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# Flood Monitoring and Management using Remote Sensing

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## 1. Introduction

India is one of the most flood prone countries in the world. India, due to its geographical location, climate, topography and large population, has a greater impact of flood disasters. Twenty-three of the 35 states and union territories in the country are subject to floods. Around 40 million hectares (mha) or nearly 1/8 of Indian geographical area is flood prone and the country's vast coastline of 5700 km out of 7500 km is exposed to tropical cyclones (National Flood Control Commission Report, 1980). The annual average area affected by floods is about 7.57mha and the affected crop area is about 3.5 mha. The average loss in financial terms is about Rs13,000 millions. On an average the human lives lost is about 1595 (Gopalakrishnan, 2002).

Floods occur in almost all major river basins in India. The Indo-Gangetic and Brahmaputra river basins are the most chronic flood prone areas and are regarded as the worst flood affected region in the world (Agarwal and Sunita, 1991). Every year states like Assam located in Brahmaputra basin and Bihar, Uttar Pradesh and West Bengal located in Indo-Gangetic basin face severe flood problems. Nearly 75 per cent of the total Indian rainfall is concentrated over a short monsoon season of four months (June-September). As a result the rivers witness a heavy discharge during these months, leading to widespread floods in Uttar Pradesh, Bihar, West Bengal and Assam. The Himalayan Rivers also carry a large amount of sediment, causing erosion of the banks in the upper reaches and over-topping in the lower segments. Inadequate capacity of the rivers to contain within their banks the high flows brought down from the upper catchment areas following heavy rainfall, leads to flooding. The tendency to occupy the flood plains has been a serious concern over the years. Because of the varying rainfall distribution, many a time, areas which are not traditionally prone to floods also experience severe inundation. Areas with poor drainage facilities get flooded by accumulation of water from heavy rainfall. Excess irrigation water applied to command areas and increase in ground water levels due to seepage from canals and irrigated fields also are factors that accentuate the problem of water-logging. The problem is exacerbated by factors such as silting of the riverbeds, reduction in the carrying capacity of river channels, erosion of beds and banks leading to changes in river courses, obstructions to flow due to landslides, synchronisation of floods in the main and tributary rivers and retardation due to tidal effects (NDMA, 2008). Drainage problems also arise concurrently if floods are prolonged and the outfalls of major drainage arteries are blocked. One of the major reasons for the floods is the massive indiscriminate deforestation, which leads to large amounts of topsoil coming loose in the rains. Thus, the soil, instead of soaking up the rainfall, flows down into the river and in turn causes the riverbeds and its tributaries to rise.

## 2. Phases of Flood Management

Flood disaster management cycle has three main phases viz. flood preparedness (before flood occurs), flood response (during a flood) and the last phase called flood mitigation (after flood has occurred). Flood preparedness involves identification of chronically flood prone areas, identification of areas that are liable to be affected by a flood and planning of optimum evacuation plans. Flood response involves the immediate action taken once the flood disaster has occurred in terms of the identification of the region affected, spatial extent of inundation, flood damage statistics, flood progression and recession etc which can help in carrying out the relief and rescue operations on ground. Flood mitigation phase starts after the flood has occurred by identification of the changes in the river course due to flooding, status of flood control works, river bank erosion, drainage congestion, flood hazard and risk vulnerability assessment .

## 3. Space inputs for flood disaster management

The most important element in flood disaster management is the availability of timely information for taking decisions and actions by the authorities (Miranda et al., 1988, Okamoto et al., 1998). The process of collection of information by conventional means is time consuming and not cost effective. In this context, the Earth Observation satellites provide comprehensive, synoptic and multi temporal coverage of large areas in near real-time and at frequent intervals, which enables to compare the data before during and after flood disaster (Roy et al., 2008). Remote sensing data coupled with Geographic Information System (GIS) tool proves to be capable of overcoming some of the critical limitations that are being faced using conventional techniques. NRSC under the ISRO Disaster Management Support (DMS) Programme provides support during the flood response phase by providing flood based products like flood inundation maps, damage statistics, flood progression, flood recession and flood persistence to state agencies. During the post disaster phase monitors the flood situation, status of the flood control works etc. Under the mitigation phase studies towards flood hazard zonation, flood risk and vulnerability and bank erosion studies are also carried out. Apart from this flood forecasting and flood inundation simulation studies towards early warning are also initiated. Fig-1 shows the different phases of flood disaster management being addressed using remote sensing.

