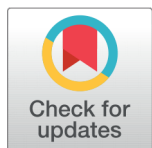


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Application of geospatial technologies in flood hazard assessment of Dhemaji revenue circle, Assam

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Abstract

Background: Land of monsoons, India has been triggered by flood and siltation annually through south-west and north-east monsoons along the floodplains of the country for millennia. Being one of the worst sufferers, Assam also experiences the severe effects of flood hazard as the region is drained by the mighty Brahmaputra and Barak basins. In this view, Dhemaji district located in the upper reach of Brahmaputra valley also bears the brunt of flood leaving massive imprints on people and landscape. **Objective:** This study is an attempt to identify the flood vulnerable zones and damages incurred in a flood period of Dhemaji revenue circle. **Methodology:** The study is based on both primary and secondary sources of information wherein the data and maps have been processed and prepared within the domain of GIS and remote sensing. **Findings:** The results indicate that the entire region is categorized into two flood hazard zones viz. least and highly vulnerable wherein the former covers 55.27% and latter 44.73% of the total area. The damages caused in respect to cropland and transportation network have also been estimated and few management strategies were recommended to cope with the hazard. **Novelty:** The existing work has used various physical factors wherein priority ranks are allotted to each based on their intensity towards flood occurrence. Thus, this study would help in identification of potential hazard zones and affected areas through mapping and modeling using geospatial techniques which are cost and time effective.

Keywords: Flood hazard; Brahmaputra valley; assessment; management; GIS; remote sensing

1 Introduction

Amongst all natural hazards, floods have evoked as the most disastrous and catastrophic event causing multifarious damage to both human and environment globally. Most of the tropical and sub-tropical countries⁽¹⁾ have experienced such extremities through ages that have ultimately jeopardized its economic assets⁽²⁾ immensely. However, the adverse flood hazard and its repercussion are increasing day by day posing serious threat to life and livelihood of its inhabitants. A host of factors such as climate change, incessant rainfall, haphazard land use pattern, population growth, and urbanization⁽³⁾ have contributed substantially in transforming the hazard into a disaster accompanied by a rise in flood frequency⁽⁴⁾.

Endowed by multiple rivers and its tributaries, India also witnesses the menace of flood and siltation along the floodplains of the country for millennia. According to Central Water Commission (CWC, 2018), during 1953-2016 the total flood affected area and population of the country was estimated as 460.26 million hectares and 2040.26 million respectively⁽⁵⁾. Nestled within the fertile plains of Brahmaputra valley, Assam also has been encountering the dreadful natural calamity owing to both natural and increasing anthropogenic activities leaving human life miserable. The flood situation of the region has aggravated after the great earthquake of 1950 raising its bed to a considerable height in the Brahmaputra valley. It is noteworthy that Dhemaji district is also frequently inundated affecting the floodplain dwellers and disturbing the ecological set-up of the valley. The district encircles four distinctive revenue circles such as Dhemaji, Sissiborgaon, Jonai and Gogamukh wherein the most flood-affected among them is Dhemaji revenue circle as Jiadhal river in north-west and Brahmaputra river in southern part swells during monsoon deluging the entire region.

Besides, being a natural phenomenon, flood cannot be prevented or stopped but its aftermath can be reduced to a certain extent. The present paper endeavors to assess the flood hazard of Dhemaji revenue circle by sorting into different vulnerable zones. Additionally, the study has also incorporated the damages incurred in respect to total number of villages, cropland and transport network. In the present milieu, it is high time to create flood and vulnerability mapping and assessment through which few formulations of effective strategies could be generated⁽⁶⁾. Further, the study has been integrated using geospatial tools that helps better to enhance in mapping and monitoring of the floodplains so that the decision makers and planners could initiate holistic approach to reduce and cope with the hazard in a sustainable and viable way⁽⁷⁾.

Study area

Located in the eastern most part of Assam, Dhemaji district comprises of four revenue circles viz. Dhemaji, Sissiborgaon, Jonai and Gogamukh. For the present study, the chronically flood affected plain area i.e. Dhemaji revenue circle has been undertaken covering an area of 467.32 km². The longitudinal and latitudinal extension of the study area is 94°25' E to 94°37' E and 27°16' N to 27°37' N respectively ([Figure 1](#)). The study area is encircled by Arunachal Pradesh in north, Gogamukh revenue circle in west, Brahmaputra river and Dhakuakhana in south and Sissiborgaon revenue circle in eastern side. The district is criss-crossed by innumerable tributaries and sub-tributaries of Brahmaputra such as Silly, Simen, Jiadhal, Gainadi, Moridhal, Subansiri wherein, the chief river of the study area is Jiadhal causing havoc to the entire region annually. Moreover, the annual rainfall of the region ranges from 2600 mm to 3200 mm and temperature varies between 39.9°C during summer and 5.9°C in winter.

