



## 1. Introduction

Flood affected area maps are one of the very important non-structural methods of flood damage mitigation. These maps are useful in planning and regulating developmental activities in flood plains, construction of relief, rescue, and health centres. Satellites provide synoptic observations of the natural disasters at regular intervals that help in disaster risk reduction in the country. Over a period of time, National Remote Sensing Centre (NRSC), ISRO has created a repository of large data pertaining to the floods & cyclones in different areas of the Country. These historical flood maps, generated by NRSC/ISRO, are useful for identification of flood affected areas. At the behest of the National Disaster Management Authority (NDMA), NRSC/ISRO has prepared the Flood Affected Area Atlas for India using the available historical satellite datasets spanning over 25 years (1998 to 2022).

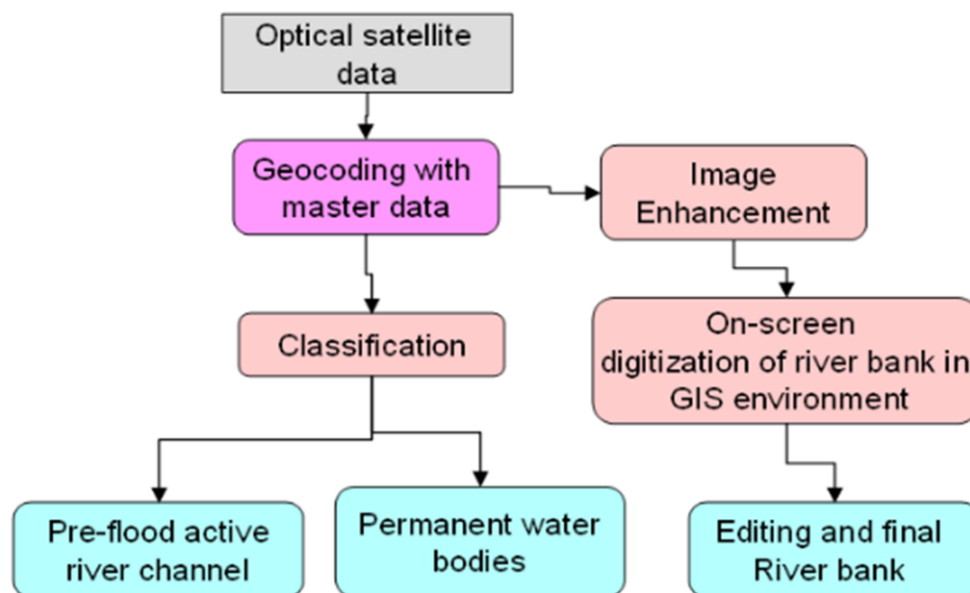
## 2. Methodology for Satellite Based Flood Inundation Mapping and Monitoring

Satellite-based technologies and Earth Observation (EO) data are essential for the assessment of flood inundation information - a remote sensing application to support flood disaster management in India. Daily information is received through flood disaster watch enabling the tracking of the data on river water level, rainfall, spatial runoff, and other available field data is analyzed. Flood conditions in terms of flood progression, recession, and persistence are assessed using multi-date satellite data at regular intervals. This information is also used to generate flood maps that can help in identifying areas that are at high risk of flooding.

Indian Remote Sensing (IRS) satellite and foreign satellite datasets (optical and microwave) during this period were acquired covering different flood magnitudes in India and used in generating the flood affected area maps after its thorough analysis. Water levels of various gauge stations during the period 1998 to 2022 has been obtained from Central Water Commission and used the preparation of flood affected area atlas of India. These state level flood maps are validated by the state disaster management organizations of major flood-prone states.

## 2.1. Pre Flood Satellite Data Preparation

Pre-flood satellite data over flood-prone states are acquired and analyzed before the onset of the flood season. River bank lines, permanent water bodies, and active river channels are extracted. These datasets and layers are used as reference layer for further analysis on change detection. These images are considered as reference satellite images, and the currently acquired satellite data is geometrically co-registered for maintaining consistent positional accuracy. Various steps followed for pre-flood data generation are shown in Figure.1. In addition, latest Landuse / Land cover information at 1: 250000 scale is also utilized in the process of pre-data preparation .



