Chapter 5
Remote Sensing and GIS Application in Flood Management: A Case Study of the Jiadhal River Basin of Dhemaji District, Assam, India

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5.1 Introduction

Flood is one of the common destructive acts of nature which is spread globally and causes extensive loss to lives and properties. Riverine floods are most widespread due to heavy, prolonged rainfall, rapid snowmelt in upstream watersheds or the regular spring thaw (1991). The area affected by flood every year covers a large portion where the density of population is very high, and that is why flood hazards throughout the world are responsible for causing heavy damage to the human lives (Das, 2019). Floods have a direct consequence which leads to loss of lives and property and damages to infrastructures, ecosystems, and also to historical and cultural values (Jonkman, 2005), and the other effects includes outbreaks of diseases as well as tertiary effects like loss of soil fertility, famine, and poverty (Opolot, 2013).

Like all other natural hazard, flood is also very difficult to control, and the drainage problem arises concurrently if the flood is for a longer duration of time. In India, the rivers flowing from the Himalayan causes flood problems in the Ganga-Brahmaputra region owing to the high discharge of sediment which blocks the drainage arteries and also causes changes in the river courses and braiding of channels (Murthy & Prasad, 2004). In the Brahmaputra floodplain region of Assam, the event of flood is of frequent occurrence, and because of this the region has to face the worst situation of flood every year. The state has a chronic history of devastating flood, and the situation has not changed much over the years (Saikia & Das, 2002). The Jiadhal River in the Dhemaji district of Assam, a subtributary of the Brahmaputra River creates a devastating hazard to the people living in that area. It is

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one of the most frequently flooded rivers of the district. Flood occurs in the river due to the overflow of water resulting in embankment failure and later on shifting of the river. So, a flood hazard map for this area is very much essential to identify the flood-affected areas of the region for proper planning and development of the region. Remote sensing and geographical information system (GIS) application in regard to flood management have been considered as an important tool. Remote sensing and GIS help to gather information for floodplain areas and also to compare the data collected before and after the flood. With the help of remote sensing and GIS, a flood hazard zone map can be generated using satellite imagery and digital elevation model (DEM). The main objective of the flood hazard zone map is to prevent the loss of lives, properties, and infrastructures and to enhance awareness among the people about the importance of flood disaster preparedness (Thakuriah & Saikia, 2015).

This study takes into account the Jiadhal River due to its devastating effect of flood during the monsoon season. The roads, railway lines, and embankment in the region have been subjected to breaching during the flood season, and the risks have been increasing every year, and the left embankment has undergone a numerous breaching event within the last few decades compared to the left embankment (Borgohain et al., 2016). The study aims to generate a flood hazard zone map of the river and the nearby areas with the help of weighted overlay method in ArcGIS 10.3 to identify the areas which have higher potential for hazard. The study is limited to the factors like attitude, slope, drainage network, drainage proximity, land use/ land cover, and geomorphology. Therefore, the paper describes about the utilities of remote sensing and GIS in flood hazard mapping.

5.2 Study Area

The Jiadhal River situated in the Dhemaji district of Assam is a north bank subtributary of the Brahmaputra River. The basin extended from 27°8′24″ N to 27 °45′0″ N latitudes and from 94°15′25″ E to 94°37′22″ E longitudes (Fig. 5.1). The total area of the catchment is 1124.65 km^2. It originates in the West Siang district of Arunachal Pradesh where the three rivers Siri, Sido, and Sika join together and flow down as the river Jiadhal. These three rivers contribute most of the runoff and sediment discharge in the main stream. The river passes through a narrow gorge in Arunachal Pradesh and enters into the plains of Assam in a place called Jiadhalmukh. The name Jiadhal derived from the two words “Jia” which means “alive” and “dhal” means “flash flood” as the river has a great tendency of flash flood during the monsoon season (Borgohain et al., 2016; Sharma & Sarma, 2018). In Assam the upper reach of the river is known as Jiadhal, and the lower reach is known as Kumotiya. According to the Water Resource Department, government of Assam, the morphology of the River Jiadhal has been changed drastically, and the frequent changed in the river course created problem in understanding the channel