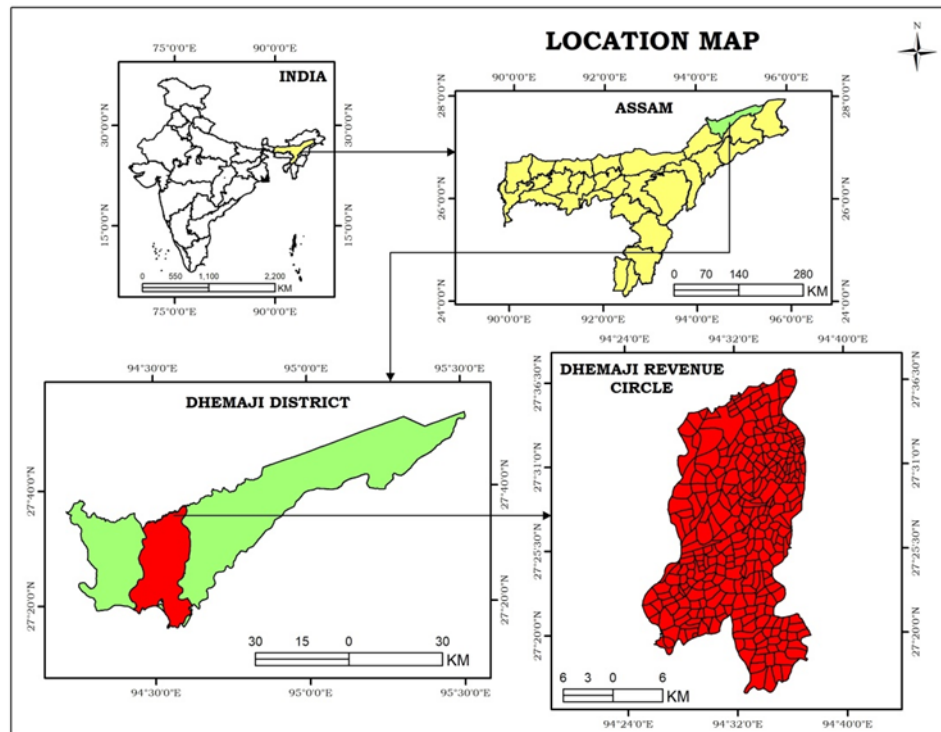


Fig 1. Location map of the study area

2 Methodology

A detailed methodology was considered involving data collection through both primary and secondary sources. The base map of the study area was prepared based on Survey of India toposheet (1967) and Assam Administrative Atlas (2011). In order to produce the flood vulnerability map of Dhemaji revenue circle, few influencing factors such as drainage density, rainfall, geomorphology, land use and land cover (LULC) and digital elevation model (DEM) were considered^(8,9). The thematic maps such as drainage density and geomorphology were produced based on topo sheet and DEM. The rainfall distribution map has been prepared through IDW technique. While the LULC was made from satellite imagery of LANDSAT 8 using supervised approach for the year 2019. All these maps were combined and interpreted in GIS platform. Further, based on the processed data, reclassification and ranking of the layers were assigned to quantify the severity of the flood hazard through map algebra derived from the Arc tool⁽⁹⁾. After computation of the flood vulnerable map, the village layer was overlaid to assess the flood-prone regions of the study area. Additionally, socio-economic impact data were also collected from various sources viz. Dhemaji Revenue Circle Office, Water Resource Office, District Disaster Management Authority (DDMA) etc. In collaboration to this, primary data involving a structured questionnaire was designed using random sampling technique and GPS to assess the damages incurred by flood-affected villages of the study area. Moreover, in order to lessen the severe impact caused by the hazard in the study area, few management strategies have also been developed.

3 Results and Discussion

Flood Hazard Assessment

Assessment of flood hazard deals with the ways through which identification of flood risk and its management is carried out thus, providing a well-defined flood scenario of the concerned area. Based on the scenario, effective measures and approaches are adopted within a structured framework to overcome the disastrous event. Moreover, the vulnerability concept is applied for the measurement of potential risk with the combination of socio-economic ability to tackle the worst situation resulting from the disastrous event. Being a recurrent phenomenon, flood hazard assessment and mapping plays a pivotal role in order to understand the underlying factors causing the hazard so that its risk could be addressed and mitigated to some extent^(9,10).

The following provides description regarding the five parameters taken under consideration for preparation of the flood hazard map.

Major flood influencing factors

1. Drainage density-Drainage density is a vital element in flood analysis of a region. It denotes the ratio between total lengths of the stream to its contributing area within a river basin⁽⁹⁾ indicating spacing of channels. The drainage density of the study area (Figure 2) is divided into four classes viz. very low (<1.5), low (1.5-2.5), moderate (2.5-3.5) and high (>3.5) shown in (Table 1). The very low and low category occupies about a majority of 97.03% of the study area indicating more prominence to flood because due to presence of few drainage channels, water cannot surpass swiftly through it within a short time.

