Flood Hazard Risk Assessment and Mapping of a Sub-watershed of Imphal River Basin, Manipur, India: A Multi-resolution Approach

Maisnam Bipinchandra, Ngangbam Romeji and Chandramani Loukrakpam

Abstract Flood is one of the major disasters that prevail in the northeastern India. Mapping of spatial inundation patterns during flood events is regarded for environmental management and disaster monitoring. This study emphasized on the assessment and flood inundation mapping of sub-watershed of Imphal River Basin of Manipur. Multispectral datasets from Landsat-8 OLI and Sentinel-2 and Digital Elevation Models (DEM) from ASTER and Cartosat with 30 and 10 m resolutions, respectively, are used for producing flood inundation maps. Hydrologic Engineering Center's River analysis system (HEC-RAS) and RAS mapper are used in this study to generate flood inundation map. The study involved the assessment of flood map derived from multi-resolution two-dimensional hydrodynamic model approach. The result from the study provides the required assessment of impacts of flood events in the study area and will help the policy-makers to take an effective decision-making for mitigation and preventive measure of the region.

Keywords Flood · Inundation mapping · HEC-RAS

1 Introduction

Flood is a natural disaster. It is inevitable. It is a part of the hydrological cycle. It causes havoc to life and properties.

It also endangers the economic development of a country. *"Flooding is a general temporary condition of partial or complete inundation of normally dry areas from overflow of inland or tidal waters or from unusual and rapid accumulation or runoff"* [1]. Floods cannot be prevented totally but preventive measures and mitigation can

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be done. As per the Floods Directive [2], flood risk is the definition of risk as the product of "hazard" and the "vulnerability". It is necessary to focus on the prevention and risk management. There should be emphasis on risk analysis, management, and assessment so as to come up with measures to decrease the risk in the areas of interest. The comprehensive analysis and assessment of flood risk is an essential part of the whole risk management concept [3]. Flood risk may increase due to human activity and may decrease by appropriate flood management and planning [4]. Flood hazard assessment results can be adopted by land use and development planners as part of an integrative approach to improve flood preparedness that can improve future land developments and raise community awareness.

The Imphal River Basin, Manipur, India is subjected to frequent floods in the past decades causing damage to human, livestock, and agricultural crops. This in turn affects the small economy of the state of Manipur. Thus, it has become necessary to study the different factors contributing to the frequent floods so as to assess the flood risk in the river basin. For this purpose, a small part of the Imphal River Basin has been considered to analyze the extent of flood in this area so as to visualize the probable area of flood-affected areas in this basin. Apart from the causative factors of the floods, this study mainly focuses on the effectiveness or accuracy of spatial resolution of the satellite imagery in analyzing the inundation during floods. The result of the analysis depends on the spatial resolution of the satellite images which in turn affects the procedure of assessment of the flood risk in the areas likely to be inundated during floods.

2 Study Area

The Manipur is part of the eastern extended range of Himalayas, namely, Purvanchal and shares the international boundary with Myanmar in the eastern front. The state constitutes valley region in the center which is surrounded by the hill ranges in all direction and has the Total Geographic Area (TGA) of 22,327 km^2. The states extend from 92.6019450°E to 95.1753321°E longitudes and 23.4759838°N to 25.5746684°N latitude. The valley region comprises almost 10% of the TGA of the state and the remaining area is covered with hill ranges. The average elevation of the valley is about 790 m above the sea level and that of the hills ranges between 1500 m and 1800 m above mean sea level. Barak River Basin, Manipur River Basin, and Yu and Lanye River Basin are the main river basins of the state. The southwest monsoon climate is prevailing in the region and the region receives an average rainfall of 1500 mm per year and temperature ranges from subzero to 36 °C [5]. The population of the state as per 2011 census is 2,855,794. The density of population is 130/km^2. The study area is a part of the Imphal River Basin in the state of Manipur, India. The economy of the state is primarily agriculture, forestry, cottage, and trade.