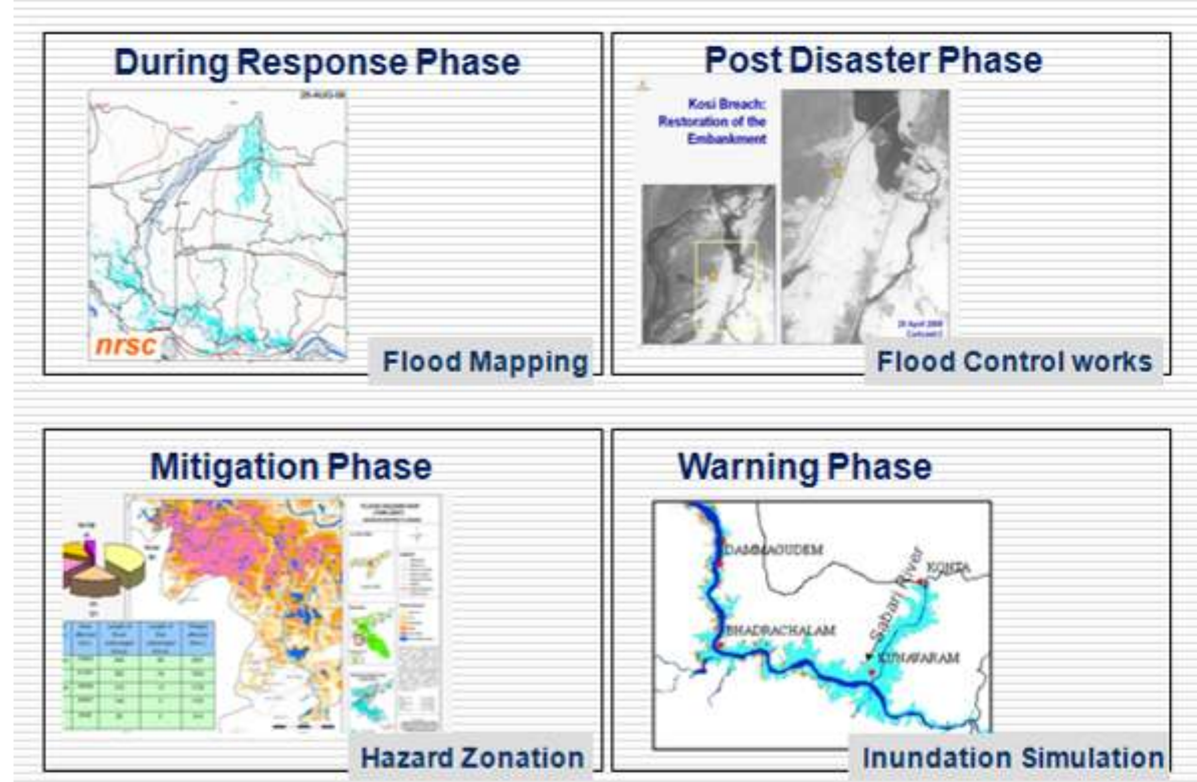


Fig-1 Different phases of flood disaster management being addressed using remote sensing.

## 4. Early Warning

The Godavari river system is one of the major river systems in the country and one of the most flood-prone in the Southern India. Heavy rains in the catchment of Godavari River during the first week of August, 2006 caused heavy loss to lives and infrastructure in East Godavari, West Godavari and Khammam districts of Andhra Pradesh (India).

**Flood Forecasting**

Though Central Water Commission (CWC) is the main nodal agency having the mandate to provide the flood forecast NRSC has collaborated with CWC for the development of medium-range Flood Forecast Model for the Godavari Basin using space inputs (LU/LC, Soil, SRTM-DEM) and hydro-meteorological data through semi-distributed modeling approach. Flood forecasting model is run by CWC during 2010 &11 using real time 3 hrs Hydro-meteorological data. The discharge data generated as output would be very useful input for inundation simulation for developing Spatial Early warning.

**Flood Inundation Simulation**

Flood inundation simulation studies for part of Sabari tributary from Konta to Kunavaram (35 km) stretch in Godavari River basin were carried out using discharge data, land use/land cover and ALTM DTM and the results were validated with satellite data. Fig-2 shows the flowchart of the methodology used for simulation of flood inundation. The river geometry data extracted using HEC-GeoRAS, together with the discharge data and other parameters, spatial flood modeling has been carried out for peak flood situation using HEC-RAS, 1-D hydraulic model. Hourly water level data was used to generate different flood inundation patterns. Flood inundation is simulated for the year 2010 and the maximum flood inundation extent simulated by the model was compared with the corresponding actual inundated area obtained from Radarsat image. Fig-3 shows the comparison of the simulated and observed flood extent. The results obtained from the model for peak flood situation were in well accordance with flood inundation observed from corresponding satellite data.