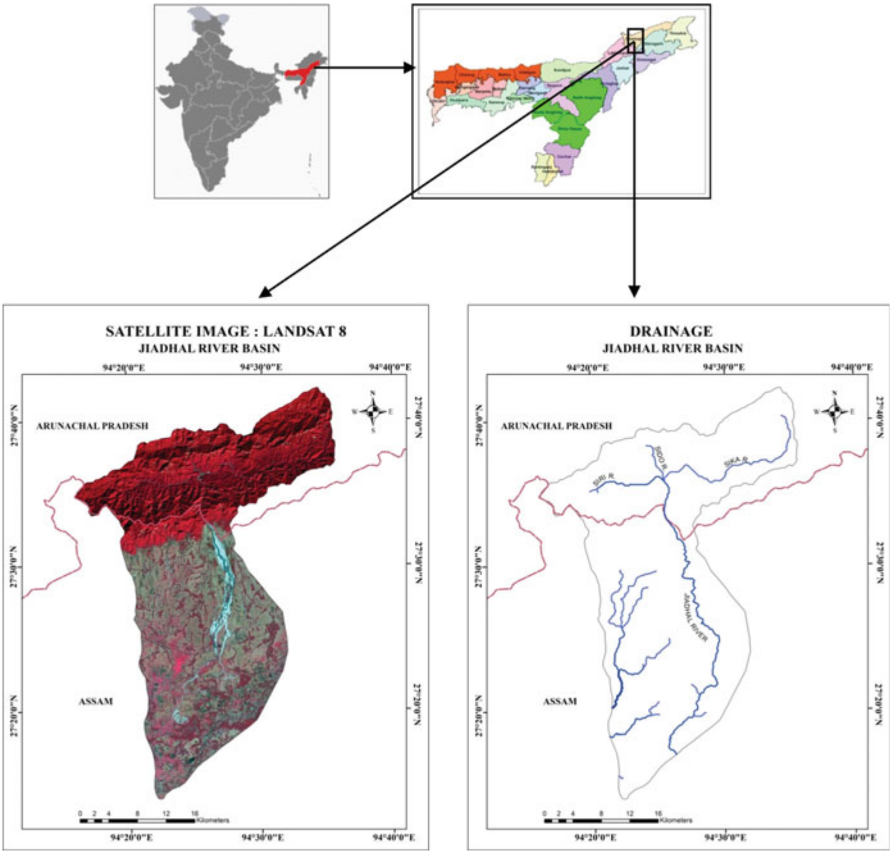

Fig. 5.1 Location map of the study area

morphology. The bed of the river has been rising continuously due to the sediment load carried from the upstream, and as a result, the river water overflows and flood occurs.

The Jiadhal River basin has two distinct geological division – (i) the upper part of the basin comes under the Siwalik formation, and (ii) the lower part of the basin consists of the alluvial sediments. The climate of the basin is typically characterized by hot and humid climatic condition. The rainfall occurs during the monsoon period, i.e., from June to September

5.3 Materials and Methodology

The datasets that was used in the study are Landsat 8 satellite imagery of the year 2017 (path 135 and row 41), SRTM DEM, and geomorphological unit map. Both the satellite imagery and the SRTM DEM were taken from the USGS (United States Geological Survey), and the geomorphological unit is taken from the Geological Survey of India (bhukosh.gsi.gov.in).

The basin boundary of the Jiadhal River has been identified from the Google Earth. The altitudinal zones, slope, drainage networks, drainage density, and flow accumulation are prepared from the SRTM DEM by using Hydrology tool from the spatial analysis tools in ArcGIS 10.3. Later on proximity buffers of 1 m, 1000 m, 2000 m, 3000 m, 4000 m, and 10,000 m were made along with the drainage network to get the scenario of flood affected areas closer to the river and far away from the river. The land use/land cover map is prepared from the Landsat 8 satellite imagery using the maximum likelihood classification method in ArcGIS.

Thus, a flood hazard zone map is prepared for the Jiadhal River basin using the weighted overlay method in the ArcGIS software with the parameters – altitudinal zones, slope, drainage density, flow accumulation, proximity to drainage network, land use/land cover, and geomorphological units. The weightage is given to all the parameters on the basis of influence in the occurrence of flood. The highest weighted value will be considered as the most flood-affected zone or the high hazard zone where the risk of vulnerability will be more as compared to the lowest weighted value which is a flood-free zone or no hazard zone.