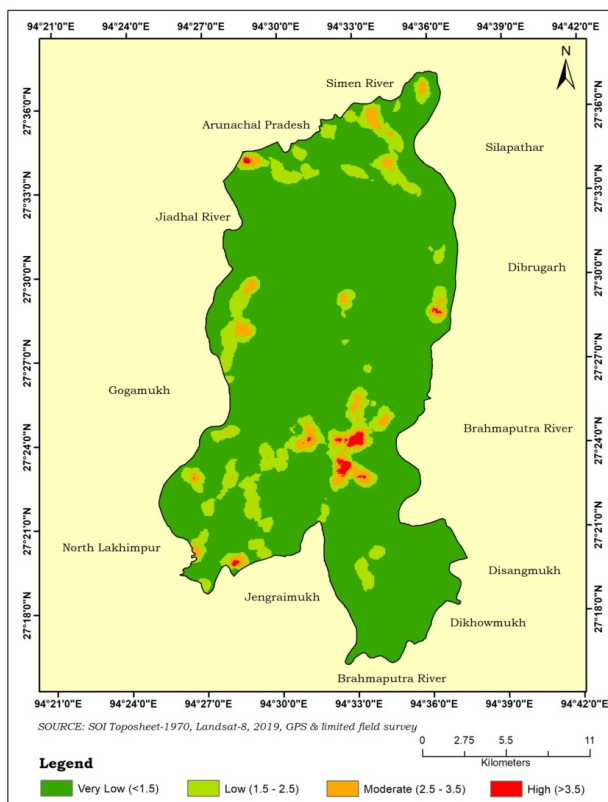


Fig 2. Drainage density map

Table 1. Category wise areas of drainage density of Dhemaji revenue circle

Drainage density (km/km ²)	Area (in ha)	Area in %	Category
<1.5	39899.24	85.43	Very Low
1.5-2.5	5419.35	11.60	Low
2.5-3.25	1178.84	2.52	Moderate
>3.5	207.87	0.44	High

2. Landuse and Landcover-LULC is yet another intrinsic element influencing the nature of flood in a particular region. LULC map for the year 2019 was prepared using supervised approach involving maximum likelihood classifier technique in GIS platform ([Figure 3](#)). The LULC of the region was classified into five categories viz. agricultural land, forest area, settlement with vegetation, lakes/ponds and rivers presented in ([Table 2](#)).

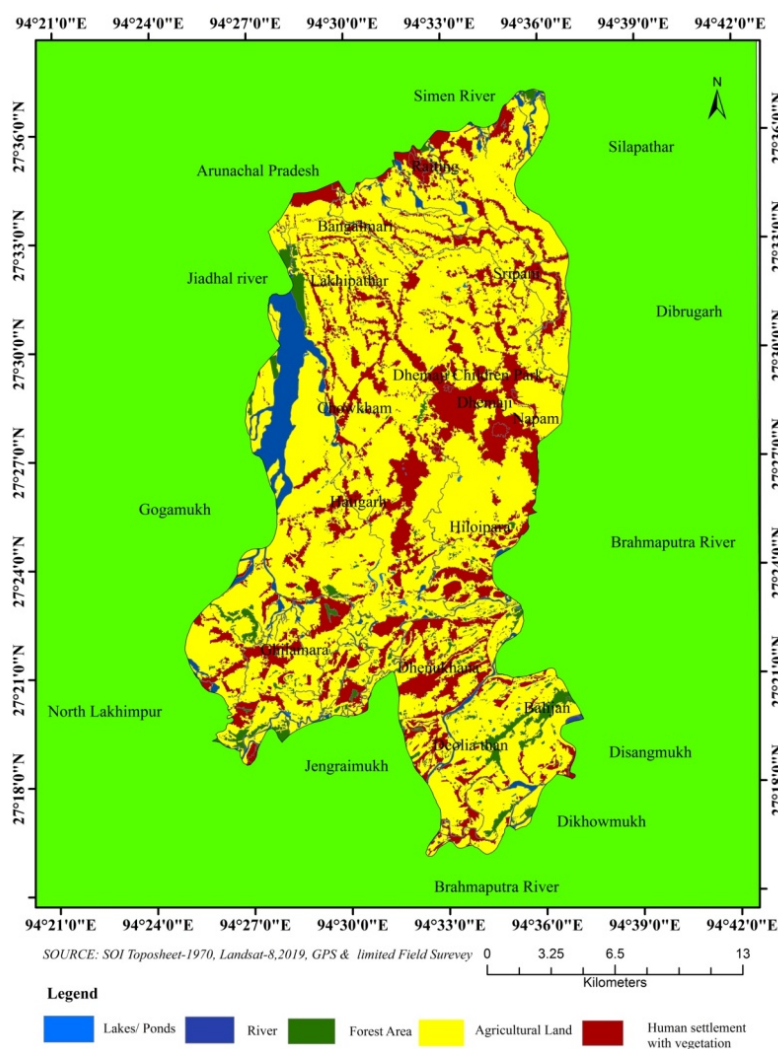


Fig 3. Land use/ land cover map, 2019

Table 2. LULC pattern of Dhemaji revenue circle

LULC classes	Area in ha	% of area
Agricultural land	33958.14	69.11
Forest area	1896.73	3.86
Human settlement with vegetation	10776.19	21.93
Lakes/Ponds	152.19	0.30
River	2351.69	4.78

Based on LULC classification, the dominant class of the region is agricultural land (69.11%) followed by settlement with vegetation. Areas covered by forests and lakes/ponds are less for which the study region witnesses acute flood and bank erosion problems.

3. Rainfall: Rainfall also constitutes as a contributing factor towards occurrence of high flood in the region. The study area receives enormous rainfall from both north-east and south-west monsoons wherein the rainfall ranges from 2416.86 mm to 2568.4 mm (Figure 4). The rainfall data for the year 2018 were interpolated using Inverse Distance Weighting (IDW) method to construct the rainfall distribution map of the study area.