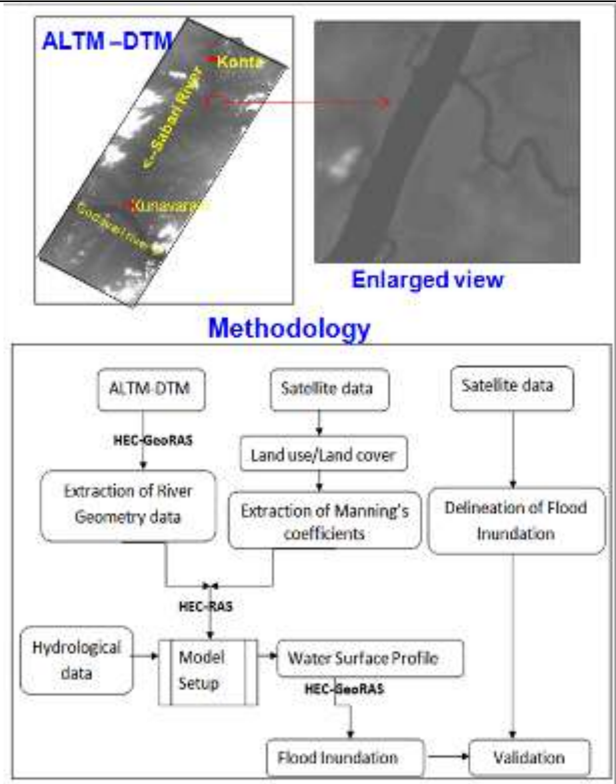


Fig-2 Flowchart of the methodology used for simulation of flood inundation

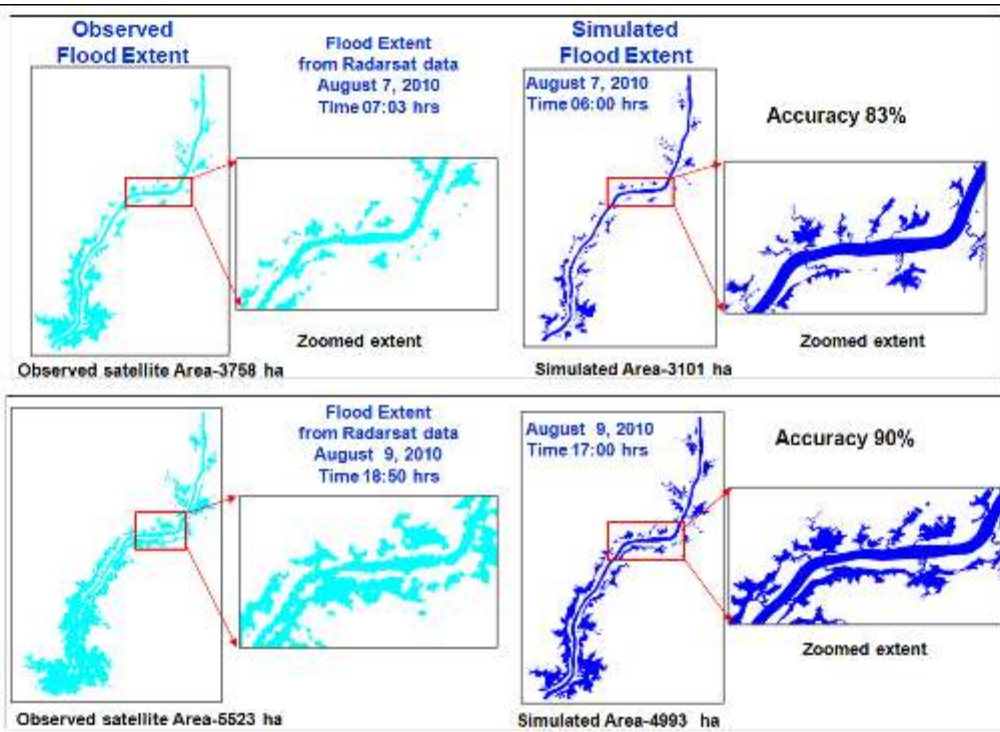


Fig-3 Comparison of the simulated and observed flood extent.

## 5. Flood Response

DSC keeps a continuous watch on the flood situation in the country through different sources. Based on the cloud cover pattern observed from meteorological satellite KALPANA-1, rainfall pattern from Indian Meteorological Department (IMD), hydrological data from Central Water Commission (CWC), and flood related information from websites, news media and state departments satellite data from various satellite sensor systems is programmed. Presently emergency requests are placed for programming of the Indian satellites (Resourcesat-1 & 2, Cartosat-1 & 2 and RISAT-1 &2) and as well as the foreign satellites (RADARSAT-1 & 2) for flood mapping and monitoring and identification of embankment breaches. The extent of flood inundation is extracted from the satellite data and flood maps at various scales i.e. state, district and detailed levels are prepared for the flood affected states. The spatial inundation maps along with estimates on submergence are generated within 5-6 hours after receiving raw satellite data product and disseminated to the State and Central governments and user departments through a VSAT based satellite communication network. In addition to the flood maps, the flood inundation layer in GIS compatible format are also transmitted to the state remote sensing application centres for further value addition and dissemination as per the requirements of the user/line departments. Successful operational use of remote sensing technology for near real time flood mapping and monitoring was done using the Bihar floods of 2008, Andhra Pradesh floods of 2009, Uttar Pradesh floods of 2010, Orissa floods of 2011 and the recent Assam floods of 2012.

**Assam Floods 2012**

During June, 2012, Assam State witnessed one of the devastating floods since 1988, due to high flood levels in Brahmaputra River and its tributaries causing huge loss of human lives, cattle and infrastructure. DSC kept a close watch on the flood situation. All efforts are made to acquire the satellite data over flood affected areas in Assam. In addition, DSC also activated International Charter "Space and Major Disasters" for frequent observations over the flood affected areas. The satellite datasets were analysed and flood inundation layer was extracted. Flood maps and flood inundated area statistics were generated and provided to State & Central Government Departments. In addition, the flood inundation layer in GIS format was provided to ASDMA, ARSAC and NESAC for further value addition at their end.