The Imphal River is a major river which originates in Senapati district at the hills of *Karong*. In this study, total length of 69.28 km stretch of the river up to *Minuthong Bridge* of Imphal East is considered. The Gaging station under the

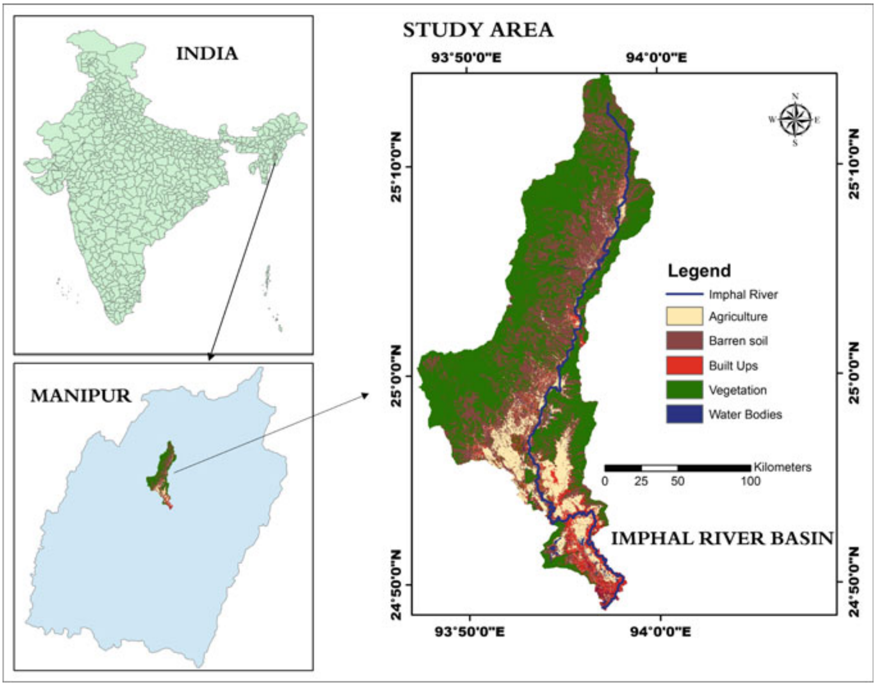

Fig. 1 Study area

Minuthong Bridge is considered as the outlet point and it flows toward the southern part of Manipur. The area of the basin under study is 374.27 km$^{2.}$ It lies between the latitudinal extent of 24°48′41.838″ N and 25°14′34.039″ N and longitudinal extent from 93°47′22.159″ E to 93°59′41.302″ E (as shown in Fig. 1).

3 Dataset and Methodology

In this study, datasets of 30 and 10 m spatial resolutions are employed for the generation of flood inundation map. Landsat-8 OLI and Sentinel-2 multispectral imageries are used for generating the LULC map. Digital elevation models of ASTER and Cartosat with 30 and 10 m spatial resolutions are used for extracting the terrain layers. As the study area is located in the Intertropical Convergence Zone (ITCZ), cloud contaminations of the satellite imagery prevail. To generate cloud-free image, Spatiotemporal Image Fusion Model (STI-FM) is employed [6] as shown in Table 1.

The DEM is preprocessed to remove the redundant values and hydrological corrected DEM is used. The Landsat-8 and Sentinel-2 are processed to convert the DN values to surface reflectance [7, 8]. The datasets after preprocessing are the input in the Geo-RAS and the input layers are generated. After exporting the processed

Table 1 Dataset

Dataset	Path/Row	Date
MOD09A1 (Base image)	H26/V06	03/12/2017
MOD09A1 (Auxiliary image)	H26/V06	01/11/2017
MOD09A1 (Base image)	H26/V06	27/12/2017
MOD09A1 (Auxiliary image)	H26/V06	09/11/2017
Landsat-8 (Base image)	135/43	05/12/2017
Landsat-8 (Auxiliary image)	135/43	03/11/2017
Sentinel-2 (Base image)	135/43	30/12/2017
Sentinel-2 (Auxiliary image)	135/43	10/11/2017

