006; Kates R.W, 2000; Kates R.W, et al., 2007; Takeuchi and Aginam 2011; Tian. Q, et al., 2015). Studies on natural hazards have been conducted for centuries (Montz and Tobin, 2011). Geographic methodologies for natural hazard assessment have grown from attentiveness on the geophysical environment to integrative studies that focus on both the geophysical and social settings (Burton. I, et al., 1978 and 1993; White. F, 1945). The development of electronic maps and spatial analysis tools has also facilitated research concerning natural hazards and has proven useful in assessing resilience, adaptability, and vulnerability, three important key concepts in climate variability and climate change research (Belmonte. C, et al., 2011; Ho and Umitsu, 2011; Frazier. G, et al., 2013; Malcomb. W, et al., 2014; Santos. A, et al., 2014; Silva. A, et al., 2015; Varis. O, et al., 2014). Generation a good of flood risk zones map requires a tool having complete variability of functionalities and capable of using both spatial and attribute data. The efficacy of Geographic Information Systems (GIS) may be trusted on in this regard. (Ayeni. B, 1998; Clement. A, 2013). The present study as similates the use of Arc GIS software to analyze satellite data and other data in order to finalize the flood risk zone in order to save lives and protect resources from flooding.

2. STUDY AREA

Panchganga River Basin the present study area is in the northern part of Kolhapur district, Maharashtra, India. It flows through the borders of Kolhapur and is a major tributary of the Krishna River, which confluences at Narsobawadi. Panchganga river does not have a true origin being formed at Prayagafter the confluence of its five tributaries. It is, however, formed by the joining of four streams, namely Kasari, Kumbhi, Tulsi, and Bhogawati, in its upper catchment. Local tradition believes the existence of an underground stream namely Saraswati which along with the other four streams constitutes the Panchganga. The study area (Figure-1&2) Panchganga river basin covers an area of about 2582.797 sq. km. on the Earth's surface(Panchganga River Information - The Gazetteers Department - KOLHAPUR District).

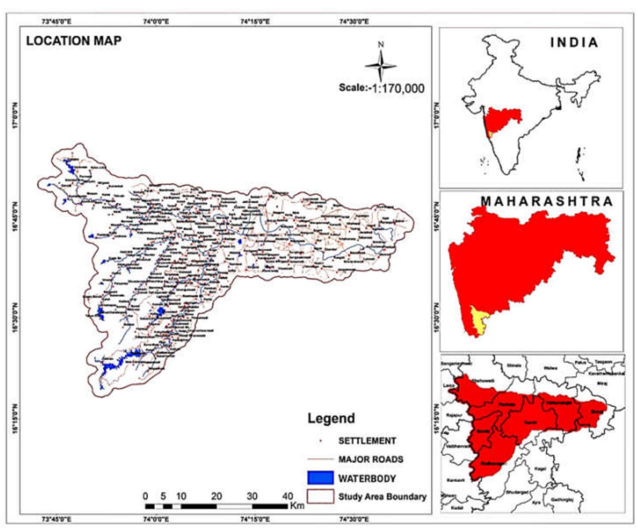


Figure 1: Location Map of the Study Area

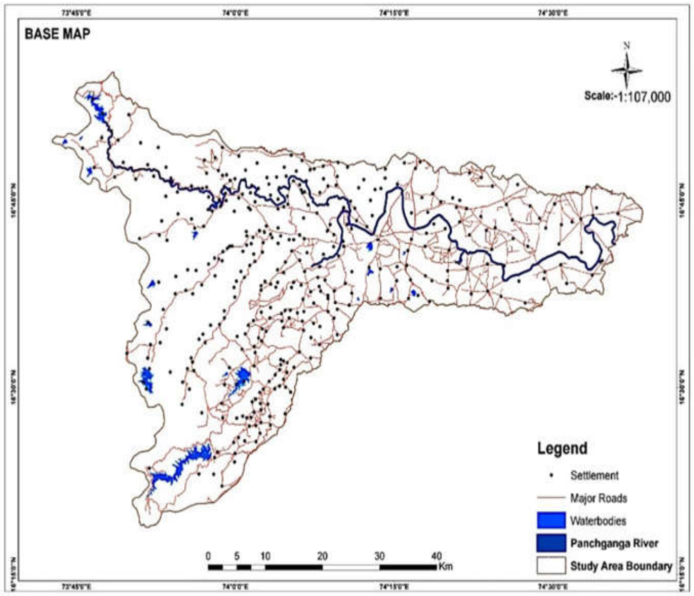


Figure 2: Base Map of the Study Area

3. DATA & SOFTWARE USED

The study was constructed by using both primary and secondary data collected from different sources. In order to study and analyze the flood risk assessment of the study area, satellite-based remote sensing data was used extensively. Table 1 listed below shows the details of various data sets and software used

.

Table 1: Data & Software Used

Areas	Type of Data & Software		Data Source & Software Version
Data Used	Top sheets		SOI
	Geology		GSI
	Soil		NBSS
	Sentinel 2		USGS
	DEM		Bhuvan
	Rainfall	Grid format	CHRS
		Excel sheet format	Agriculture Department, Maharashtra govt.
Software Used	Arc GIS		10.2.2
	ERDAS Imagine		2013

Table 2: Taluka wise Annual Rainfall

Sr. No.	Taluka Name	Annual Rainfall 2005 in (mm)	Annual Rainfall 2006 in (mm)	Annual Rainfall 2018 in (mm)	Annual Rainfall 2019 in (mm)
1	Hatkanangale	1334.0	1609.6	543.7	1252.1
2	Shirol	1050.0	958.0	417.3	892.1
3	Panhala	2540.0	2735.0	1178.1	2607.7
4	Shahuwadi	3450.5	3097.2	2561.2	3147.5
5	Radhanagari	5227.0	5471.0	2215.2	3123.8
6	Bavda	6912.6	7304.0	3946.9	5771.1
7	Karvir	1743.0	1397.7	962.5	1948.1

4. METHODOLOGY

Multi-criteria evaluation (MCE) was adopted to compute the flood hazard analysis. To run MCE, the selected flood causative factors such as elevation, slope, drainage density, geology, soil type, land use, and rainfall were developed and weighted. in order to generate a flood hazard map using a suitable class weighted value. A weighted overlay technique was computed, Arc GIS 10.2.2 Model Builder was used for this purpose. Details of the methodology are documented in the flow chart in (Figure-3).