## Overview of Flood Situation

DSC has acquired and analysed satellite data of 27, 29 & 30 of June and 2 July 2012 and provided the overview of the flood situation to the concerned. Fig-4 shows the flood affected areas in various districts of Assam State during 27-Jun to 02-Jul, 2012. It was observed that about 4.65 lakh hectares of area was inundated. Major flood inundation was observed in the districts of Nowgong, Cachar, Marigaon, Sonitpur, Marigaon, Lakhimpur, Barpeta, Kamrup (R), Jorhat, Karimganj, Golaghat, Sibsagar, Dhemaji, Dibrugarh and Darrang districts.

## Affected Transport Network

Due to the severity of the floods, roads were damaged at several places. About 426 km length of major roads in Assam state was observed to be affected by these floods as on July 02, 2012. Significant damages to railway track due to these floods were reported. About 88 km length of railway track in Assam state was observed to be affected by these floods as on July 02, 2012. Fig-5 shows the affected railway track in parts of Dibrugarh district as observed by Indian microwave remote sensing satellites, RISAT-1 & 2.

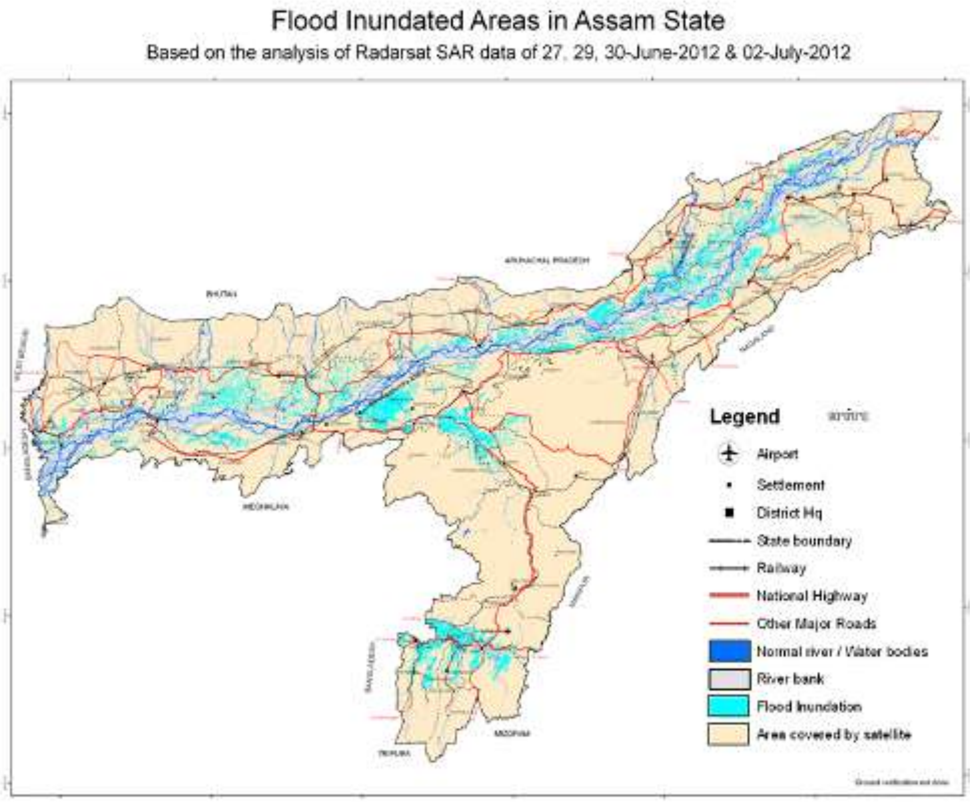


Fig-4 Flood inundated areas in Assam State during 27-Jun to 02-Jul, 2012.