5.3.1 Land Use/Land Cover

The land use/land cover is an important factor for flood hazard mapping. To generate the thematic layer, Landsat 8 OLI-TIRS multispectral satellite imagery of 2017 was downloaded from USGS with a minimum percentage of cloud coverage for the study. The supervised classification has been used in the study to classify the different land use/land cover categories in the ArcGIS 10.3 software. Later on, the land use/land cover classes of the Jiadhal River basin have been categorized into six classes: (i) dense forest (333.23 km^2), (ii) sparse vegetation (354.45 km^2), (iii) water bodies (7.60 km^2), (iv) agricultural land (213.35 km^2), (v) barren land (33.27 km^2), and (vi) sandbars (10.09 km^2). It is seen from Fig. 5.2 that the maximum part of the dense forest falls in the upper catchment area of the river basin, i.e., in the state of Arunachal Pradesh, and a little part of the dense forest can be seen in the foothills. The lower part of the catchment mostly comprises of sparse vegetation which covers the maximum area of the basin followed by agricultural land, barren land, sandbars, and water bodies. The settlement class was not included in the classification because of less number of pixels for the same and was creating difficulties in the image classification process. Most of the areas in the lower catchment are suitable for

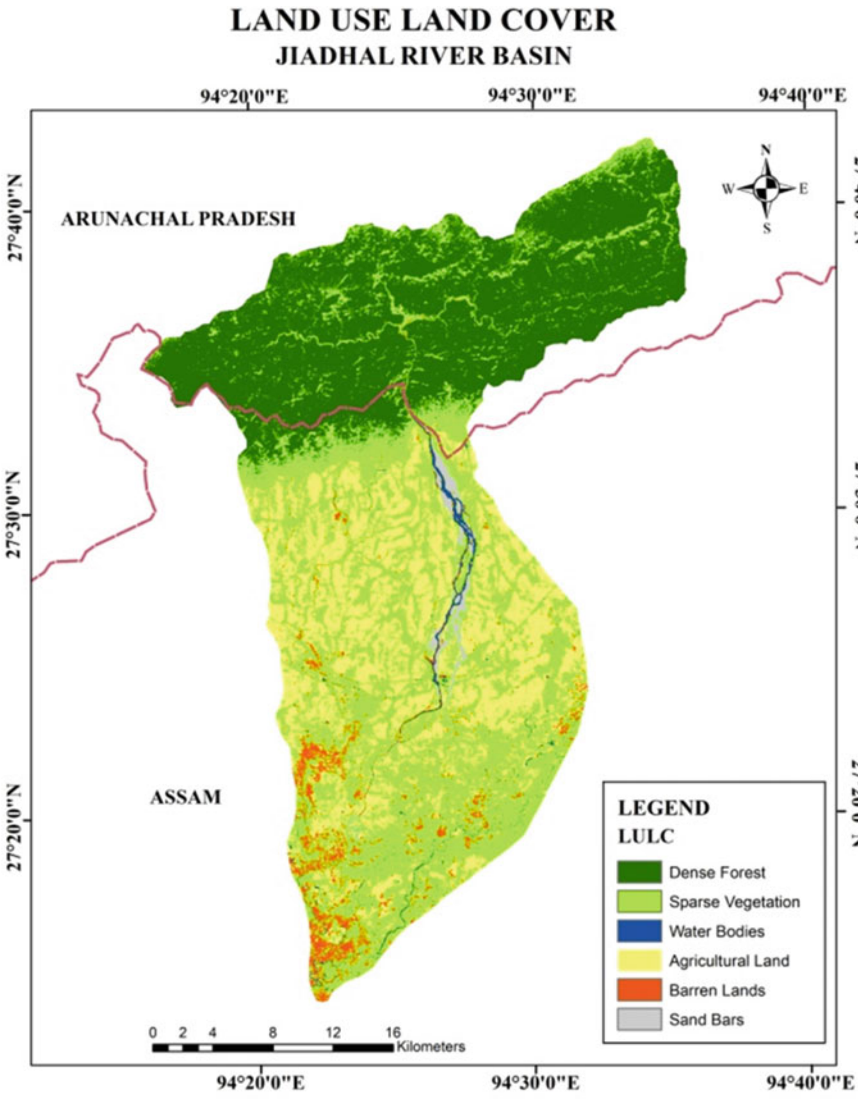

Fig. 5.2 Land use/land cover

agricultural purposes because of the alluvial soil, and also the double-cropping method is practiced in the area. The sparse vegetation is used as grazing land for domestic animals. The water bodies include rivers, ponds, lakes, and wetlands locally called as beels.