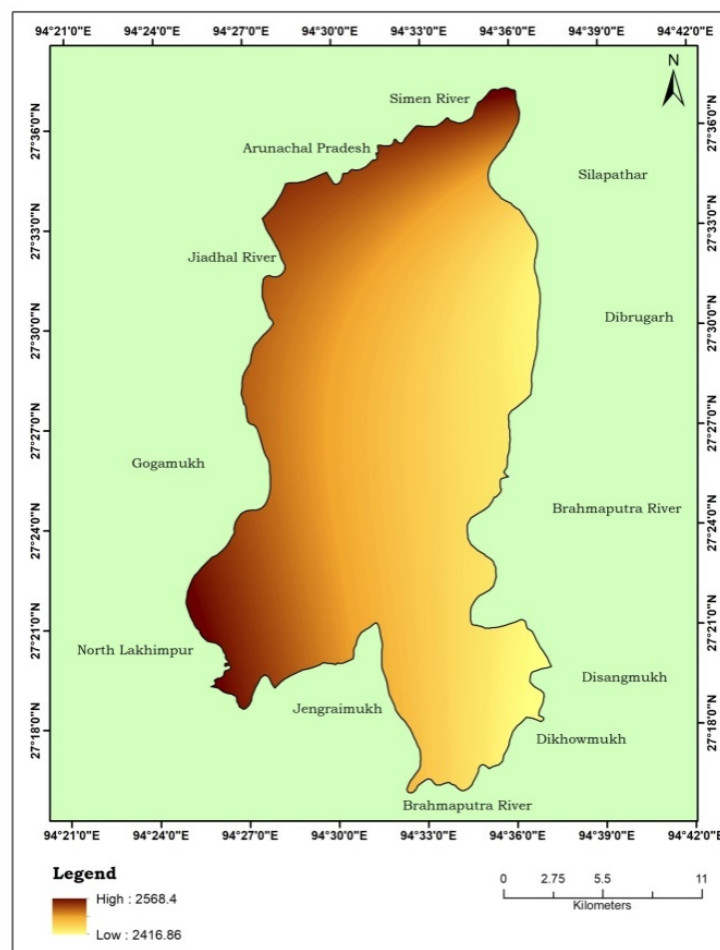


Fig 4. Rainfall map, 2018

4. Geomorphology- The geomorphological characteristics is yet another parameter responsible for flood formation of an area. Geomorphologically, the region is divided into two features - pediment and pediplain wherein pediplain covers majority of the area making it more vulnerable to flood (Figure 5).

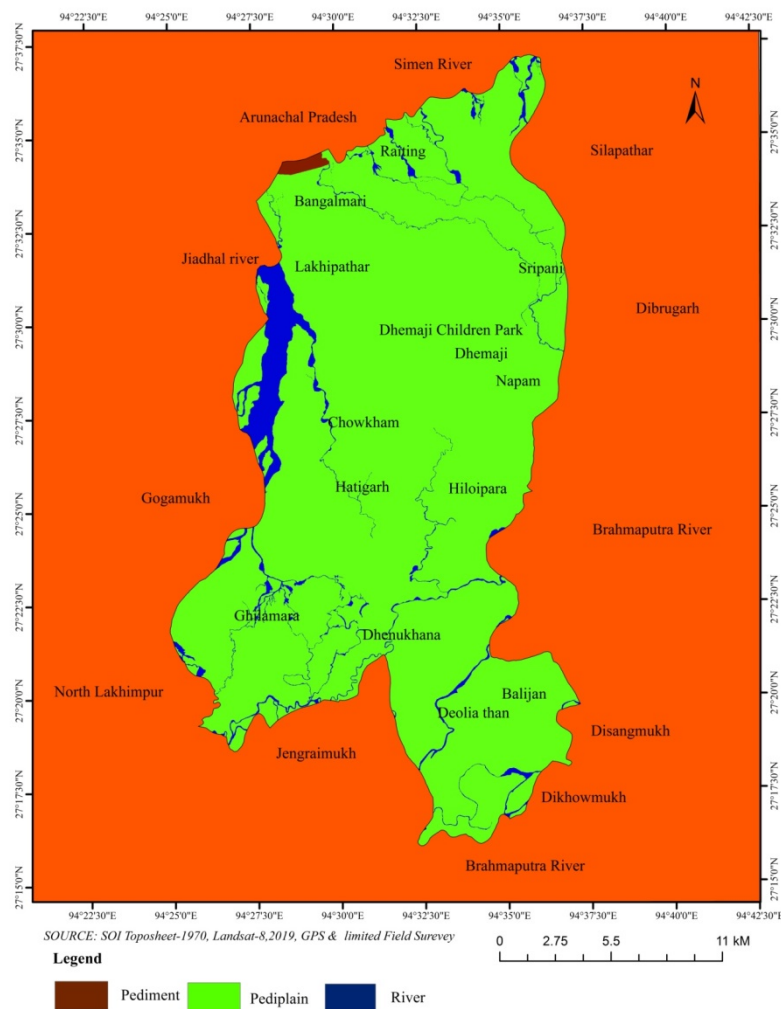


Fig 5. Geomorphology map

5. DEM - The Digital Elevation Model (Figure 6) of the region signifies the elevation ranging from low (19 m) to high (143 m). The north-west to south-west portion of the region consisting of Jialhal river along with the floodplains of Brahmaputra in south and south-east part of the study area is highly flood-prone having low elevation of 20 m to 40. On the other hand, presence of hilly terrain in the northern part of the region closer to Arunachal Pradesh comprises of high elevation (>60 m).