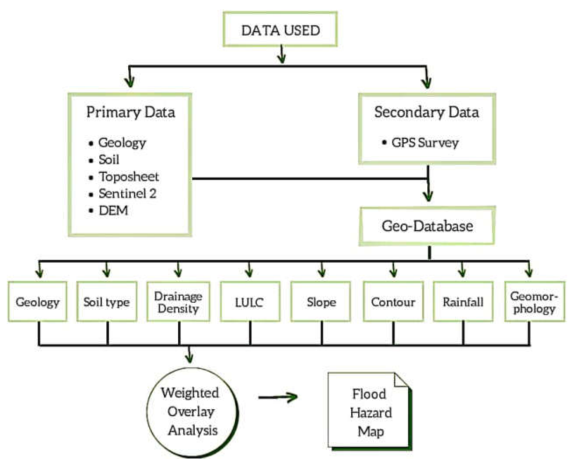


Figure 3: Methodological Flow Chat

5. RESULT & DISCUSSION

5.1 Geology

Geologically the area is covered with unclassified basalt flows, mainly Aa simple flows, megacryst flow, essentially Aa simple flows, and laterite. The lithology comprises basalt with isolated patches of laterite outcrops, all on top of the Archean-Proterozoic basement. The western and the northern region is fundamentally composed of Aa flows, which forms when lava flows rapidly. There is rapid heat loss resulting in an increase in the viscosity in these circumstances. Aa lavas are associated with high discharge rates and steep slopes. The megacryst flows are all along the margin of mainly Aa simple flows. The center to the eastern region has unclassified basalt flows as per the recently available data (Figure 4).

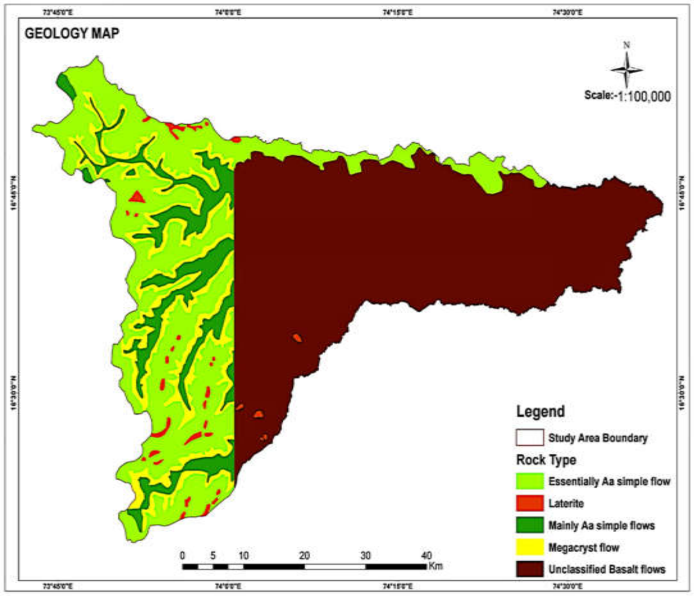


Figure 4: Geology Map of Panchganga River Basin

5.2 Soil Type

Water movement in the soil is influenced by soil drainage. Soil type, structure, texture, and physical condition of the surface and sub-surface soil layer are all significant elements in soil drainage. In the study area, loamy, fine, clayey soil types are present. Owing to their loose texture the clayey, fine, and loamy soils are more effective in soil erosion than all other soil types; due to loose texture. If loose texture soil is present in the flood-prone area then it gives the highest scale of flood hazard rating. The soil map of the study area is included in (Figure-5).

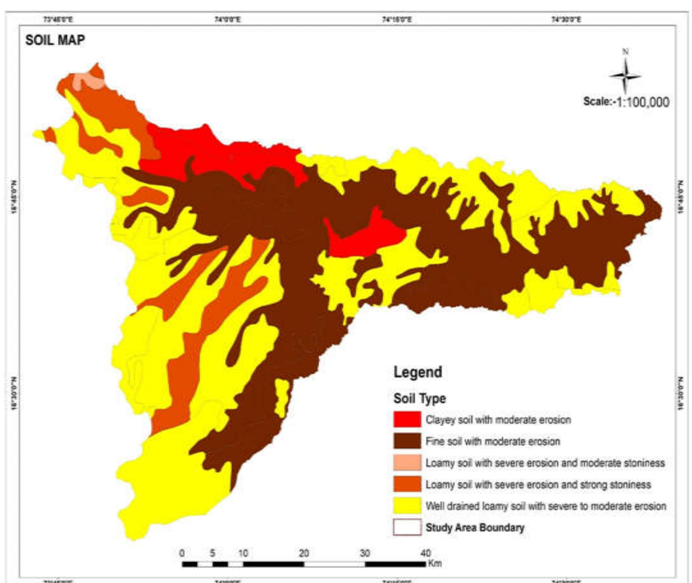


Figure 5: Soil Map of Panchganga River Basin

5.3 Drainage

Panchganga the main river in the study area flows from west to east and it is a major tributary of the Krishna River, with which it joins at Narsobawadi. The river basin covers 2582.797 sq. km with its tributaries Kasari, Kumbhi, Tulsi, and Bhogawati. Panchganga river has no true origin, being formed at Prayag after the confluence of its five tributaries. It starts from Prayag Sangam (16°44'04"N, 74°10'44"E) (Village: Chikhli. Taluka: Karveer, Dist: Kolhapur). Majority of the first-order streams originate in the northwest and southwest regions of the drainage basin. The basin broadly shows a dendritic type of drainage pattern. The streams are generally flowing west to east, following a pattern similar to that observed with the contours. Waterbodies are observed mostly in the southwestern, hilly regions. (Figure-6).

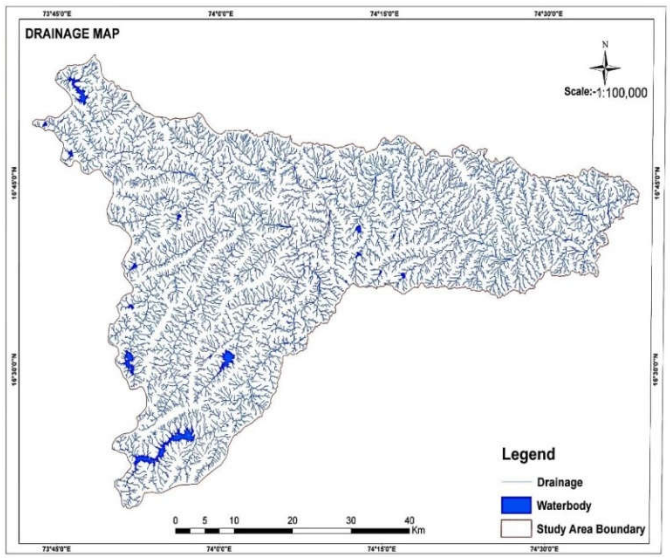


Figure 6: Drainage Map of the Study Area

5.4 Elevation and Contour

Western part of the Panchganga river basin signifies the highest elevation of 1024 mts and falls under the high hill mountain range category. Whereas the eastern part of the basin represents the lowest elevation of about 45 2mts, and is classified under the low-lying area. In the rainy season, runoff water travels from the highest elevation to the lowest elevation, flooding the low-lying areas (Figure 7). A contour map has been prepared by considering a contour interval of 20m. The western part of the Panchganga river basin represents closely spaced contours that indicate a steep slope, with the highest contour value of 1020mts. Whereas the eastern part of the basin represents distant contours that indicate a shallow slope, with the lowest contour value of 460mts. The river flows downhill from higher to lower elevations, perpendicular to the contour line above it (Figure 8). A 3D View of the Panchganga River Basin is depicted in Figure 8a.