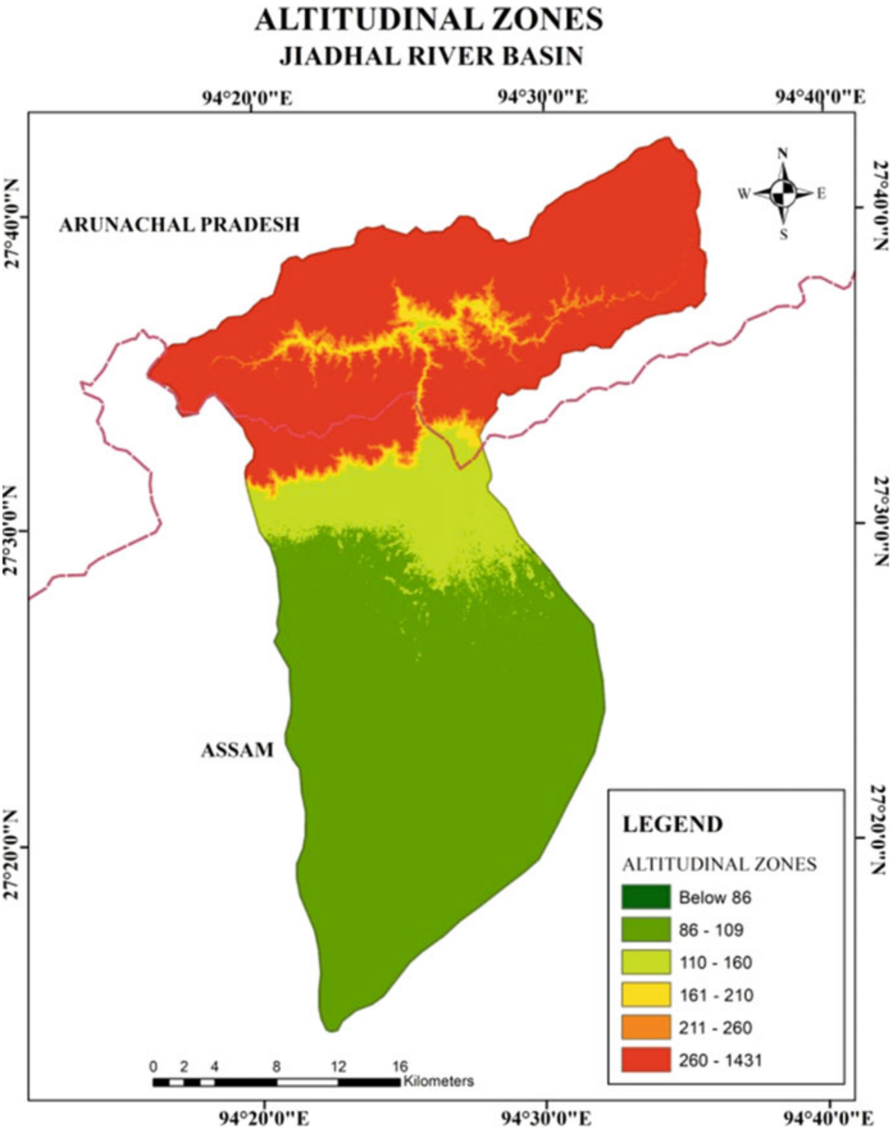

Fig. 5.3 Altitudinal zones

5.3.2 Altitudinal Zones

The altitude or the elevation plays an important role in flood hazard. Flood mostly occurs where the altitude is very low, and the high altitudinal zones are free from flood havoc. The altitudinal zone map of the Jiadhal River basin was prepared using the Shuttle Radar Topography Mission (SRTM) DEM of 30-meter resolution in ArcGIS 10.3 shown in Fig. 5.3. The highest point of altitude is 1431 m above mean sea level, and the lowest point is 86 m above mean sea level of the river basin. This difference in the altitude creates a great variation in the gradient of the river and is considered as one of the factors for which the river follows down changing its course continuously. This continuous changing pattern of the river causes flood in the plain areas which leads to embankment breaching and sand deposition to the new areas of the river basin (Bormudoi & Nagai, 2016).

