Flood Inundation Mapping and Analysis Using SAR Data at Middle Reach of the Brahmaputra River

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ABSTRACT

Guwahati city is one of the cities in Assam which is flooding frequently. This research develops mapping of flood-prone areas which is analyzed as the reasons of flooding. Efficient monitoring and prediction of floods and risk management for large river is quite impossible without the use of Earth Observation (EO) data from space. As a matter of fact, one of the most important problems associated with flood monitoring is the difficulty to determine the extent of the flood area as even a dense network of observations cannot provide such information. The flood extent information is used for damage assessment and risk management, and benefits to rescuers during flooding; it is also very important for calibration and validation of hydraulic models to reconstruct what happened during the flood and determine what caused the water to go where it did. The use of optical imagery for flood monitoring is limited by severe weather conditions, in particular presence of clouds. In turn, SAR (synthetic aperture radar) measurements from space are independent of daytime and weather conditions and can provide valuable information to monitoring of flood events. This is mainly due to the fact that smooth water surface provides no return to antenna in microwave spectrum and appears black in SAR imagery. The objectives of this study is to Identify and classify flood plain using satellite images and analysis of satellite derived water level over Brahmaputra river during monsoon season. The study using Sentinel -1A SAR images in flood water detection, monitoring of spatial extent and propagation of flood inundation were described and analysed in this thesis. The SAR images were first calibrated, filtered, and geometrically corrected. Afterward, threshold method was applied to extract the inundation areas from the SAR images. Probabilistic inundation scenario is developed by combining satellite derived inundation, water level and modified discharge. Due to the penetration capacity of SAR (Synthetic Aperture Radar) data through clouds, it has ability to continuous observation of flood events for producing accurate rapid and cost effective flood mapping. This study illustrates that the SAR data along GIS can be used effectively for flood water mapping, monitoring and analyzing the propagation of flood water in a flood prone area.

Keyword: - *SAR data, Remote Sensing, Flood Mapping,Flood extent, Flood duration*

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1. INTRODUCTION

A **flood** is an overflow of water that submerges land that is usually dry. Flooding may occur as an overflow of water from water bodies, such as a river, lake, or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground in an area l flood. Mainly, the flood occurs because of heavy rainfall, or melting of snow or both when the flow in river is so high that its natural cross-section is unable to contain it. Apart from the overflow of rivers, the floods may be caused by the failure of some dam, with a sudden release of huge amounts of water, causing considerable damage to life and property. In India, almost all the rivers carry heavy flow during the monsoons. In the upper reaches, where the rivers flow through mountainous terrain, there is generally no overflow of the banks during high flows. In lower reaches especially where the area is flat, the rivers overflow their banks and cause inundation of low laying lands, submerged standing crops an property and disrupt communications. In India, from the point of view of flood problem, the rivers can be grouped under four categories:

1) Brahmaputra Region

2) Ganga Region

3) North-West Region

4) Central India Deccan Region

One of the major challenges during flood is to get an overall view of the incident with accurate extent of the affected area and, to predict the possible developments. Using traditional methods such as ground survey and aerial observation, flood mapping is time consuming, expensive and need to be involved skilled persons. Moreover, if the occurrence is extensive then it is very difficult to monitor the flood event accurately and very quickly. On the other hand, due to bad weather conditions it is not possible to acquire timely aerial observations also.

Now-a-days, the availability of multiple satellite data can be used as an effective alternative to monitor flood situation and extent in the particular area. However, in monsoon climate region, huge cloud cover, rains and haze during and post flood events can represent a strong constraint to the utilization of optical remotely sensed data. In contrast, micro-wave remote sensing equipped with synthetic aperture radar (SAR) system, because of their exclusive cloud, rain and haze penetration capacity, offers a primary tool for real-time assessment of flooded areas. Beside the penetration capacity of SAR data, the most important advantage of using SAR data is that land and water contrast can be easily distinguished. SAR sensors are able to detect flooding because flat surfaces reflect (acts as a specular reflector) the signal away from the sensor, decreasing the amount of returned radiation. This causes relatively dark pixels in radar data for water areas which contrast with non-water areas.