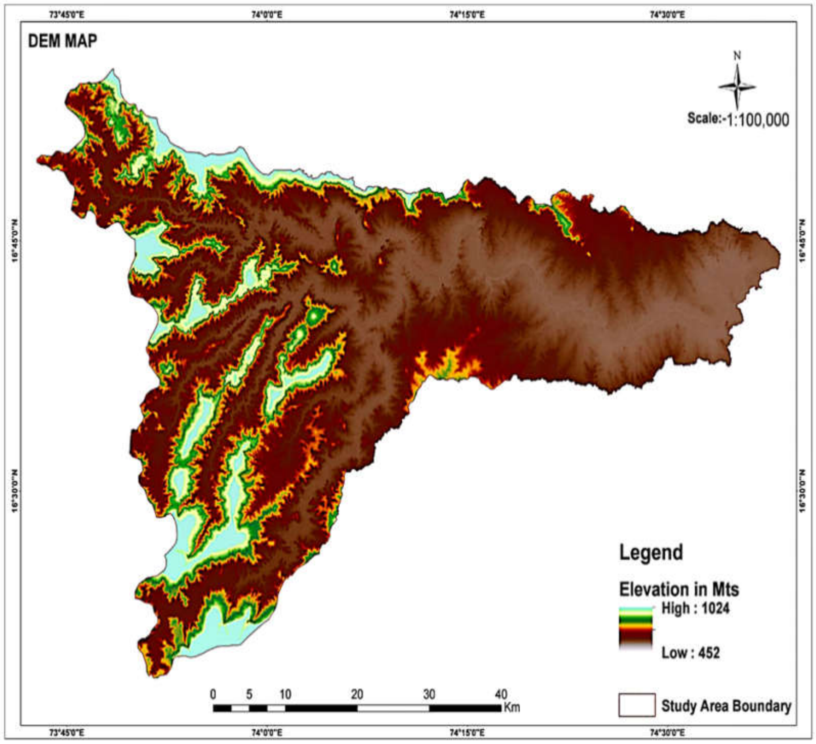


Figure 7: Elevation Map of the Study Area

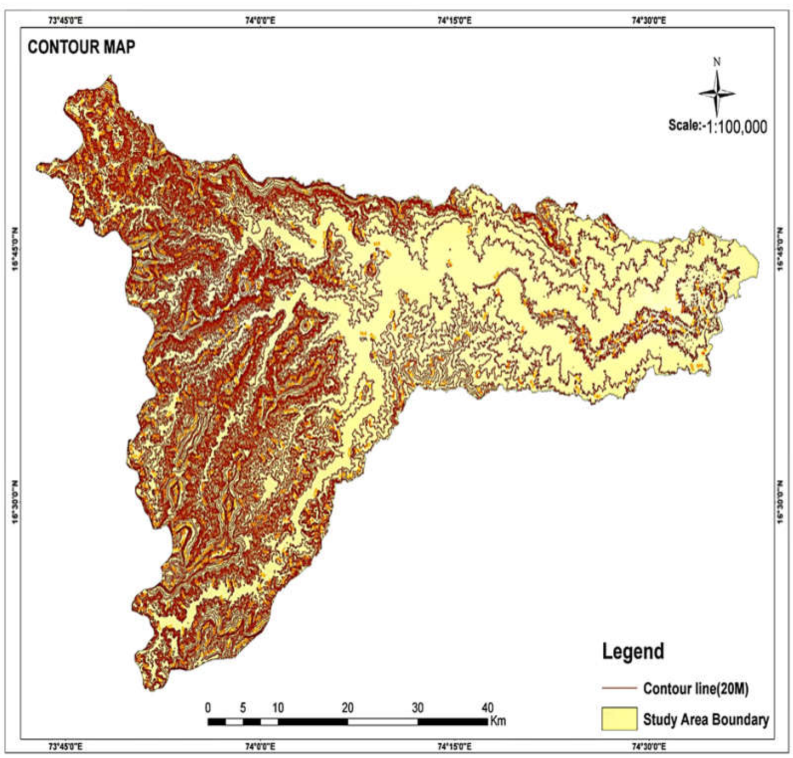


Figure 8: Contour Map of the Study Area

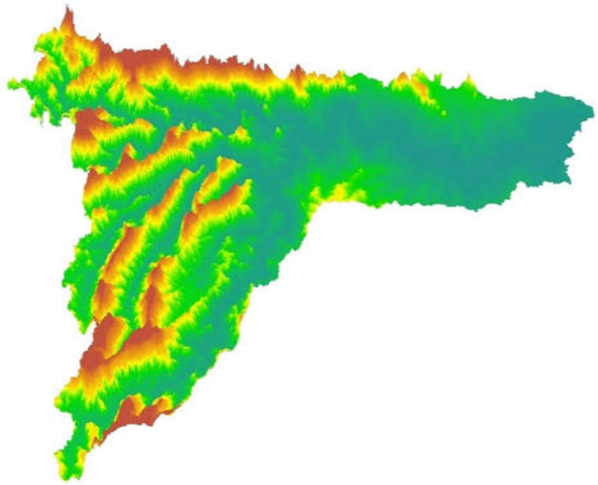


Figure 8a: 3D View of the Panchganga River Basin

5.5 Slope

This map provides a colorized representation of the slope. The degree of slope steepness is represented by the dark to light colours- flat surfaces are denoted as dark green, shallow slopes as light green, moderate slopes as yellow and steep slopes as orange-red. The degree of slope is high in the western part which indicates a steeper slope and the presence of a mountain or hill range. The degree of slope decreases towards the east which indicates flatter terrain. Slope and flood hazards are in inverse relationship with one another. Steeper the slope, the lower the risk of flood hazards. Shallower the slope, the higher the risk of flood hazards. Water will run rapidly via overland flow and enter into the river on steeper slopes. Also due to the steep slope angles, rain is less likely to infiltrate into the ground in these areas. With more overland flow rate, this can also cause flooding (Figure-9).