5.3.3 Slope

Slope is another effective element of flood, as the slope increases, the danger of flood also increases (Thakuriah & Saikia, 2015). The flow velocity of the river also increases with the increase of river slope (Thakuriah & Saikia, 2015). The slope map for the study area was prepared using the SRTM DEM. The slope was calculated in terms of degree and the divided into six categories or classes. The slope ranges from 0 to 73 degree. The slope of the study area ranges between 0 and 73. When the slope is plain or low, there are more possibilities of flood occurrence.

5.3.4 Flow Accumulation

The flow accumulation is always created by using the flow direction, and if the value of flow accumulation is greater, then there is a chance for runoff in the river. The outlets of large rivers will have large values, and small rivers will have small values.

5.3.5 Drainage Network

The drainage delineation was carried using Hydrology tools in ArcGIS 10.3 using SRTM DEM. There are three major tributaries of the Jiadhal River, i.e., Siri, Sido, and Sika, in the upper catchment. After the convergence the river is known as Jiadhal and flows southward through a narrow gorge and enters into the plains of Assam.

5.3.6 Drainage Proximity

Drainage proximity or drainage buffer was prepared using the drainage network. Proximity buffers of 1 m, 1000 m, 2000 m, 3000 m, 4000 m, and 10,000 m were made along with the drainage network as shown in Fig. 5.4 to get the scenario of flood-affected areas closer to the river and far away from the river. It is seen from the