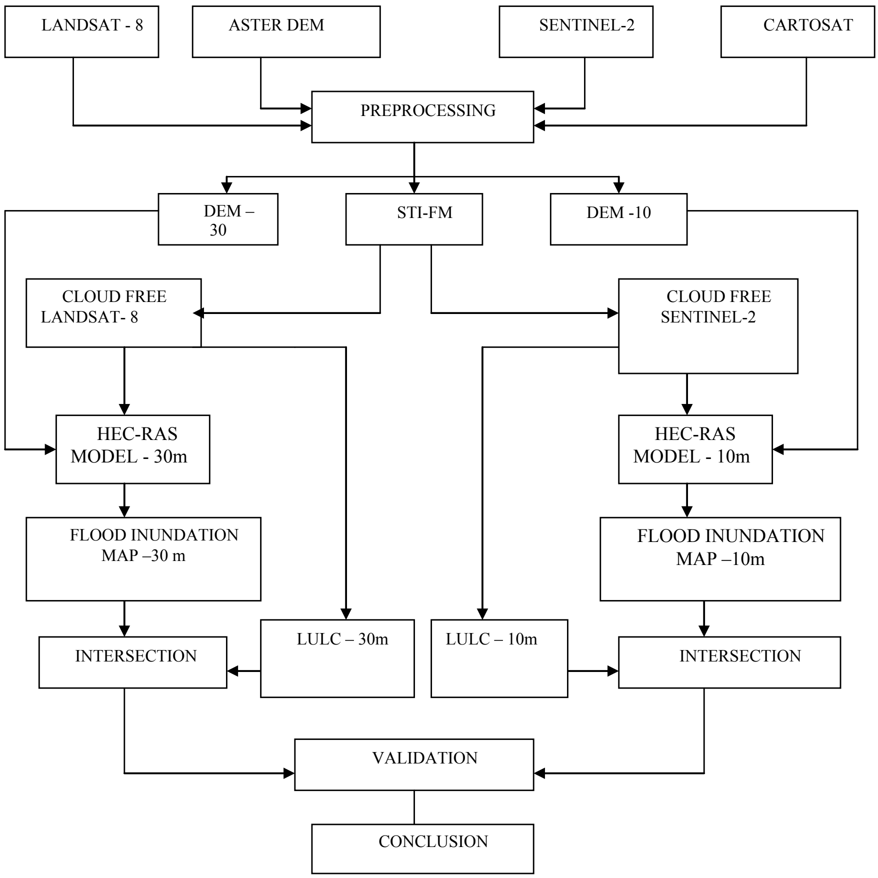

Fig. 2 Methodological flowchart for generating the flood inundation map of the Imphal River Basin, Manipur

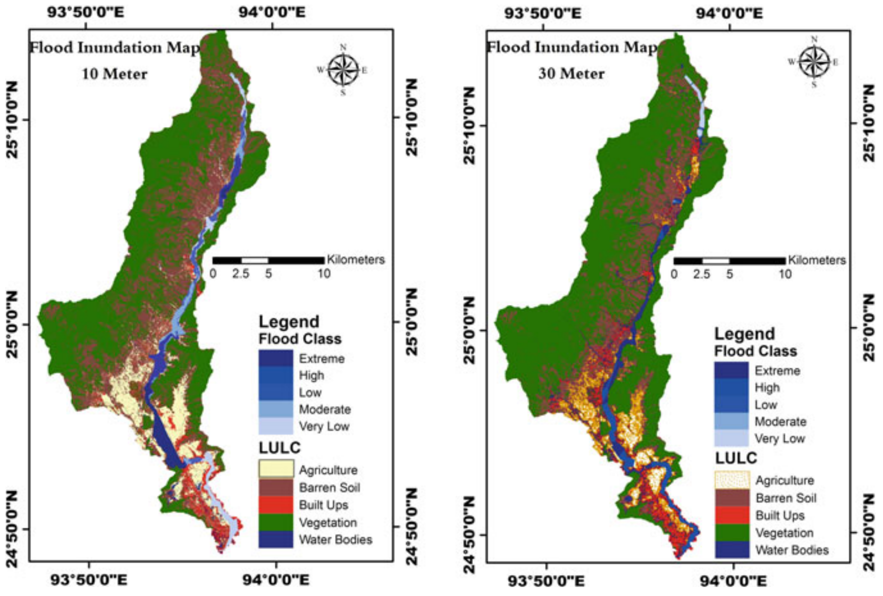

Fig. 3 Flood inundation map (10 and 30 m)

terrain layers, the two-dimensional hydrodynamic model is executed in HEC-RAS [9]. The output result from HEC-RAS is then employed as the input to the RAS mapper and thus the flood-inundated area of the study area is generated as shown in Fig. 2 (Fig. 3).

4 Results

After the generation of flood inundation map, it then overlays with the LULC class and the area under the influence of various flood class is calculated. The intersection table for the flood inundation from 10 to 30 m spatial resolution is given in Tables 2 and 3.