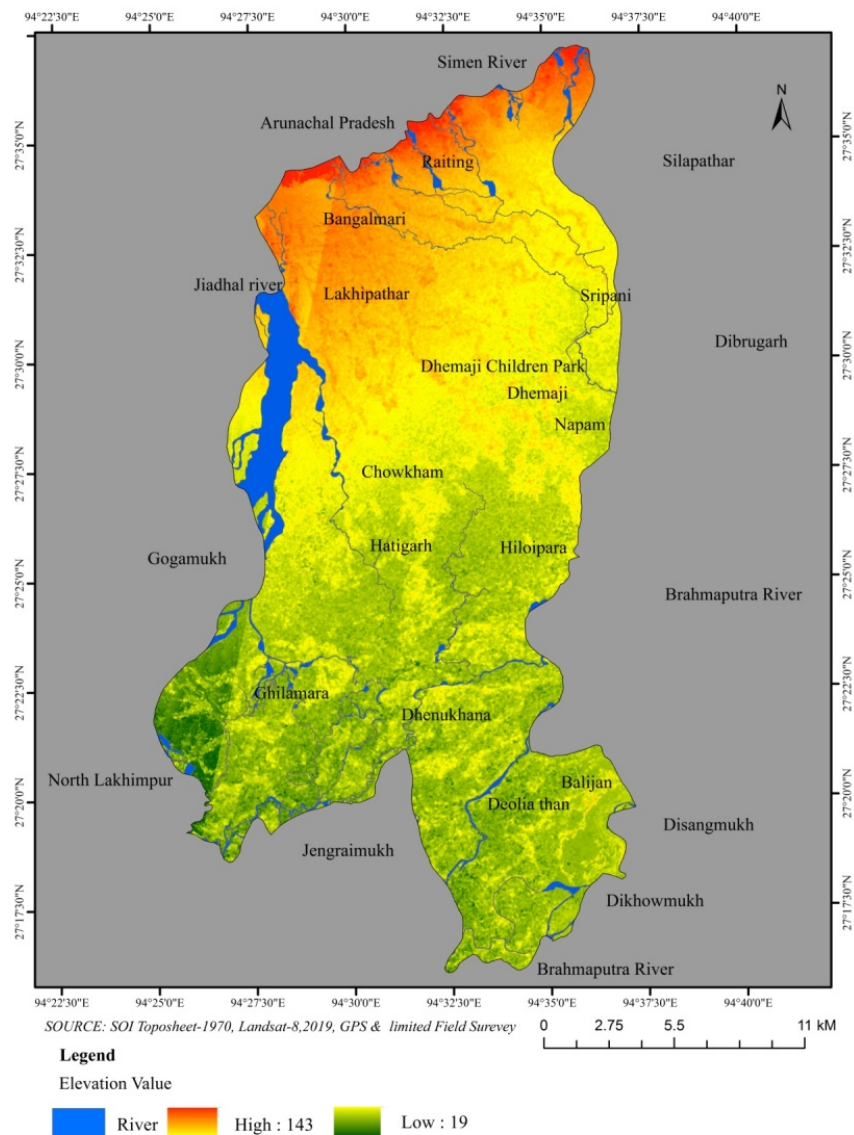


Fig 6. Digital elevation map

In the present study, after preparation of five individual flood determining parameters, all these raster layers were combined, reclassified and ranked according to their severity and capacity towards occurrence of the flood⁽⁹⁾. Based on this criteria, the flood vulnerable maps have been generated through overlapping process in Arc GIS wherein three probable flood vulnerable zones have been categorized viz. least vulnerable, vulnerable and highly vulnerable zones (Figure 7). The least vulnerable zone occupies 25829.01 ha representing 55.27% area, vulnerable zone represents 18846.63 hectares (40.33%) and the highly vulnerable involves a minimal of 2057.16 hectares (4.4%).