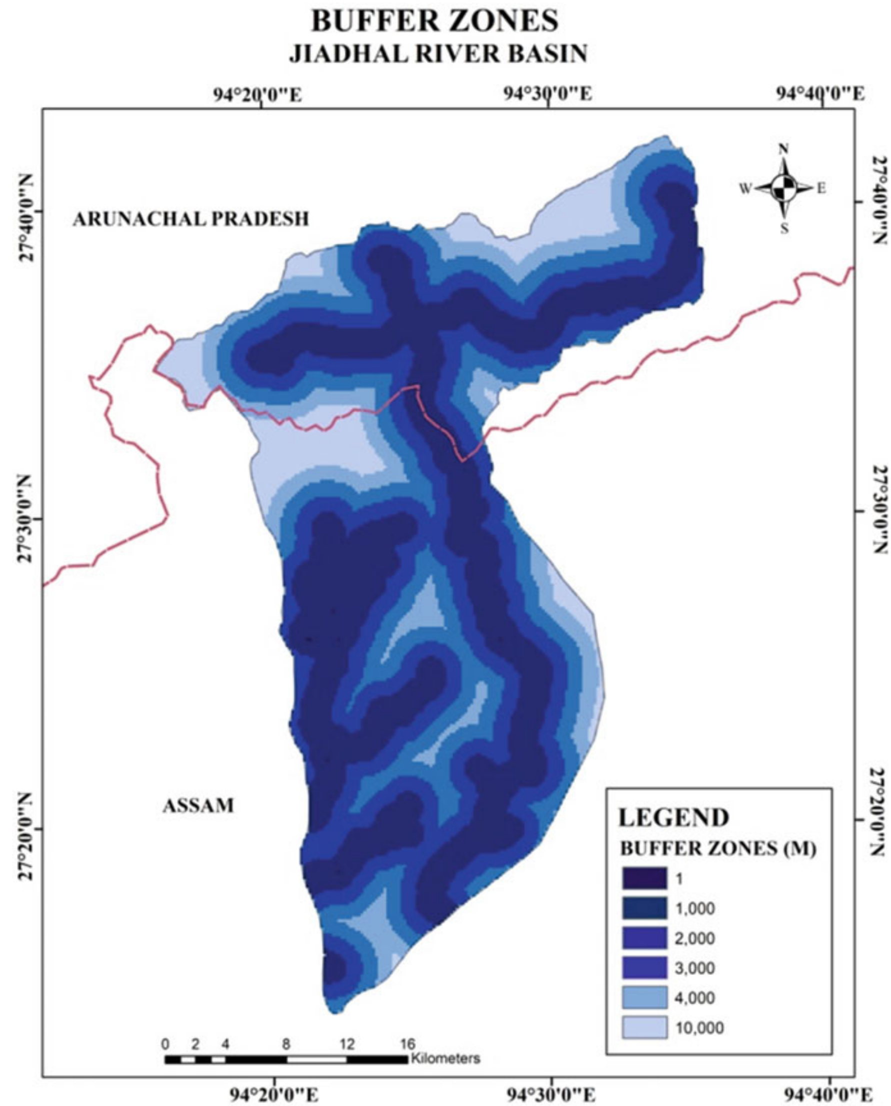

Fig. 5.4 Buffer zones

map that the occurrence of flood along the river in 1 m distance and 1000 m distance is more than that of 10,000 m distance.

5.3.7 Geomorphological Units

Since the Jiadhal River originates in Arunachal Pradesh and flows down to Assam, so it has mainly two physiographic divisions, i.e., the mountainous region and the plain region. The plain region covers a major part of the basin than the mountainous region. Further on the basin area can be divided into eight geomorphic units – (a) alluvial plain, (b) flood plain, (c) highly dissected hills and valleys, (d) low dissected hills and valleys, (e) mass wasting, (f) moderately dissected hills and valleys, (g) piedmont slope, and (h) water body (river). Highly dissected, moderately dissected, and low dissected hills and valleys are part of the Eastern Himalaya. It covers the entire northern part of the basin. There are few patches of mass wasting that cover a very little portion of the basin. Piedmont slopes connect the foothills and the alluvial plain. A small section of the flood plain is seen in the mountain region in the confluence of the three rivers Siri, Sido, and Sika where it forms the Jiadhal River. The maximum part of the lower basin is covered by flood plain areas. A major portion of it is seen along the river with extensive stretches of sand deposits. There are also some small ponds or lakes locally known as *beels* seen within alluvial plains and the flood plains.

5.4 Results

5.4.1 Flood Hazard Zones

Flood hazard mapping is an important component of land use planning in flood-affected areas as it helps in identifying the risk zone in the basin and prioritizes their mitigation effects (Forkuo, 2014). Flood hazard is defined as some threat, natural, technological, or civil to people, property, and environment, and is viewed as the probability of the occurrence of a potentially damaging flood event of a certain magnitude in a given area within a specific period of time (Sanyal & Lu, 2004). The concept of flood hazard is very important in flood management especially in the determination of flood risk (Opolot, 2013). The flood hazard zone map for the Jiadhal River basin has been created using the weighted overlay method in ArcGIS 10.3 (Table 5.1). The parameters taken are altitudinal zones, slope, flow accumulation drainage proximity, geomorphological units, and land-use/land-cover. The weightage was given to all the parameters on the basis of influence in the occurrence of flood and were assigned on a scale of 1 to 5. The flood hazard zone map that has been prepared for the Jiadhal River has five hazard zones, i.e., high, moderated, low, least, and no hazard zones. There are a total of 277 villages in the study area, out of which 260 villages are under moderate hazard zones, and the total area covered by this zone is 536.37 sq. km. The high hazard zone occupies 17.14 sq. km., whereas the moderate hazard zone covers 536.37 sq. km.of the total area shown in Table 5.2.