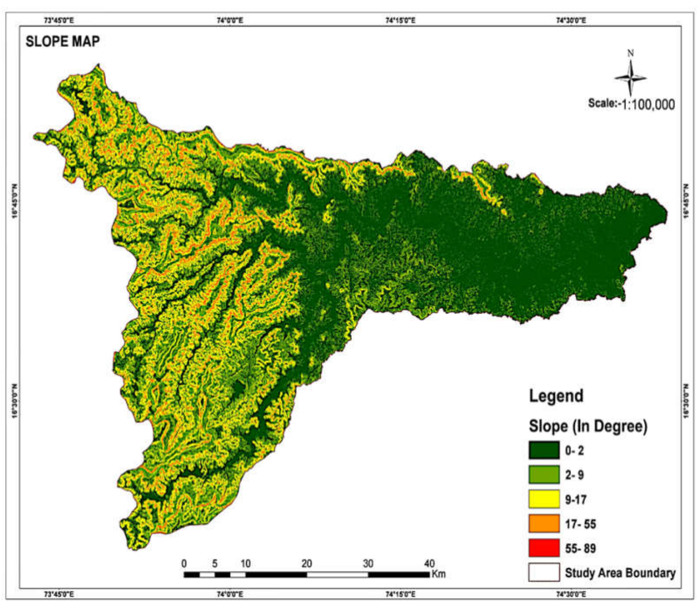


Figure 9: Slope Map of the Study Area

5.6 Land Use / Land Cover

The land use and land cover (LULC) data files define the vegetation, water, natural surface, and cultural features on the land surface. The LULC map was prepared by using USGS satellite image and ERDAS software. An unsupervised classification method was used for creating the LULC of the study area. LULC is divided into five different classes; forest, agriculture, waterbody, settlement, and barren land. According to the LULC analysis, the area of settlement is 91.416928sq.km. while the area under agriculture is 900.364681sq.km.Over 532.540034sq.km. of the area is under forest cover. The remaining area is barren land which covers 1025.24467sq.km. Waterbodies cover an area of about 42.83872sq.km. Hilly mountainous region is covered by forest, discrete type of vegetation is present all around the study area, agricultural land is seen to occur on the banks of the river, and water bodies are located in the southern and western part. The river and its major tributaries flow towards the east. Dispersed settlements are present in the study area but high settlement density occurs in the north-eastern part of the study area. Due to the flood hazard, agricultural lands and settlements as well as other resources are highly affected. Forest land is less affected by this hazard, and the forests help in controlling the floods (Figure-10).

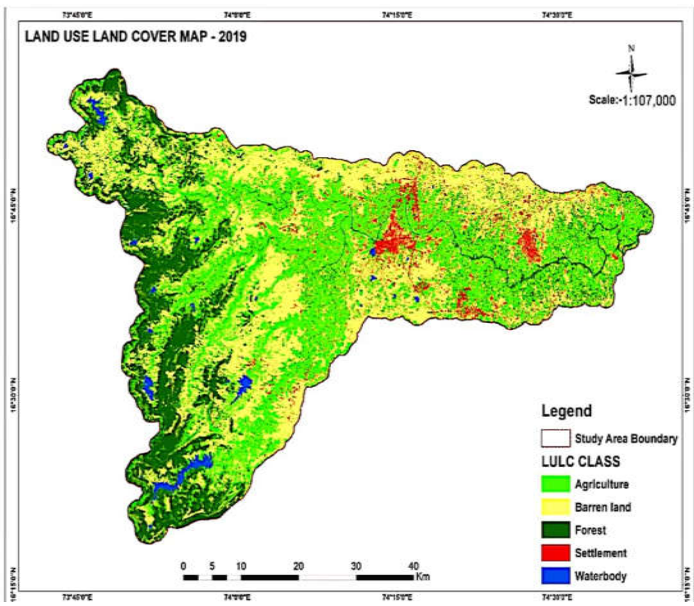


Figure 10: Land Use / Land Cover Map of the Study Area

5.7 Rainfall

Rainfall is an important factor contributing to the flooding of the Panchganga River. A rainfall grid map has been utilized for the analysis and extracted for the given study area using ArcGIS 10.2.2. The following rainfall maps were prepared using the PERSIANN-CCS grid format data. The data obtained was yearly average rainfall for the years 2005, 2006, 2018, and 2019 respectively. The maps prepared are in a grid format with a resolution of 4km x 4km (Figure11-14). The amount of rainfall received is more in the western part of the basin due to the Sahyadri mountain range. The highest amount of average yearly rainfall received was 1414 mm in the year 2019. Bavda receiving the highest amount of rainfall followed by Radhanagari, Shahuwadi, Panhala, Karvir, Hatkanangale and Shirol respectively.