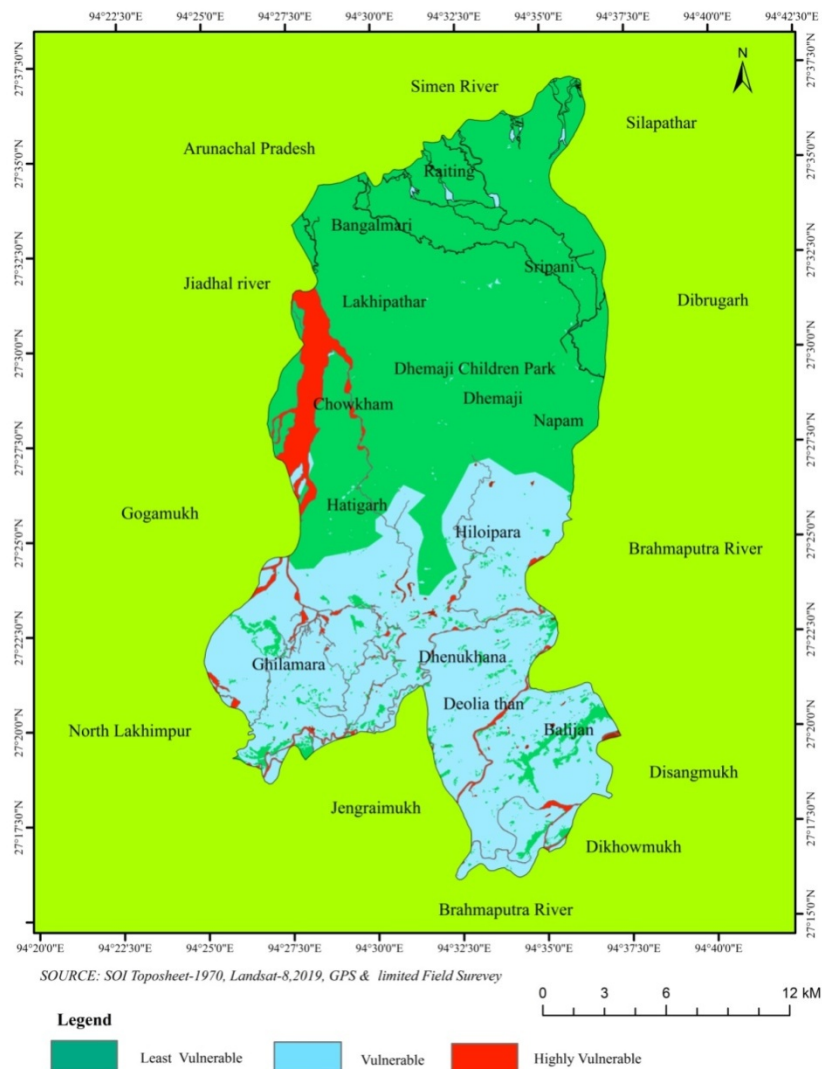


Fig 7. Flood vulnerability map

From Figure 7, it can be estimated that the northern portion up to central part of Dhemaji revenue circle falls under least vulnerable zone due to high elevation along with dense vegetation and forest cover. The region covering central to southern part of the study area is considered as vulnerable zone with some pockets witnessing high vulnerability. On the other hand, north-western part of the region surrounding the Jialdhal river experiences flood hazard threats. This can be attributed due to incessant rainfalls, high population density, gentle slope coupled with haphazard urban growth, injudicious anthropogenic activities, sparse vegetation and forest cover etc.

Flood Damage Assessment

Annually, the disastrous event leaves its imprint on the landscape thereby destroying economy, social and environment vividly. The extent of vulnerability to flooding of a region can be measured through flood damage assessment. Flood damages are classified into tangible and intangible damage wherein the former type deals with material damages involving various insurable losses while the latter is associated

with anxiety, annoyance, distress, insecurity, ill health, loss of life etc. (10,11).

Additionally, the flood susceptible villages were also recognized by overlapping the village layer of the study area upon the produced flood vulnerability map (Figure 8). Thus, the generated maps have classified the villages into two zones based on flood vulnerability wherein a total of 160 villages were identified as least vulnerable to vulnerable with a lesser risk and 144 villages classified under vulnerable to highly vulnerable zone. It is noteworthy that amongst all, the severely flood inundated villages experienced by the people of the study area are identified as Kawai Mari, Barpak Bhareki, SolmoraPathar, Puthimari, Kathtokia Doloni, Nimatichuk, Barua Pathar, Ghogua Chapori, Narowa Than, Chengamari and No. 2 Kami Pathar. Moreover, this villages were drowned in flood for several days during the flood wherein fatalities of approx. 30,000 people have been recorded along with huge animal casualties.