The specific objectives were as: 1) Identification and classification of flood plain using satellite images. 2) Flood discharge estimation using satellite altimetry derived water level and river width from microwave satellite images. 3) Probabilistic inundation scenario by combining satellite derived inundation, water level and modified discharge.

2. Study Area

The Brahmaputra River is one of the major trans-boundary river of Asia, being the fourth largest in the world in terms of average flow discharge of 19,830 m^3/sec. It ranks 22^{nd} in terms of catchment area which is around 380,000 km^2 from Tibet plateau to the Bay of Bengal. The river is 2900 km long, out of which it traverses in an easterly course of 1,625 km in Tibet, a south and westerly course of 918 km in Northeastern India and a southerly course of 337 km in Bangladesh. The longitudinal slope of the river varies at different reaches, being 0.27 m/km from Kobo to Dibrugarh, 0.17 m/km from Dibrugarh to Nematighat (near Bessamora), 0.15 m/km from Nematighat to Tezpur, 0.14 m/km from Tezpur to Guwahati (near Guwahati). The Guwahati city lies between the mighty Brahmaputra and the Shillong Plateau. The city has an elevation of 55.5 m. The metropolitan area of Guwahti is 556 km^2. The geographical coordinates of Guwahati are $26^0$10’45’’N Latitude and $91^0$45’00’’N Longitude.

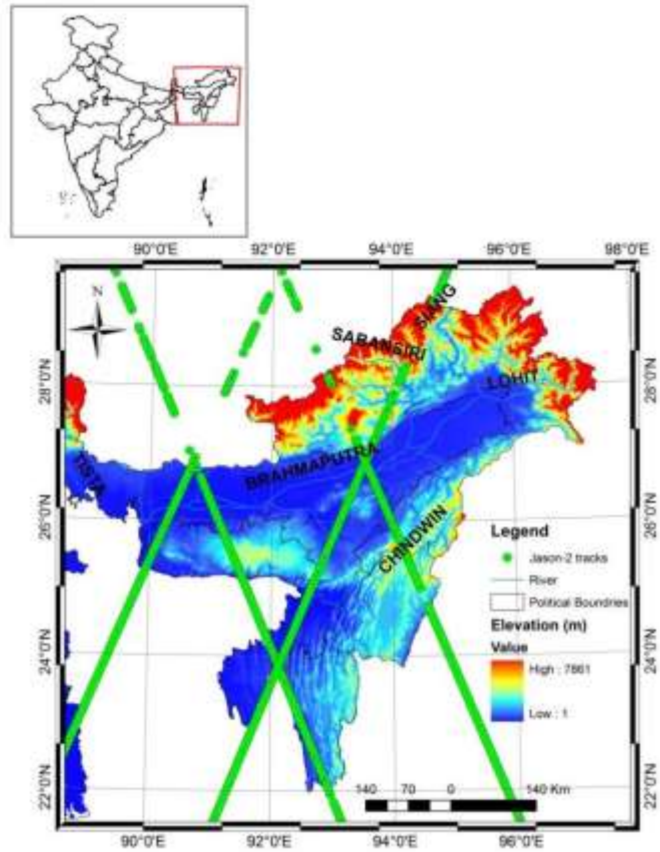

Fig -1: Topographic map of the Brahmaputra basin on which the Jason-2 satellite tracks are superimposed.

Fig -2: Middle reach of the Brahmaputra River (Downstream of Guwahati).

3. STUDY AREA AND METHODOLOGY

Various satellite data are used in this study. The use of optical imagery for flood monitoring is limited by severe weather conditions, in particular presence of clouds. In turn, SAR (synthetic aperture radar) measurements from space are independent of daytime and weather conditions and can provide valuable information to monitoring of flood events. This is mainly due to the fact that smooth water surface provides no return to antenna in microwave spectrum and appears black in SAR imagery. Hence, we used SAR data for identification and classification of flood plain. In our study we used Level-1 Ground Range Detected (GRD) Sentinel-1A data, which incorporates already some basic preprocessing. The microwave images from RADARSAT-2 satellite are also used, which was launched on 14 December, 2007. It has a Cband (5.405 GHz) synthetic aperture radar that provides data in different operation modes. The data acquisition in different operation mode provides images at different spatial resolution for various applications. The Scan SAR narrow band images are used for the study area, which provide data in 25x25 m spatial resolution.