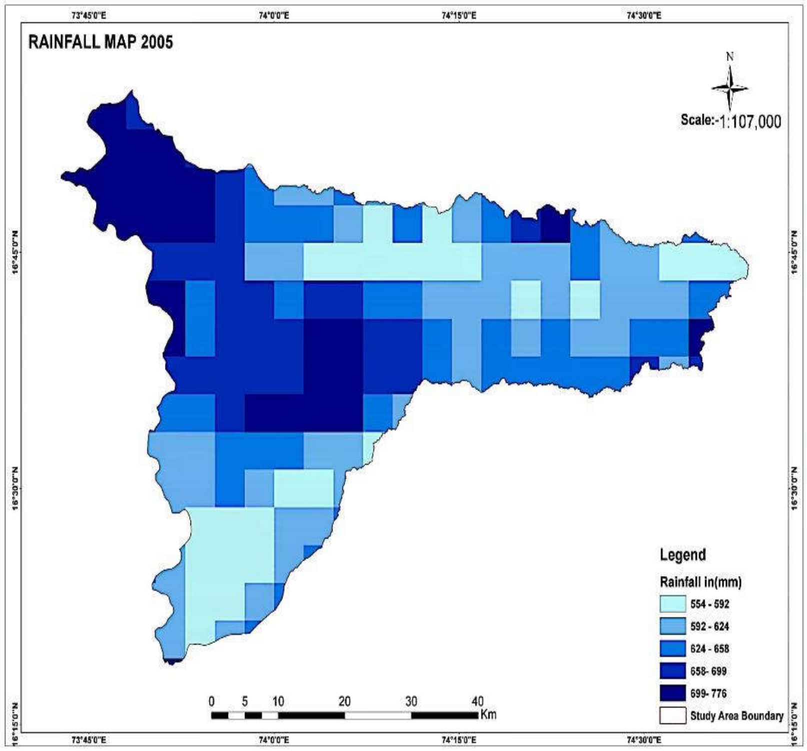


Figure 11: Rainfall map 2005

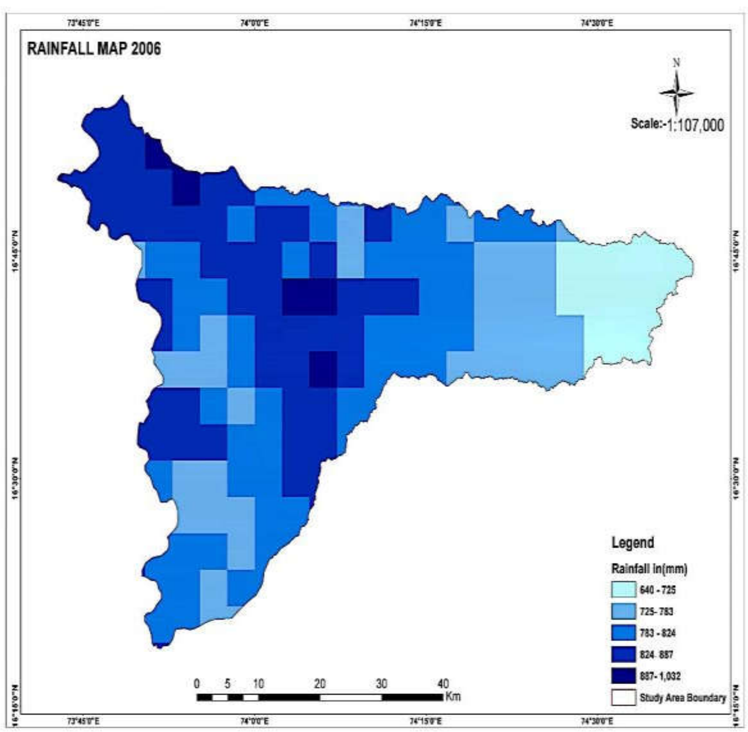


Figure 12: Rainfall map 2006

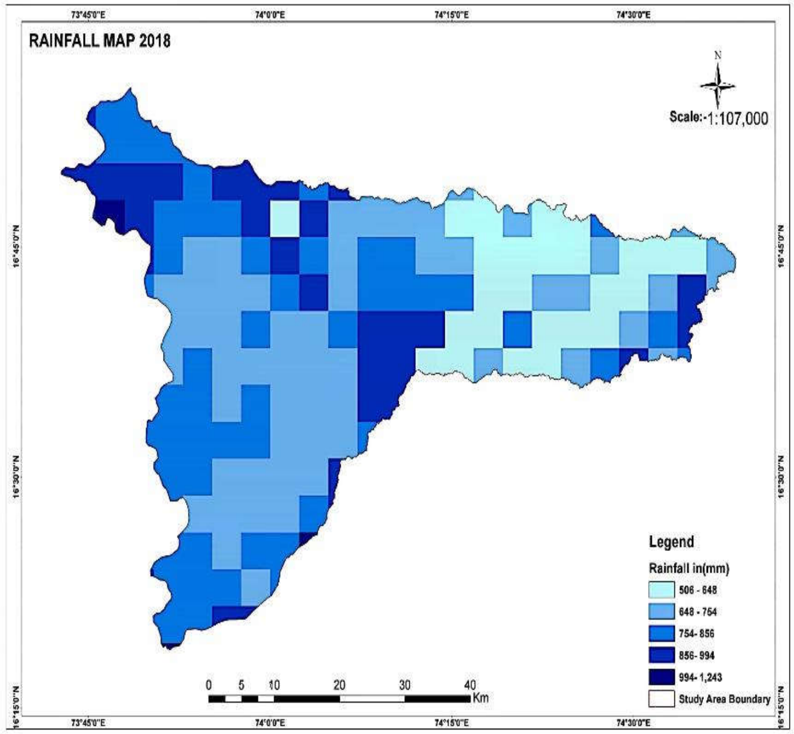


Figure 13: Rainfall map 2018

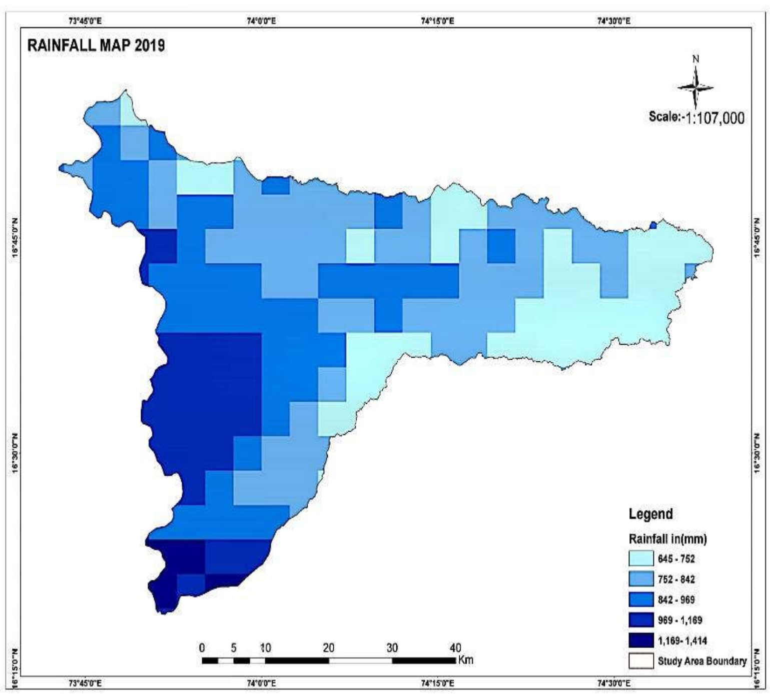


Figure 14: Rainfall map 2019

5.8 Flood Hazard

Multi-Criteria Evaluation a GIS technique was used for the preparation of a flood hazard map of the Panchganga river basin. This model was created using all primary and secondary data with the help of the Arc GIS 10.2.2 model builder tool. Weighted overlay analysis method was implemented to prepare a flood hazard map using different class weighted values. In the western region of the basin lies the Bavda taluka and major parts of Shahuwadi, Panhala, and Radhanagari talukas which indicate very low to low flood hazard, the central region of the Panchganga basin is covered by Karvir taluka which indicates a very high to high flood hazard zone. Parts of Hatkanangale and Shirol talukas lie in the eastern part of the Panchganga basin which indicates a high to moderate flood hazard zone. The given maps represent the data of areas under different flood zones in Panchganga river basin as observed in four years – 2005, 2006, 2018 and 2019. The maps indicates that most area of this basin came under Very High Flood Zone in the year 2019, while least area was found to be under Very High Flood Zone in the year 2006. All four years have more or less equal amount of area under High Flood Zone, followed by a similar pattern in Moderate Flood Zone. This is indicative of 2019 being the worst hit year by floods in comparison to the other years in consideration.