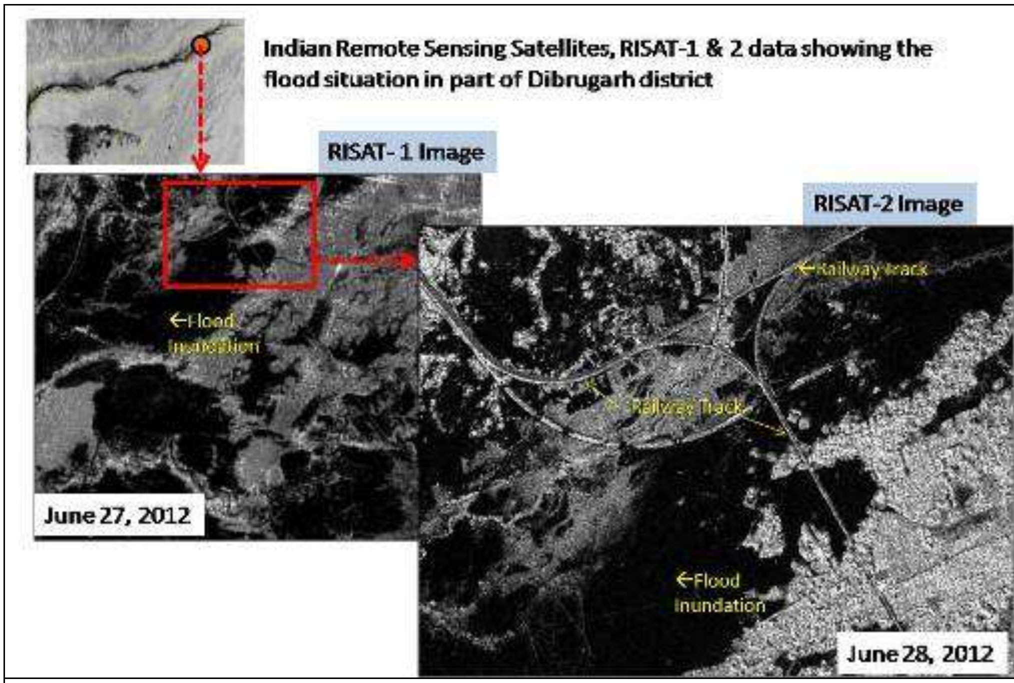


Fig-5 Indian remote Sensing satellites, RISAT-1 & 2 showing the flood situation and the affected railway track in parts of Dibrugarh district.

## Marooned Villages

The flood waters marooned several villages in the State and many villages were surrounded by flood waters for several days. About 3829 villages were observed to be affected by flooding as on July 02, 2012. In Nowgong district about 312 villages were affected by floods upto 02-July, 2012. It is observed that about 77 villages are marooned for more than 6 days, 85 villages for 4-5 days and 75 villages for 1-3 days. Recession in flood was also observed in 75 villages in Nowgong district.

## Flood Situation at Kaziranga National Park

Kaziranga National Park is one of the most severely affected areas in Assam during these floods. Loss of life of several wild animals was reported. Following figures show the temporal changes in flood inundation around Kaziranga National Park area during June 27-30, 2012 (Fig-6) and detailed view of flood inundation around Kaziranga National Park area (Fig-7). Recession in flood inundation is observed in some parts during June 27-30, 2012.

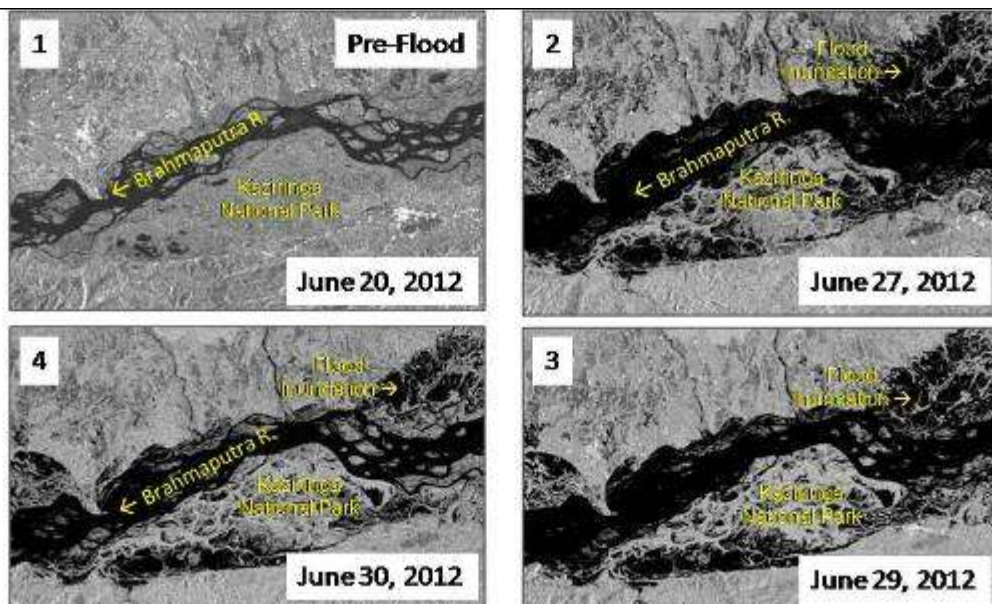


Fig-6 Satellite images showing temporal changes in flood inundation around Kaziranga National Park area during June 27-30, 2012.


Fig-7 ResourceSat-2 image showing the detailed view of flood inundation around Kaziranga National Park area as on July 01, 2012.

## 6. Flood Mitigation

Towards flood mitigation DSC has carried out flood hazard zonation, flood risk and vulnerability and bank erosion studies. Flood Hazard Zonation (FHZ) is one of the most important non-structural measures, which facilitates appropriate regulation, and development of floodplains thereby reducing the flood impact. Flood hazard zonation maps for Assam state is prepared, whereas for Bihar state the flood hazard maps are being validated and the atlas will be released soon.