**Figure.1. Flowchart for Pre-flood Data Preparation**

## 2.2. Satellite Data Processing

Satellite sensors can capture images in different wavelengths such as visible, infrared, and microwave, which are used to detect changes in land cover, identify areas that are under flood inundation. Different types of satellite data can be used for flood mapping, including optical and microwave data, each with its own advantages and limitations. Optical data, for example, can provide high-resolution images, but it can be limited by cloud cover. Synthetic Aperture Radar (SAR) sensors will penetrate through cloud cover and is used for interpretation of images of the flood-affected areas. By using a combination of different types of satellite data, flood

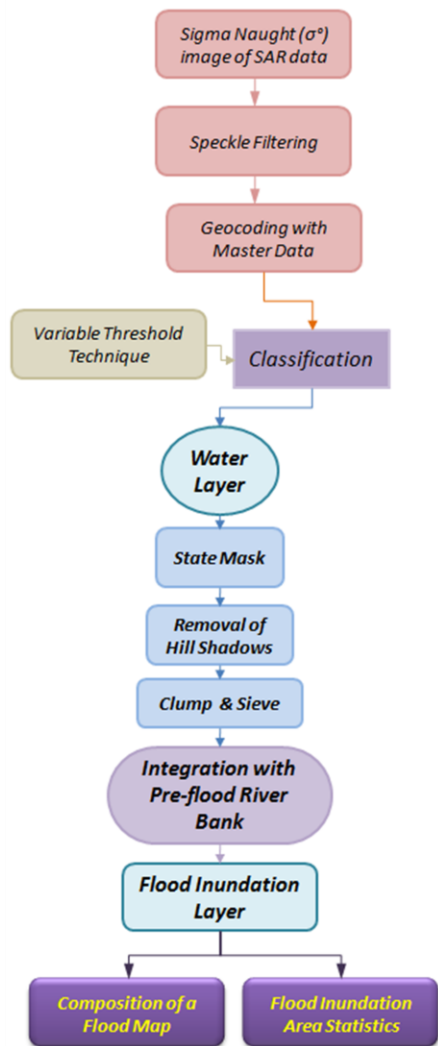
mapping can provide valuable information to support flood response and mitigation efforts.

### 2.2.1. Optical Satellite Data Processing

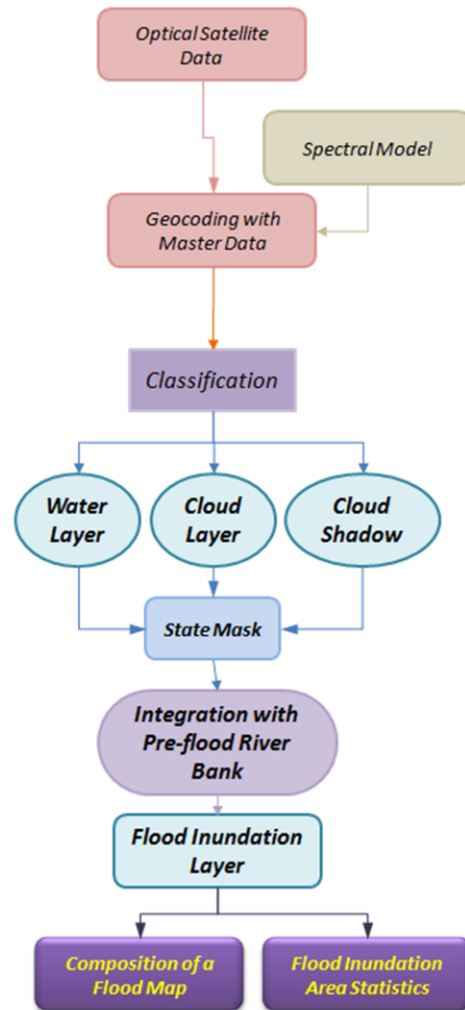
Satellite images are classified using digital image processing software to extract water pixels from the image. In case of optical satellite data, unsupervised classification is performed over optical remote sensing data to include the classes viz. main active river channel, tributaries, and water bodies. A classified image is generated, which is further converted to vector format. Enhancement techniques are used to increase the contrast between the features in the image.