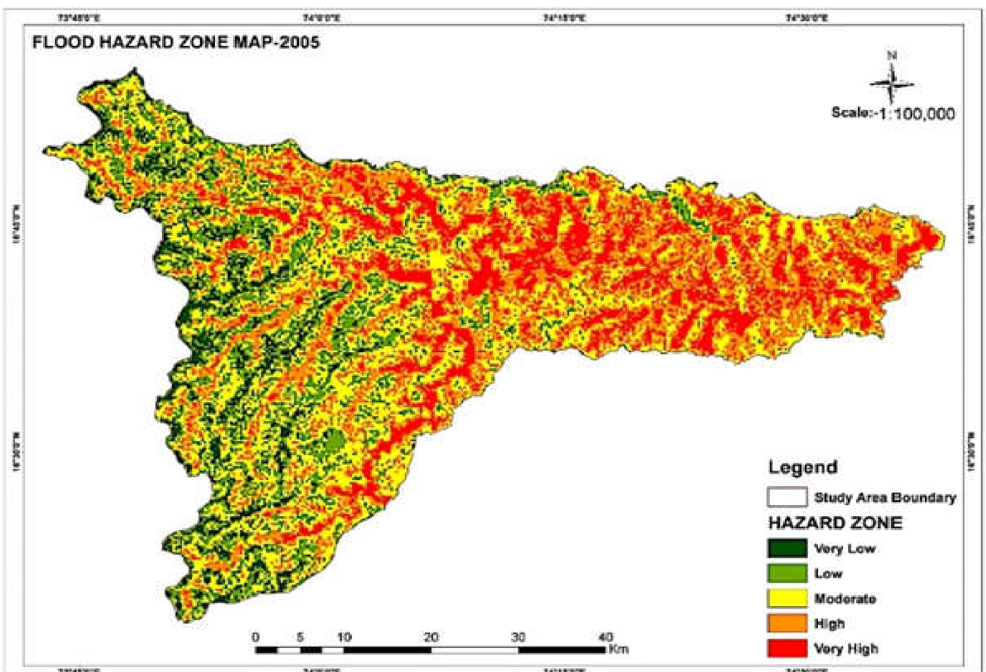


Figure15: Flood hazard map 2005

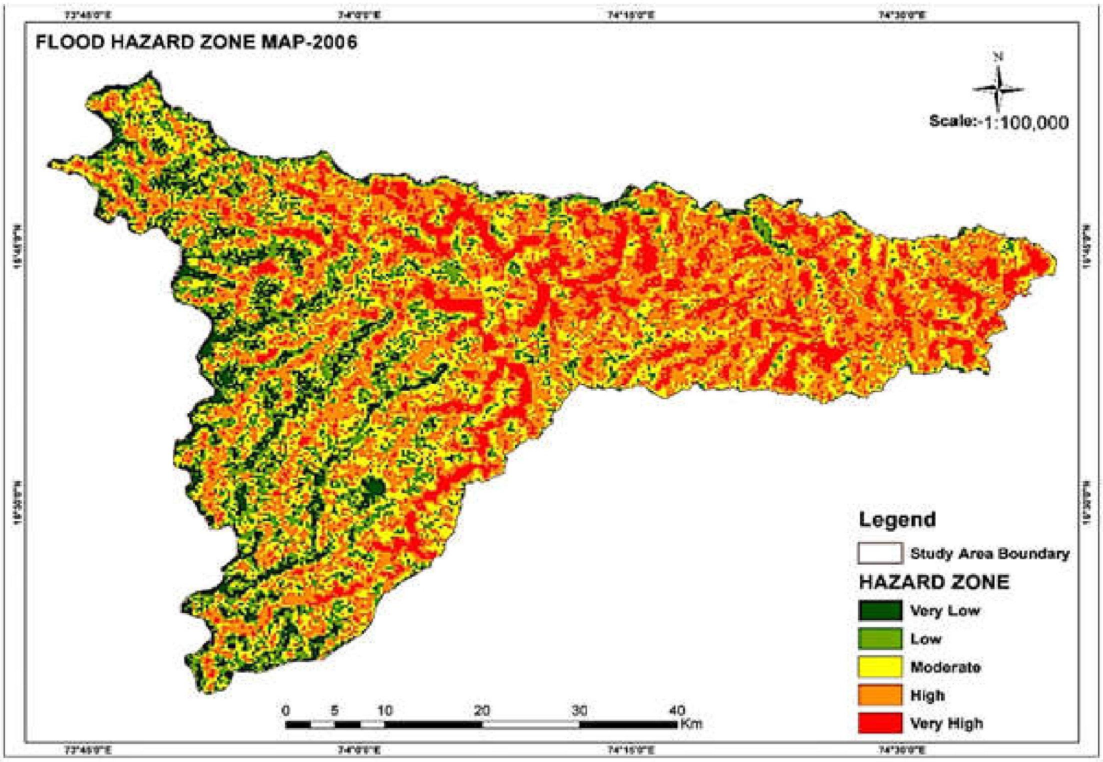


Figure 16: Flood Hazard Map 2006

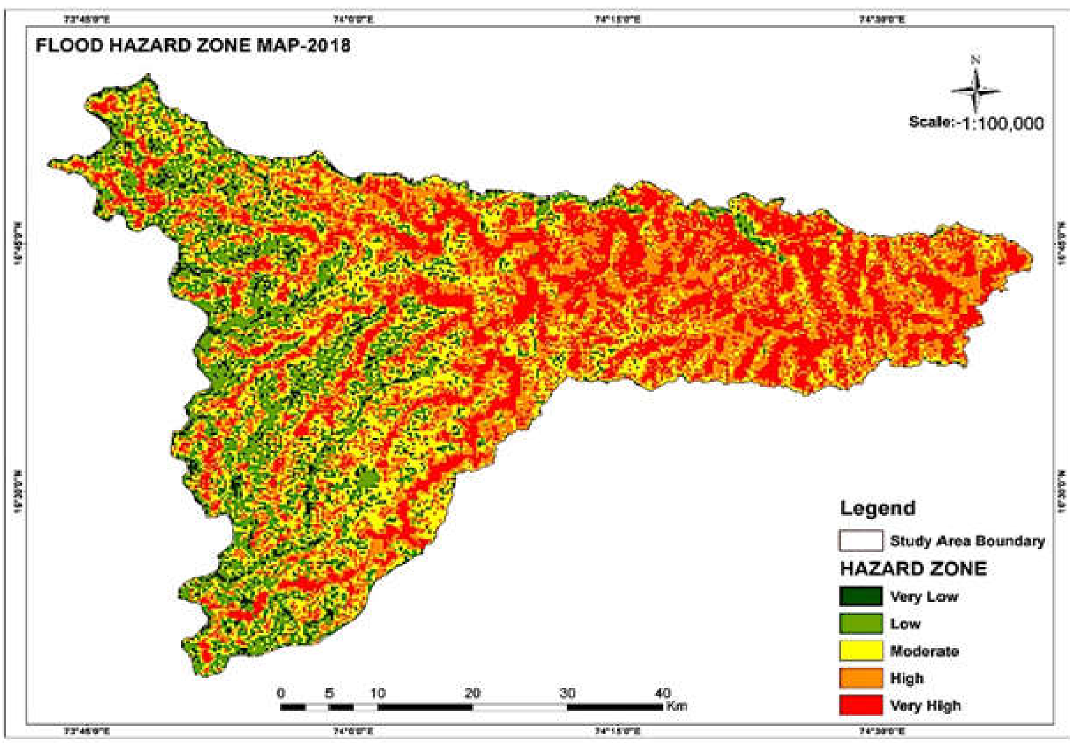