Table 2 Intersection table of flood inundated from 10 m resolution (Area in km^2)

	Barren	Vegetation	Built-ups	Agriculture	Water bodies
Very low	1.755699992	1.114869952	2.437259912	1.193150043	0.524001002
Low	1.81467998	1.11401999	0.513608992	0.563069999	0.393115997
Moderate	1.773489952	0.774062991	0.425680012	1.106549978	0.29824999
High	2.580840111	0.579051018	0.316897988	1.660609961	0.625528991
Extreme	2.247839928	0.414826006	1.329699993	2.28008008	0.878027976

Table 3 Intersection table of flood inundated from 30 m resolution (Area in km^2)

	Barren soil	Vegetation	Water bodies	Built-ups	Agriculture
Very low	0.79816002	0.654501021	0.376581997	0.0576073	0.01575
Low	0.0198037	0.019346301	0.019054901	0.00982073	0.00037439
Moderate	0.0276049	0.0230939	0.030146301	**0.0234037**	**0.00105122**
High	1.83958006	0.595206022	2.390350103	**3.04906011**	**0.505913973**
Extreme	3.04116988	1.299329996	2.034389973	**1.15612996**	**0.453613997**

This study mainly focuses on the flood inundation and its intensity on the land use class of agriculture and built-ups. Tables 2 and 3 show the variation in the spatial extent of the flood-affected region of the study area for the above mentioned two land use classes.

The comparison is made in between the two results obtained from the two different spatial resolutions. As the result of the comparison, the area under “extreme flood” is observed to be **2.28008008** and **0.453613997 km²** for 10 and 30 m, respectively. For “high flood” and “moderate flood”, the area is found to be **1.660609961** and **1.106549978 km²** from the 10 m resolution. Similarly, in case of 30 m resolution, the extent is observed to be **0.505913973** and **0.00105122 km²**, respectively.

As in case of “Agriculture class”, similar analysis is considered for the “Built-ups class” and result is found in similar pattern. The extreme flood class is observed to expand over more spatial extent in case of 10 m than the 30 m. In case of “High class”, the result from 30 m has more spatial extent than of 10 m and the pattern is vice versa in case of the “Moderate flood class”.

5 Validation

In this study, the flood inundation of a region is considered to be based on the topography of the study area. Slope in degree and elevation in meters are classified into five classes based on the National Remote Sensing Centre classification. The region with low slope and low elevation is considered to have maximum risk of flood and area with high slope and elevation is considered to have least risk of flood.

The classified slope and elevation (Figs. 4 and 5) layers of both 10 and 30 m overlay, respectively, after setting equal influence to both the parameters. The resultant overlay flood hazard risk map is given in Fig. 6.

The flood inundation map generated from the RAS mapper is then intersected with the flood hazard map generated as mentioned earlier. The accuracy assessment is performed in the region of intersection and thus the more accurate flood inundation map is inferred.

The intersected imageries are validated using error matrix and accuracy assessment is performed. The accuracy assessments of the intersected images are done using the flood hazard map acquired by integrating slope and elevation of the study