### 2.4.2. Microwave Satellite Data Processing

In case of microwave satellite data a backscattering (Sigma naught) image is generated, and water bodies are extracted using a variable threshold technique model. State mask, hill mask, and hill shadow mask are applied to the extracted water layer. Further, isolated water pixels, which are not likely to be water pixels, are separated by grouping and removing them. The flow chart of the methodology for processing of SAR data, optical data are shown in Figure 2 and 3. The advantage of using SAR satellite data over optical data is its ability to penetrate cloud cover and also data acquisition during both day and night times. Water surfaces are generally smooth at radar wavelengths and can consider specular reflectors, which yield small backscatter. The surrounding terrain is assumed to be rough at radar wavelengths which exhibit diffuse scattering with moderate backscatter. Hence, water is considered low-intensity areas, whereas the surrounding terrain corresponds to brighter intensities. Thresholding is the traditional method of detecting flooding in open areas. Intensities below the threshold are regarded as flood or open water, whereas pixels with intensities above the threshold are regarded as dry land. The threshold will depend on the contrast between the land and water classes and generally needs to be set for each satellite scene. The backscatter depends on the frequency, incidence angle, and polarization and is sensitive to ripples on the water surface induced by wind waves.. The use of Synthetic Aperture Radar (SAR) is particularly useful for flood mapping as it can acquire images regardless of weather conditions and can provide high-resolution data. Additionally, SAR can provide data in multiple polarizations, which can be used to differentiate between different types of land cover and improve flood mapping accuracy.