### Flood Hazard Zonation for Assam

A flood hazard zonation atlas is prepared based on the analysis of more than 90 satellite datasets acquired during 1998-2007 flood season over Assam region. The atlas has been released by the Hon'ble CM of Assam (Fig-8). The flood inundation layers generated from the analysis of the satellite data for different flood waves in a calendar year were integrated in GIS environment to generate the maximum flood inundation extent observed in that year. The maximum flood inundation layers corresponding to various years (1998-2007) were integrated for assessing the frequency of inundation and subsequent generation of flood hazard layer. The flood hazard has been classified into five categories based on frequency of inundation (Table 1). 'Very Low' category indicates the areas which are inundated once or twice during the 10-year period. Similarly, 'Low' indicates three to four times, 'Moderate' indicates five to six times, 'High' indicates seven to eight times and 'Very High' indicates the areas, which are regularly subjected to inundation. Area under each category was estimated and flood hazard maps at state and district level were prepared. Further, cropped area (from land use) was also integrated with flood hazard layer to assess the impact. The statistics for cropped area affected under each hazard category was computed.

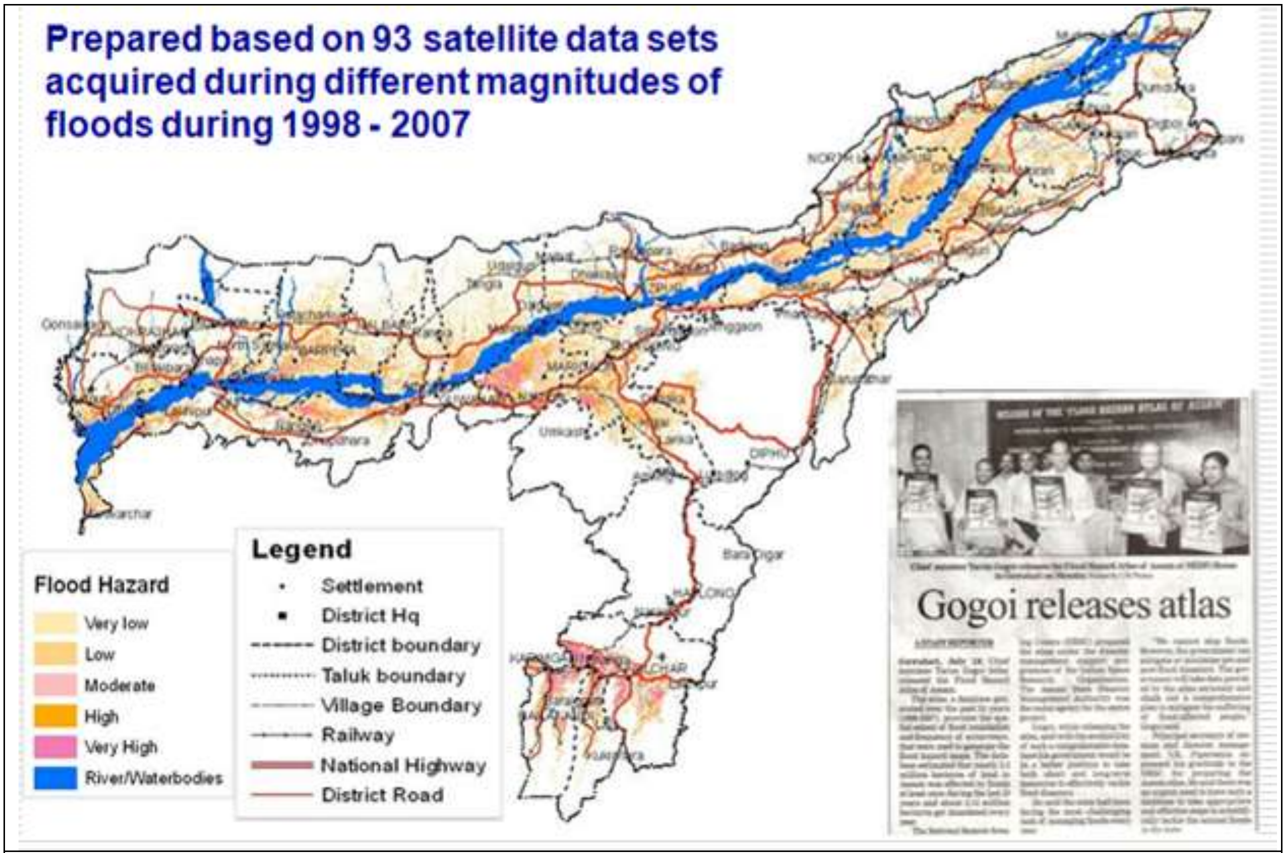


Fig-8 Flood hazard zonation map for Assam state.

It is observed from the analysis that about 22.21 lakh hectares of land constituting about 28.31% of total geographical area (TGA) of Assam state is affected by flooding (Table 2). Out of the total flood affected area of 22.21 lakh hectares, about 1.28 lakh hectares of land falls under very high flood hazard category. This area is observed to be continuously under submergence during the last ten years period. About 2.24 lakh hectares of land falls under high flood hazard category, indicating that this area has been subjected to flooding for about 7-8 times during last ten years. Area falling under moderate flood hazard category (area subjected to inundation 5-6 times during last ten years period) is estimated to be about 3.51 lakh hectares, constituting about 4.48% of TGA of Assam state.