Figure 17: Flood Hazard Map 2018

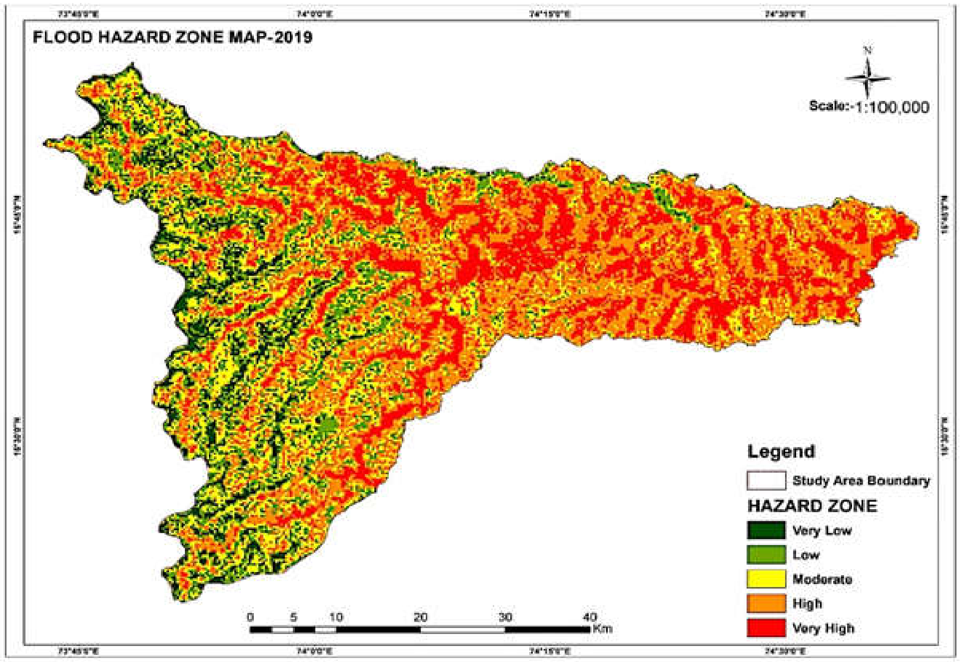
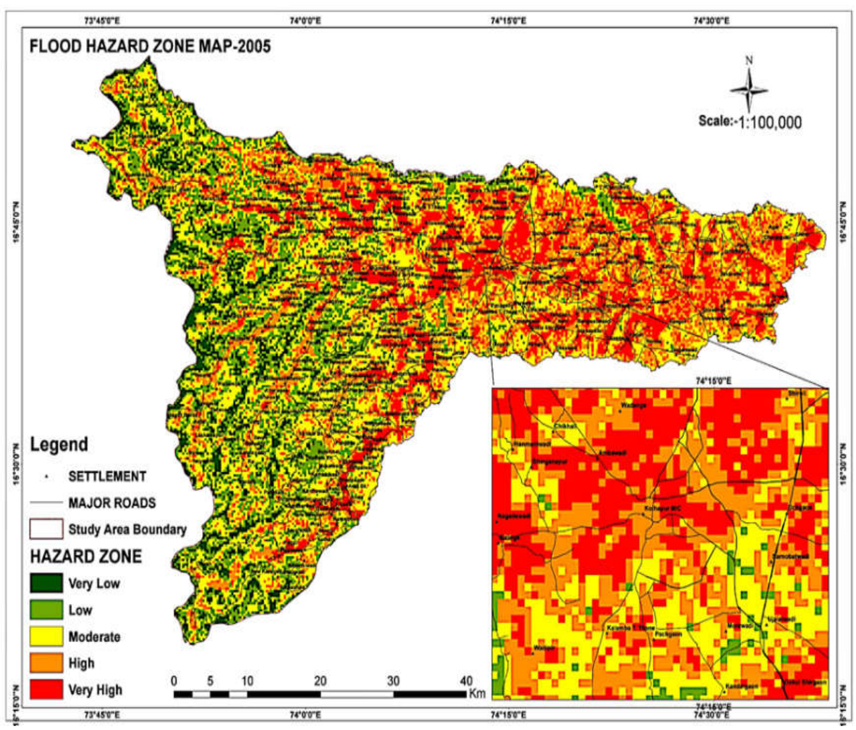
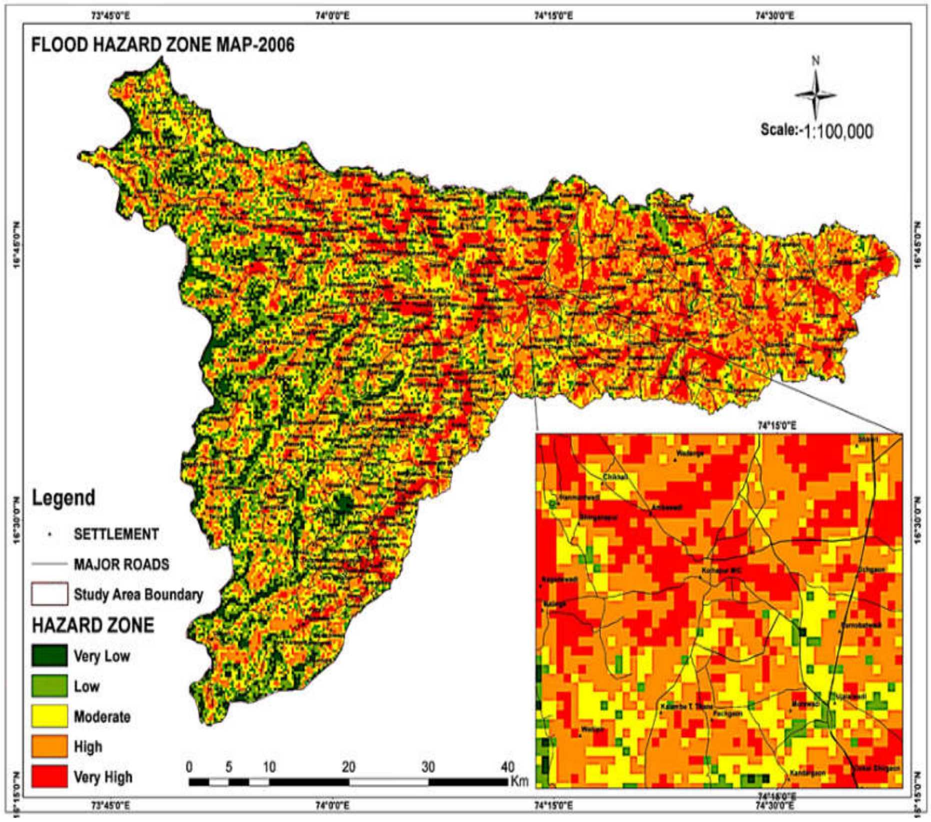