The methodology involved image processing, creation of flood maps and analysis of flood water propagation. For quantitative analysis, SAR images need to be calibrated first and therefore, image calibration was applied to SAR images using SNAP (Sentinel Application Platform) so that the pixel value of the images directly represents the radar backscatter of the reflecting surface. Since the SAR is an active system, there is speckle noise in SAR data. Speckle is a system phenomenon and is the result of the interaction between the radar pulse and the different scatters of a distributed target that considerably reduces the interpretability of the images. Therefore, it is needed to remove the speckle noise during pre-processing step of SAR data. Filter technique is widely used method to remove speckle noise from the SAR data. Here, we used Single Product Speckle filter with 3 by 3 window and images were processed to remove the speckle noise. Raw digital image usually contains geometric distortions and can be corrected by analysing welldistributed ground control points (GCPs), called geometric correction. Mapping of flooded area using SAR data, involved classifying SAR images into water and non-water areas. It was mentioned earlier that in SAR image inundated areas appear in dark tone, which can be clearly delineated from the non-inundated areas due to the surface roughness of water and land. SNAP, Erdas Imagine and ArcGIS image processing and GIS software were used for image processing, analysis and mapping.

4. RESULTS

Spatial and temporal dynamics of the flooding in the study area were revealed, calculated and analysed using SAR data and GIS. The inundation area and spatial extent of flood over the time period is shown in below flood maps. We analysed past 10 years discharge data of Guwahati gauge station and prepared a hydrograph using mean discharge of monsoon months. Bellow hydrograph also contains the various available SAR image's discharge and from this graph we divided our flood map in three categories, 1) flood maps for max. discharge in every monsoon months 2) flood maps for min. discharge in every monsoon month and 3) flood maps for mean discharge in every monsoon months. Total 12 flood maps are prepared and analysis of area affected by flood is also done.