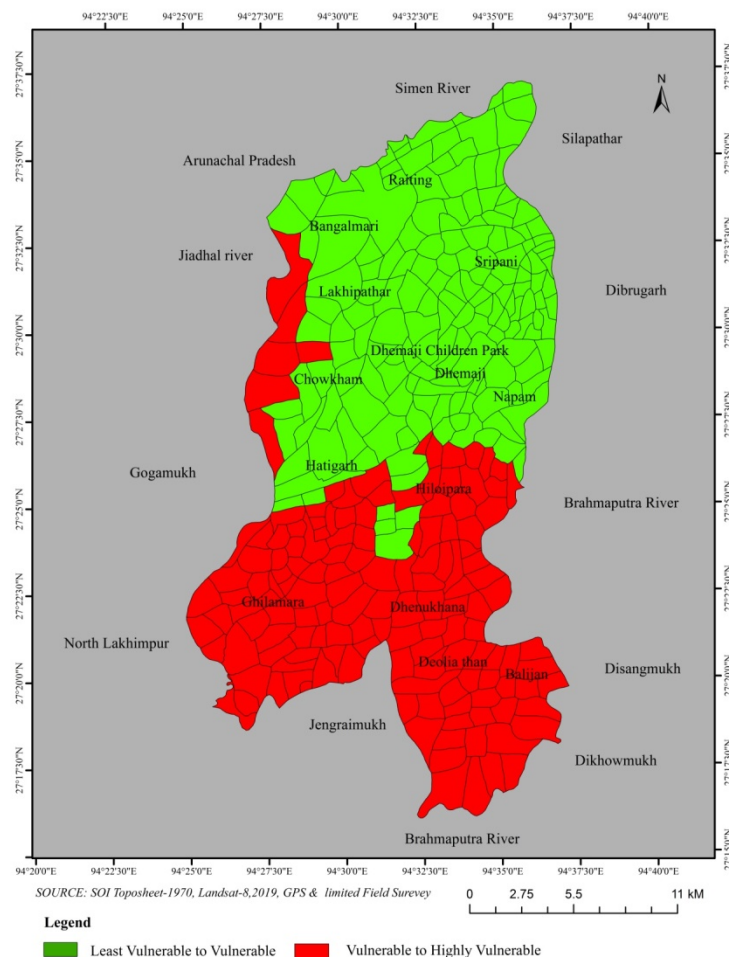


Fig 8. Flood affected village map

Since Dhemaji district experiences acute flood and siltation problem, there occurs fertile agricultural land due to sand deposition during high flood. Being an agrarian economy, the farmers had to suffer a lot as each year their croplands are washed away by the natural disaster causing immense loss to their properties. The study revealed that during 2018, the total loss of agricultural land from field survey was estimated at 16364.54 ha (Figure 9). Further more metalled and unmetalled road network of the study

area such as Bengenagarah-Kathalguri road, Khalihamari to ButikurBaparamDutta road, Seujiapathar-YedotGaon road to SolmaraPathar etc. has been acutely ruptured due to inundation by flood for couple of days(Figure 10).