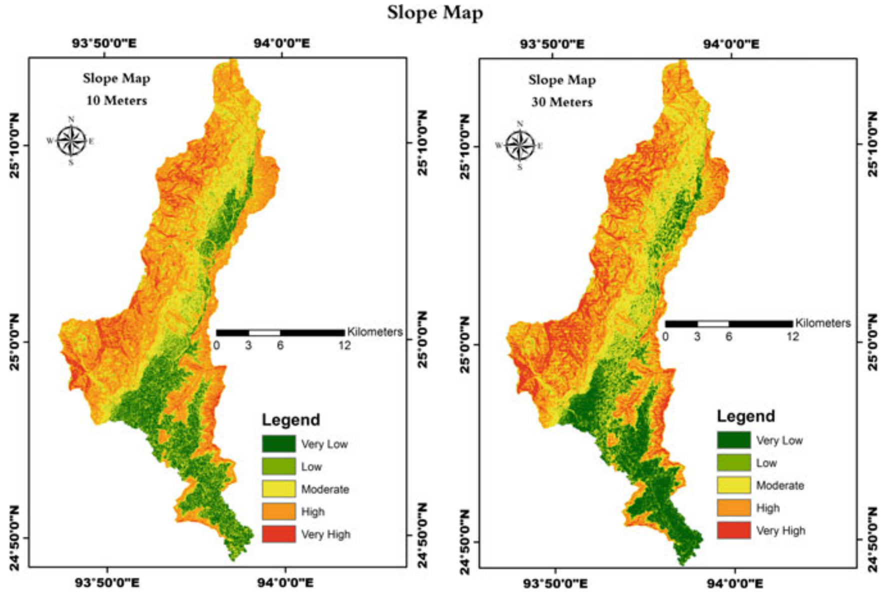

Fig. 4 Slope map

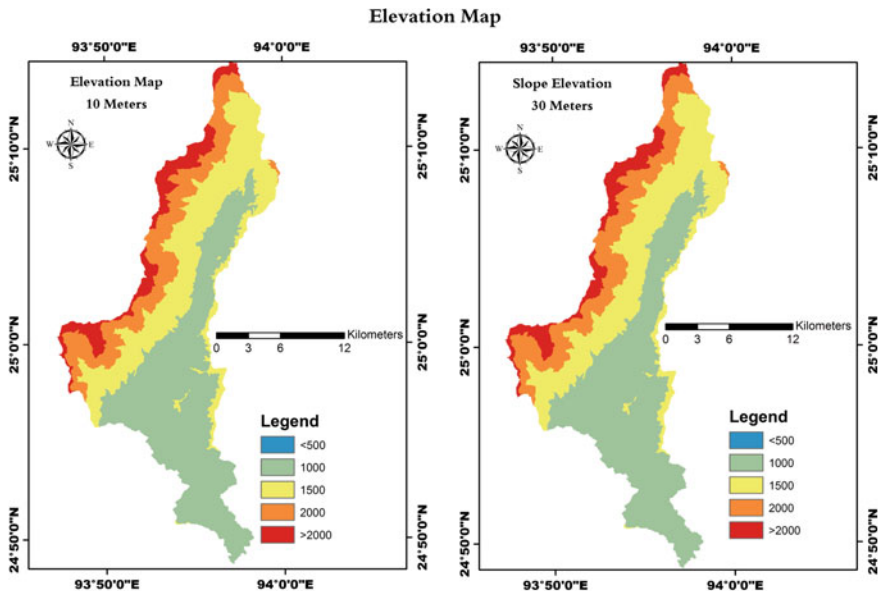

Fig. 5 Elevation map

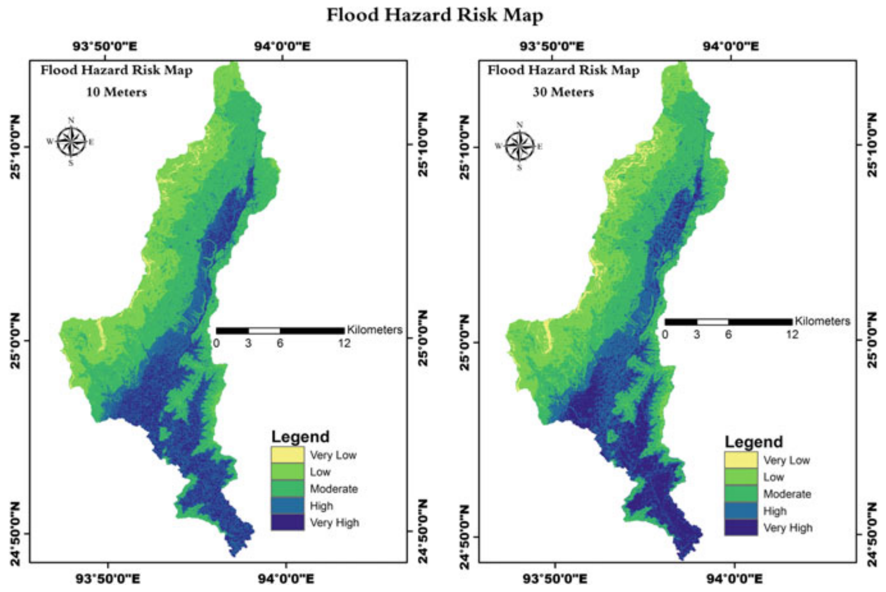

Fig. 6 Flood hazard risk map

area. The overall accuracy and kappa coefficient of that flood inundation map generated using 10 m spatial resolution are obtained as 84.45% and 0.80, respectively. In case of flood inundation map generated using 30 m spatial resolution, the overall accuracy and kappa coefficient are observed to be 70.13% and 0.67, respectively.

6 Conclusion

The flood inundation map generated using 10 m spatial resolution is found to be more accurate than that of the one with 30 m, spatial resolution. Considering the same flood event, the value of the affected inundated area on the basis of land use classes is found to be more accurate in case of the model result with finer spatial resolution as compared to the coarser resolution.

From this study, considering the model result with 10 m spatial resolution irrespective of the flood inundation intensity class, 16.02% of the total agricultural area and 26.13% of the total built-up area of the study area are affected by flood. It is expected that the result of this study would help policy- and decision-makers to take up necessary preventive and mitigation measures.

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