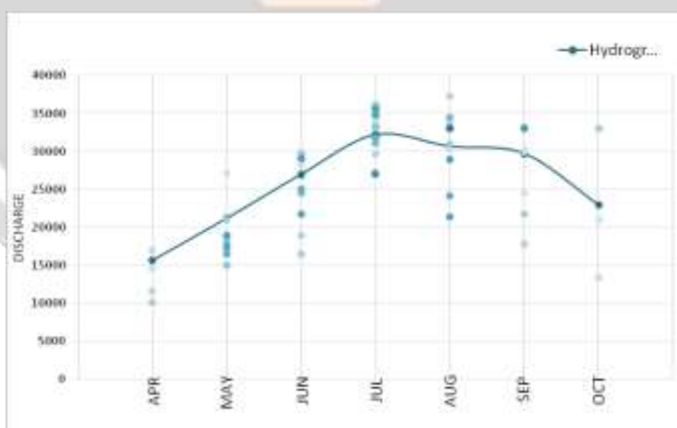

Fig -3: Flood hydrograph

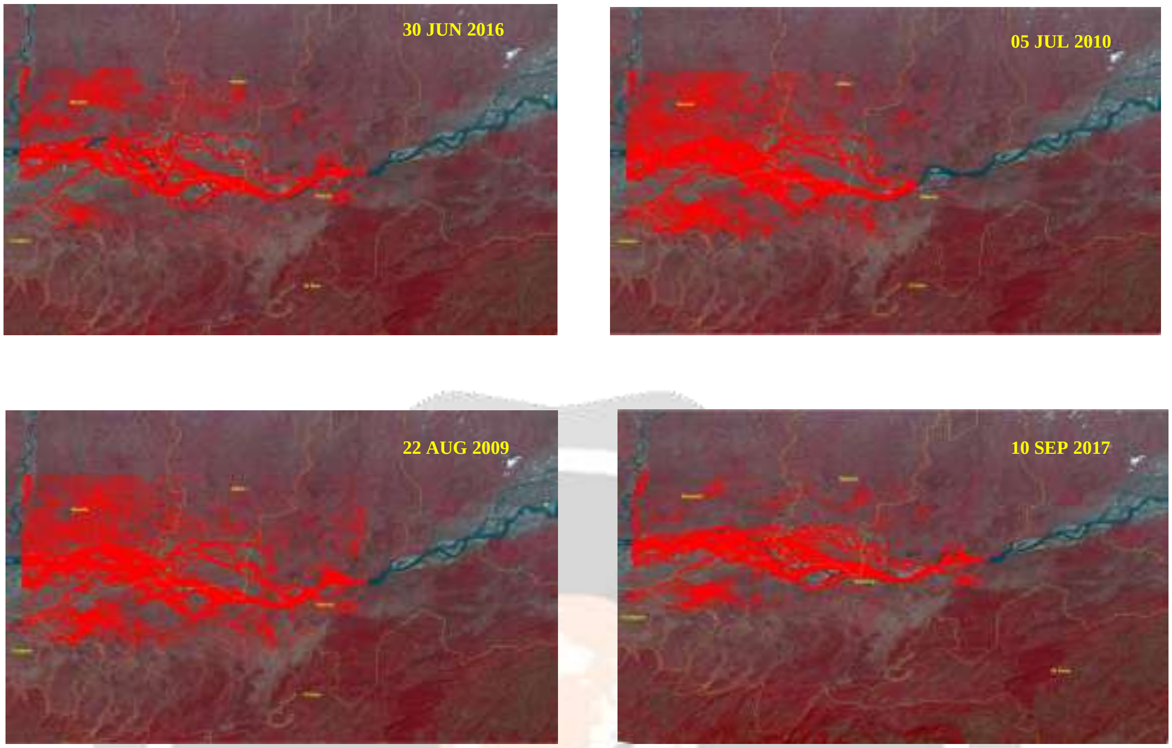

Fig -4: Flood maps for various month's max. Discharge in last 10 years

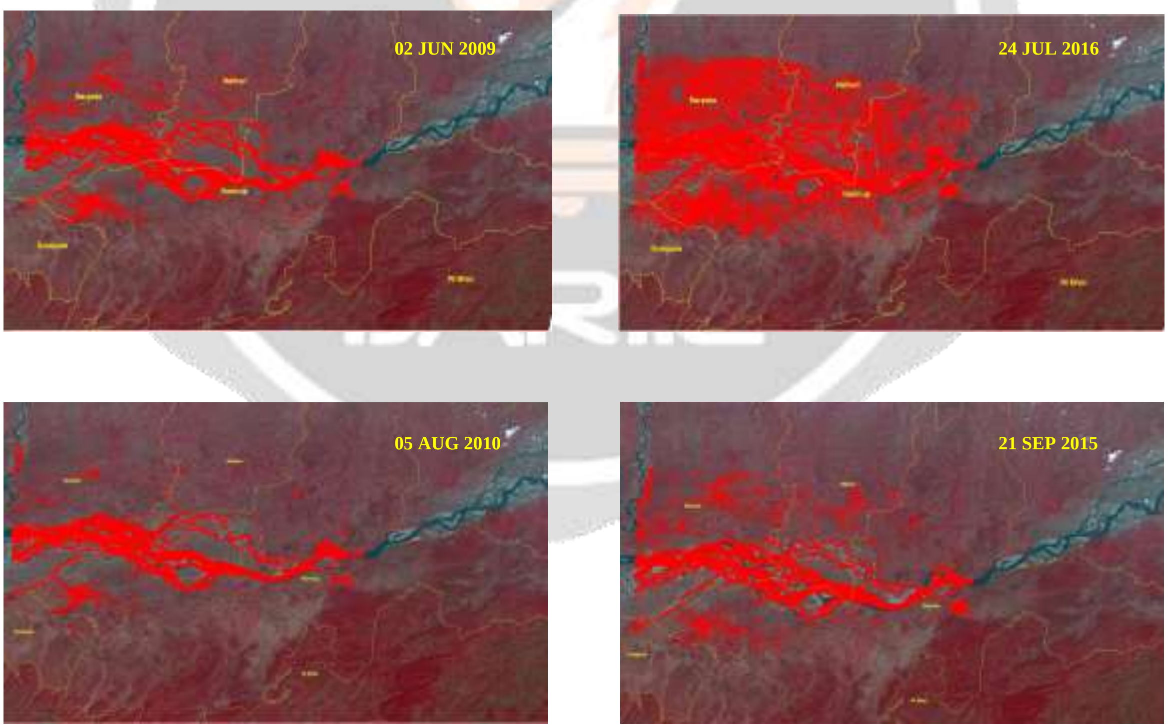

Fig -5: Flood maps for various month's mean discharge in last 10 years

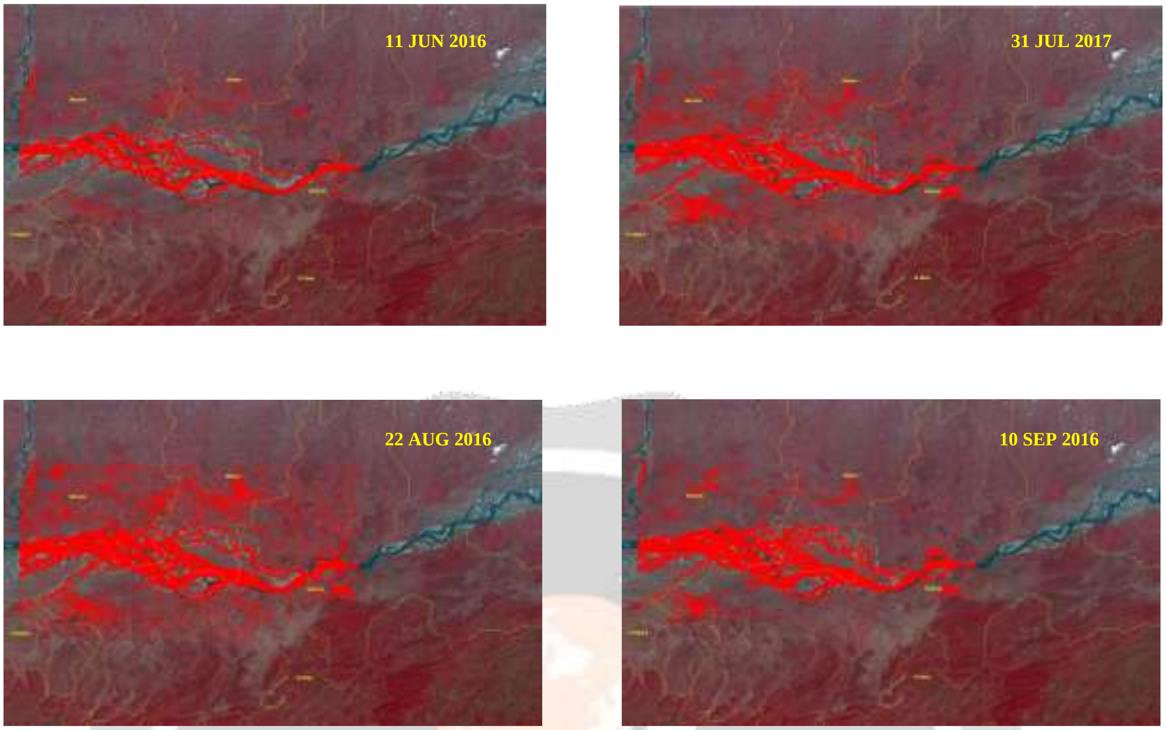

Fig -6: Flood maps for various month's min. discharge in last 10 years

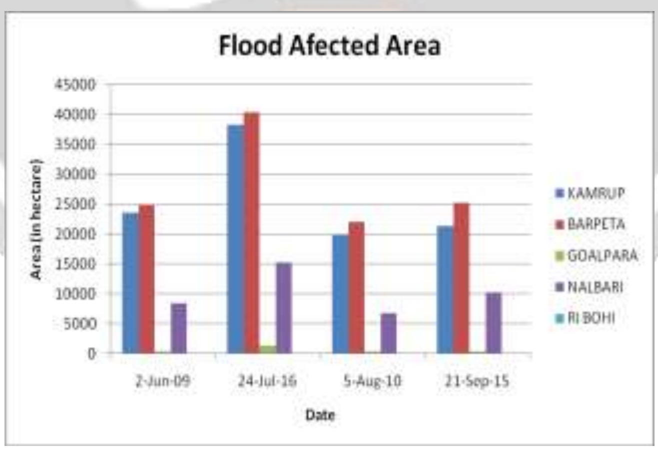

Fig -7: Area Affected by Mean Discharge Flood

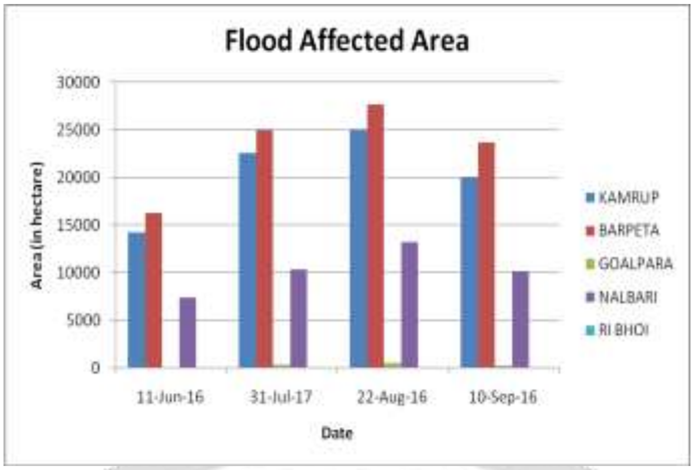