**Figure.2 Methodology for flood mapping and monitoring by SAR satellite data**



**Figure.3. Methodology for flood mapping and monitoring by optical satellite data**

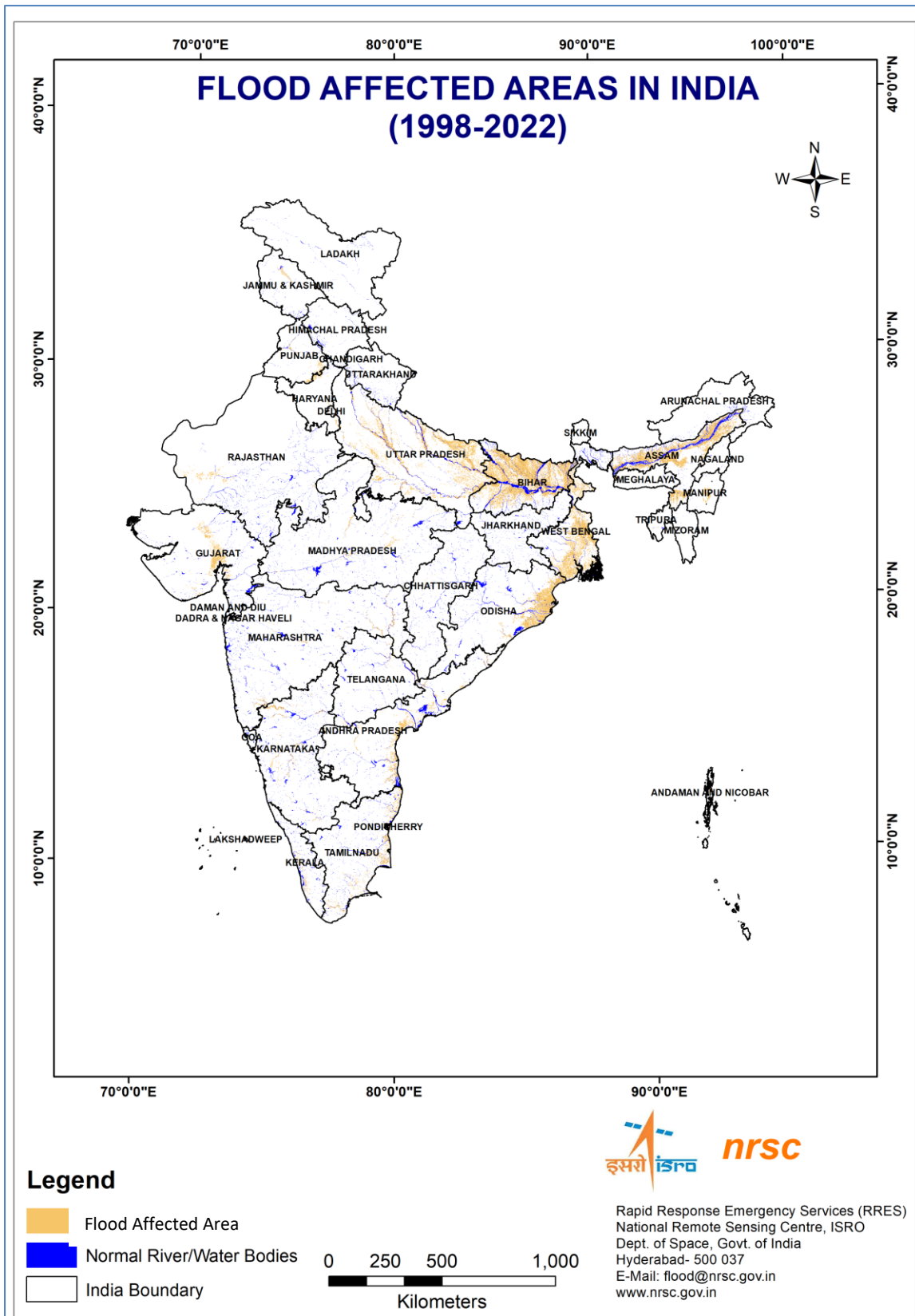
### 3. Flood Affected Area at national level (1998-2022)

Digital archival of spatial flood maps that were generated during each event of flood disaster in last 25 years in several states are utilized to prepare a Flood Affected Areas Atlas of India. Flood Affected Area Atlas will provide the opportunity to explore the regional setting of flood risk during last 25 years and identify the areas of hotspots where recurring flood occurs and also to prioritize the requirements for flood mitigation measures.

Flood mapping involves creating digital maps that show areas that are at high risk of flooding which are created using data from various sources, such as satellite imagery, topographic maps, and historical flood data, etc. A flood atlas, on the other

hand, is a collection of maps and information related to flooding in a particular region. Flood atlases typically depict the information such as flood hazard, flood frequency analysis, and historical flood data.

District / State wise flood affected area statistics were presented along the State Maps and India Map in the Atlas. Digital spatial maps shall be hosted on National Database for Emergency Management (NDEM) geoportal of ISRO. Atlas would be useful as resource of information for policy makers, planners and civil society groups and find its value towards flood risk evaluation, sustainable development and flood mitigation efforts in India. This atlas will be useful in preparing disaster management action plans at state level and in disaster risk reduction in the country.



*Disclaimer : Flood affected area map is a cumulative of flood inundation areas mapped from multi-date satellite data acquired and processed during 1998-2022 covering major flood & cyclone events. Flood inundation may include rain water accumulation / flood water in low lying areas. Estimated flood extent depends on availability of satellite data, it's date of overpass and coverage over flooded areas. Some of the Flash flood events could not be mapped due to non availability of satellite data in short duration. Flood affected area estimated in the study excludes river portion, permanent water bodies, salt pan and aquaculture lands in flood plains. Hence, actual flooded area may be more than the area estimated by satellite images.*