Figure 18: Flood Hazard Map 2019




FLOOD HAZARD ZONE MAP-2006
Scale:-1:100,000
Legend
SETTLEMENT
MAJOR ROADS
Study Area Boundary
HAZARD ZONE
Very Low
Low
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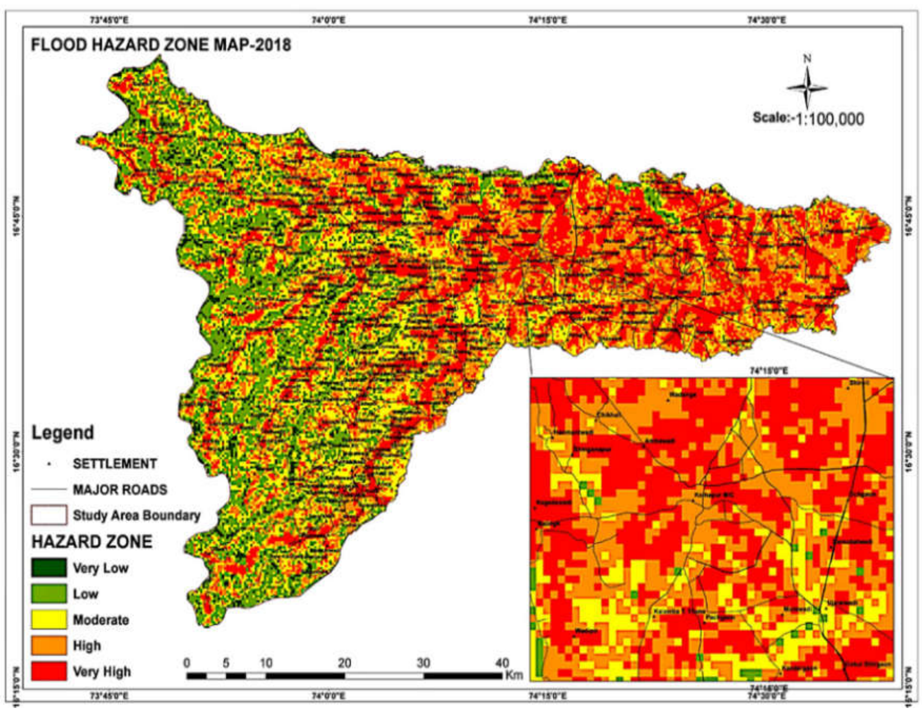
FLOOD HAZARD ZONE MAP-2018
Scale:-1:100,000
Legend
SETTLEMENT
MAJOR ROADS
Study Area Boundary
HAZARD ZONE
Very Low
Low
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Very High
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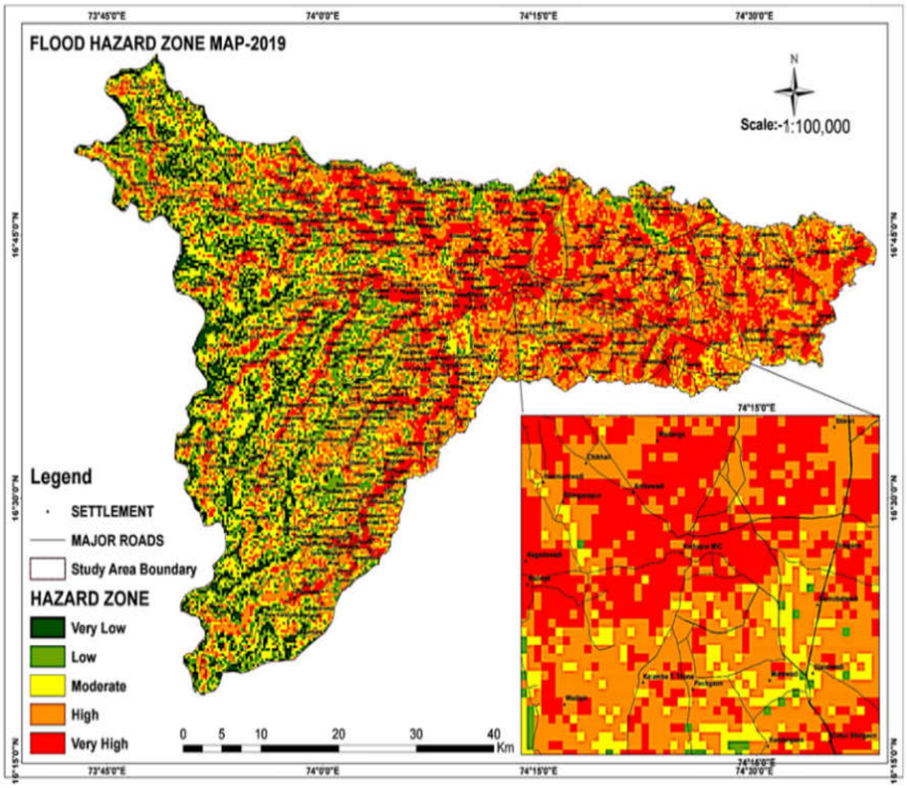

Figure 19: Comparative approach showing the increase in high to very high flood hazard over the years of the Karvir region

6. CONCLUSION

For the study of risk analysis Panchganga basin has been analyzed with a total area of 2582.797 sq.km. The ultimate flood hazard maps for the years 2005, 2006, 2018 and 2019 were generated. Each parameter has been allocated with different weightage factors using the Saaty9-point scale in order to define the relative importance that decides the dominance of the factors over the other. The final hazard map is denoted with the graduated color map that was further categorized to assign the values to each block using a varied Flood hazard Index range. From the analysis it has been investigated that due to the change in rainfall over the years and land use land cover the area under high to very high flood hazard zone has increased over the years. The comparative approach of the years state that there is a gradual increase in the area under high to very high flood hazard zone. Thus, 2019 was the worst-hit-affected year by floods.

The present study indicates a cost-effective technique for flood hazard zone mapping in the Panchganga river basin using GIS technology. The study undertaken was a regulated flood hazard zoning in order to restrict the harm. Flood mitigation reduces the overall risk of flood damage and also reduces the brutality of flood damage when it occurs. Examples of mitigation in a community may include flood plain management, discouraging development in high-risk flood areas, planning and zoning, or providing outreach and education. Examples of mitigation for homeowners may include purchasing flood insurance, the elevation of structures, or completely relocating out of the floodplain. The study is undertaken for future planning and protection of human & other resources with the assistance of concerned authorities against the flood hazard.

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