Table 5.1 Weightage of the parameters

Parameters	Weightage	Subsets	Scale value (weight)	Occurrence of flood
Altitudinal zones	25	Below 76	5	High hazard
		76–110	3	Low hazard
		110–160	2	Least hazard
		160–210	1	No hazard
		210–270	1	No hazard
		Above 270	1	No hazard
Slope	20	0–7	5	High hazard
		7–16	4	Moderate hazard
		16–25	2	Least hazard
		25–33	2	Least hazard
		33–42	1	No hazard
		42–73	1	No hazard
Flow accumulation	10	1	1	No hazard
		2	1	No hazard
		3	3	Low hazard
		4	5	High hazard
		5	5	High hazard
Buffer zones	15	1	5	High hazard
		1000	5	High hazard
		2000	4	Moderate hazard
		3000	3	Low hazard
		4000	2	Least hazard
		10,000	1	No hazard
Land use/land cover	15	Dense forest	1	No hazard
		Sparse vegetation	3	Low hazard
		Water bodies	5	High hazard
		Agricultural land	4	Moderate hazard
		Barren land	5	High hazard
		Sandbars	5	High hazard
Geomorphology	15	Moderate hills	1	No hazard
		Low hills	1	No hazard
		Piedmont slope	2	Low hazard
		Mass wasting	2	Low hazard
		Alluvial plain	4	Moderate hazard
		Flood plain	5	High hazard
		Water bodies	5	High hazard
		High hills	1	No hazard

Table 5.2 The total area, percentage, and the number of villages that comes under different hazard zones

	Hazard zones	Area in km^2	Area in percentage	No. of village affected
1	No hazard zone	117.97	12.47	4
2	Least hazard zone	225.73	23.87	6
3	Low hazard zone	48.41	5.12	3
4	Moderate hazard zone	536.37	56.72	260
5	High hazard zone	17.14	1.81	4

5.4.2 Flood Management

Flood management does not strive to eliminate flood hazard but to mitigate them (Tingsanchali, 2012). Flood management can be of both structural measures and nonstructural measures. Flood hazard zone mapping is considered as a means of nonstructural measures in flood management process to manage the flood plain development measures. Flood and drainage congestion is a major problem in the Jiadhal River basin. Due to heavy rainfall during the monsoon season, the lack of adequate gradient to drain out the high water and sediment discharge of the river and breaching of embankment flood occur in the basin area.

The communities living in the region has adopted with the flood problem and has learnt to respond positively toward flood hazard reduction. People of the Jiadhal basin have their own traditional and cultural believe to cope with the changing scenario of flood. The unique adaptation that has been taken in response to flood disasters is the stilt houses (chang-ghar) made from bamboo poles and using wooden boat as a means for transportation. For cultivation also the people adopted crop diversification and mixed cropping method as one of the critical mechanisms to cope up against heavy losses. The store houses locally called as Bhoral are higher than the houses to protect the grains from flood. The Jiadhal River is a frequently avulsing river and indigenous communities have been using bamboo porcupine to divert the flow of the river from residential areas (Das, 2015).

5.5 Conclusion

Remote sensing technology along with geographical information system (GIS) become the key tool for flood monitoring in recent years (Sanyal & Lu, 2004). But in spite of the great potential that remote sensing and GIS offer in flood management, their uses has been limited to some extent, and the presence of cloud cover during the flooding periods has been a major challenge in the use of optical remote sensing in the flood management (Sanyal & Lu, 2005). Floods of different intensity have been occurring in the flood plains since time immemorial, but with the increasing settlement in the flood plains, the loss of life and properties are also increasing. Remote sensing and GIS techniques have been regarded as a powerful tool in dealing with the various aspects of flood management like prevention, preparedness, and relief management of flood disaster, and the extensive use of these technologies has great prospect in creating long-term database on flood proneness, risk assessment, and relief management. In studies dealing with the application of remote sensing in inundated area delineation and flood risk assessment, DEM is used to visualize the interface of flood water with the terrain (Sanyal & Lu, 2004).

The main reason for heavy flood in the study area is because of the heavy rainfall during the monsoon season in the hilly part of the catchment as well as in the adjoining foothills. Flood hazard zoning and proper management of flood are very important in order to limit the damages caused by flood every year. In this study flood hazard zone map was generated based on appropriate parameters and are useful in identifying different zones that are prone to flood. The outcome of the study shows that 56.72% of the basin area comes under moderated hazard zone and 12.47% of the area comes under high hazard zone. The no hazard zone covers the major portion of the upper catchment area of the river basin. Thus, GIS has provided significant value in understanding sub-basin drainage characteristics with respect to flooding and also assists flood mitigation and land use planning.

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