Table-1 Flood hazard area under various categories

| Sl No | Hazard Severity | Flood Hazard Area (ha) | % Flood Hazard (with respect to State Geographic Area) | % Flood Hazard (with respect to Total Flood Hazard Area) | Crop Area Under Different Flood Hazard Categories (ha) |
|---|---|---|---|---|---|
| 1 | Very High | 1,28,687 | 1.64 | 5.79 | 83488 |
| 2 | High | 2,24,629 | 2.86 | 10.11 | 168802 |
| 3 | Moderate | 3,51,667 | 4.48 | 15.83 | 270558 |
| 4 | Low | 4,91,761 | 6.27 | 22.14 | 351356 |
| 5 | Very Low | 10,24,584 | 13.06 | 46.13 | 621367 |
| | TOTAL | 22,21,328 | 28.31 | 100.00 | 14,95,571 |

**Development of Village-Wise Flood Risk Index Map**

Village flood risk index map for Nagaon district has been generated using the flood hazard layer as primary input. About 50 satellite datasets, optical (IRS) and microwave (Radarsat), acquired during the last 10-year period (1998–2007) during the flood season have been analysed to extract flood inundation layer and generate composite flood hazard layer. Flood hazard layer is considered as the primary input and is integrated with land use/land cover, infrastructure and population data and weightages are assigned to each class. Based on this, village flood risk index map for Nagaon district has been generated. Fig-9 shows the flow chart of the methodology adopted for generating village-wise flood risk index. The results of analyses indicate that about

267 villages are in the moderate–high risk index zone. About 35,354 ha of the district is in high flood hazard zone and about 25,281 ha of crop area is affected annually.

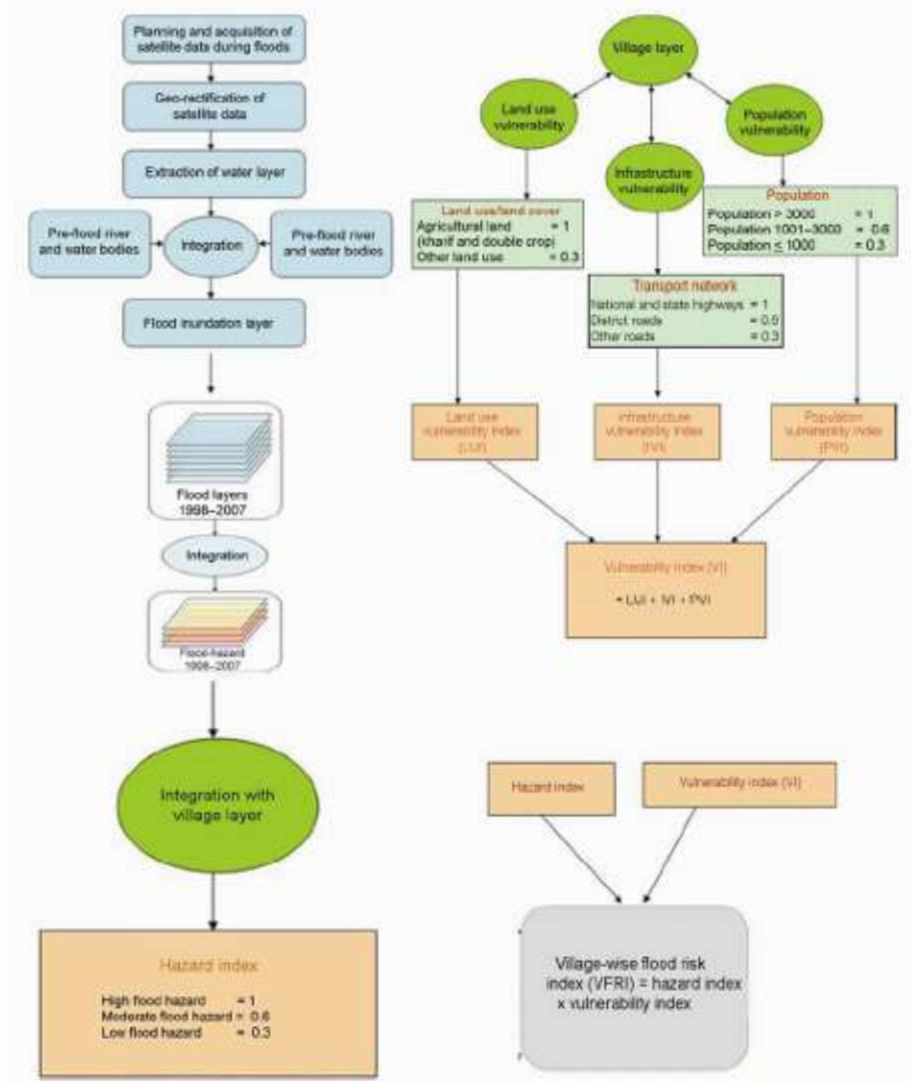


Fig-9 Flow chart of the methodology adopted for generating village-wise flood risk index.