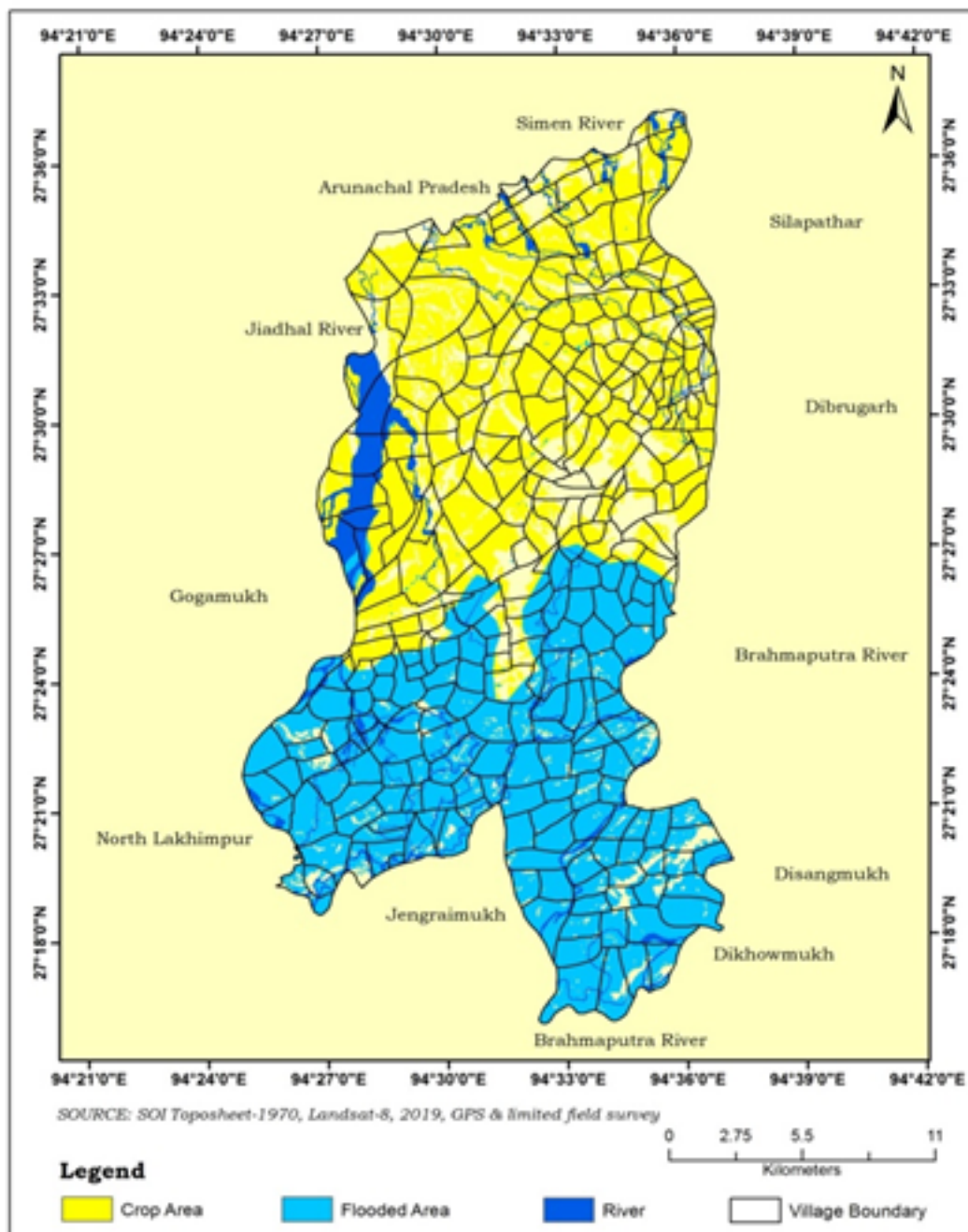


Fig 9. Crop affected map

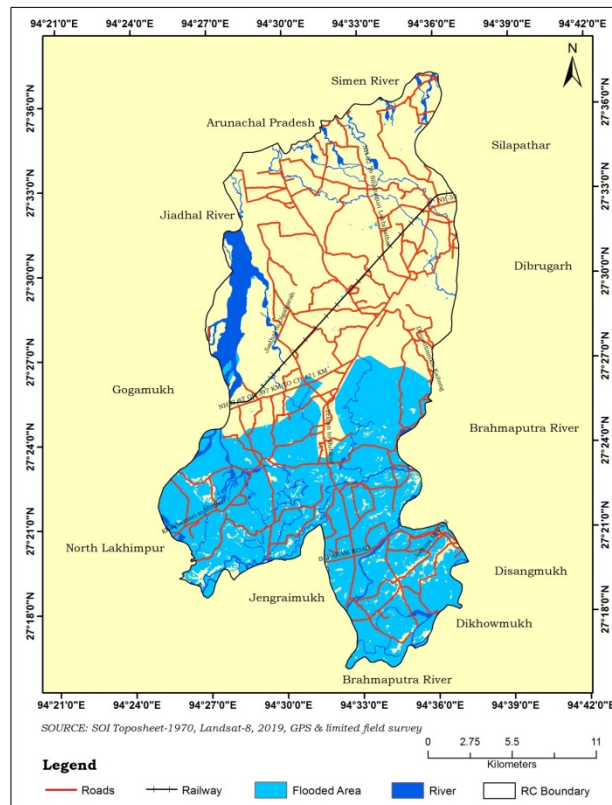


Fig 10. Transport affected map

Management strategies

Since floods are the most terrible calamity⁽¹²⁾ to both mankind and environment, there rises an overriding need to initiate few constructive management approaches so that its risks get reduced. In this context, initially it is required to understand the underlying fundamental causes associated with the flood risk and mitigation strategies⁽¹³⁾. Moreover, the approach of “living with flood” is considered as relevant since it provides the only way to cope with the devastating event⁽¹⁴⁾. This approach can also be extrapolated to the agricultural sector wherein the preparation of crop calendar within cropping system can be calibrated in view of the impending rhythm of the floods. Presently, with the aid of remote sensing and GIS applications, it is convenient in mapping and monitoring the flood risk and vulnerable flood zones of any region using multi criteria approach^(12,15).

In the study area it was observed that despite the annual ravages caused by the floods and siltation few efforts have also implemented in order to lessen its effect to a tolerable extent. Amongst them, the local people have adopted various flood and anti-erosion measures such as construction of bamboo bars to protect against embankments, raised platforms, revetment, porcupine bars, bolder spurs etc. Apart from such measures, scientific and adaptive initiatives could also be undertaken by coordination with various departments, agencies and administrations during emergency situations^(14,16). With the advent of geospatial technology nowadays even the high elevated zones or highlands could be detected through the Digital Elevation Model (DEM) that helps better to organize the flood relief camps and rehabilitation purpose^(17,18).



Fig 11. An embankment with bamboo bars in the study area



Fig 12. Bamboo bars with Polythene bags to protect embankment in the study area

4 Conclusion

The overall study reveals that the Dhemaji revenue circle of Dhemaji district has been continuously suffering from the twin menace of flood and erosion problem. Due to the monsoonal rhythm, Assam witnesses a grim situation as the rivers get swollen ultimately spills over its banks thereby washing away the crop fields, infrastructure and properties of many people. Advancements in GIS and remote sensing have paved the way from flood preparedness to risk mitigation by mapping and monitoring the flood prone areas thereby identifying and understanding the root causes of flooding^(17,19). Various flood prevention methods applied in the study has remained unsuccessful till date so it's an overriding need to consider some alternative strategies⁽²⁰⁾. Pertaining to such havoc, it is significant to increase resilience through proper planning and attention must be given on construction of houses on elevated platforms or erecting highlands in settlements for sheltering during flood⁽¹⁹⁾. The results reveal that the entire region is categorized into two flood zones viz. least vulnerable zone occupying 55.27% and highly vulnerable zone covering 44.73% of the total area. Besides, the damages incurred during 2018 estimated that about 47.36% of the villages were severely inundated affecting more than 30,000 people. The long-term flood impacts have also affected the standing crops and its production which is a prevalent phenomenon and during 2018, the total agricultural loss recorded was about 16364.54 hectares. On contrary, most of the

roads were interrupted and disconnected from the main road due to prolonged submergence under flood. The impoverishing losses must be addressed through an integrated and participatory approach drawing upon technologies to mitigate flooding and provide rescue and relief in order to cope with the hazard by reducing its risk posed. It is notable that some socio-economic criteria's might also be incorporated in hazard risk studies applying mathematical models to gain better accuracy⁽²⁰⁾. Thus, the outcome of the study will comprehend the decision makers and planners in India to evaluate such hazard through mapping and developing effective mitigation strategies.

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