Fig -8: Area Affected by Minimum Discharge Flood

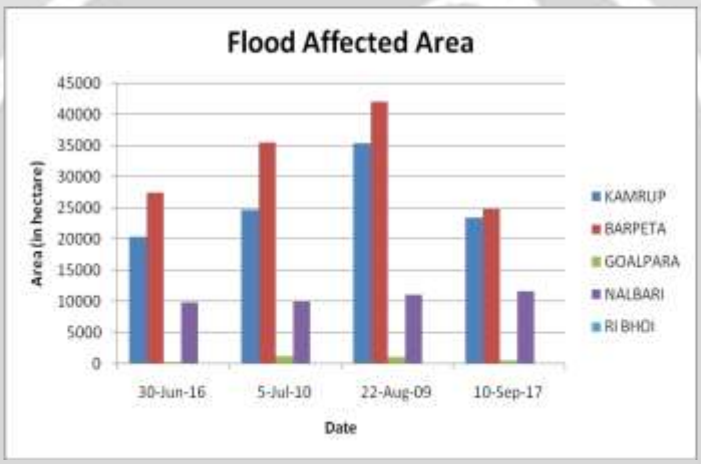

Fig -9: Area Affected by Maximum Discharge Flood

5. CONCLUSIONS

In this paper an overview of the use of SAR for flood mapping is given and experiences using the SAR data along with key processing elements and important analysis techniques that are used for the extraction of flooded area, spread of flood water and duration of flood dynamics. The main objective of this study was to detect the flood water extend and monitor the flood water propagation at middle reach of Brahmaputra River near downstream of Guwahati, Asam, India using multitemporal SAR data. In this study, using satellite data a decade of inundation was mapped and synchronized with discharge time series. It was found out that high discharge values caused inundation of downstream of Guwahati, Asam, India. A time series of inundation maps were prepared based on monthly average discharge variability, max. and min. discharge variability.

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