**Bank Erosion Studies**

Bank erosion is one of the most commonly experienced problems especially in the Brahmaputra basin. Rate of erosion in the Brahmaputra catchment, 953 ton per sq km per year, is the highest in any catchment system in the whole world (Venkatachary et.al., 2001). Resourcesat-1 IRS

LISS-III satellite data having a spatial resolution of 23m and acquired during 2002 and 2010 were used for the bank erosion and deposition studyin the Brahmaputra and Barak Rivers in Assam. The satellite datasets of 2002 and 2010 were geometrically rectified to the master map base for positional accuracy. The individual satellite data sets were mosaiced for the individual years of 2002 and 2010. The banklines of the rivers for the year 2002 and 2010 were delineated. Both the banklines were intersected to identify and estimate the amount of erosion and deposition at different pockets along the main Brahmaputra and Barak river stretch. Fig-10 shows the pockets where bank erosion and deposition has taken place from the comparison of the satellite images acquired during 2002 and 2010 for part of Assam.

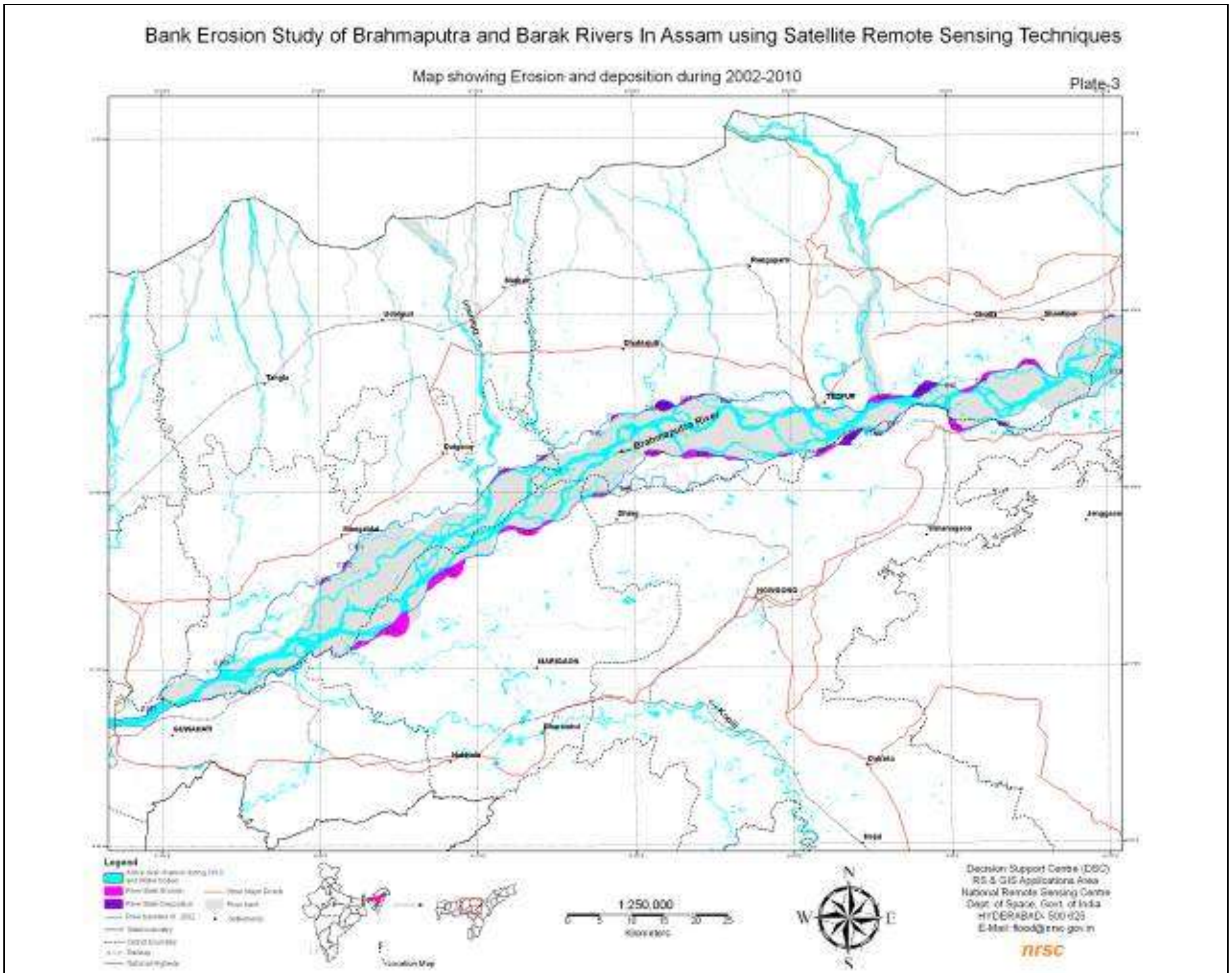


Fig-10 Bank erosion and deposition delineated from satellite images in parts of Assam.

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