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Flood vulnerability assessment by remote sensing and GIS based applications in West Bengal: A review

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Abstract- *Flooding occurs when volume of water within a body of water, such as a river or lake, overflows or breaks levees, with some of the water escaping to its boundaries and causing widespread damage of crops, structures, cattle even leading to the loss of human lives. Floods in India generally occur when water overflows catchments due to high seasonal or unseasonal precipitation. However floods mostly occur in the country during the south-west monsoon period that spreads from June to September accompanying a trail of destruction and hence the losses sustained due to floods have made it a necessity to think of measures to counter the affect. Measures include both structural and non-structural with the latter consisting mainly of Geographic Information System (GIS) and remote sensing applications. A number of research works have thus been carried out all over India which focused on GIS and remote sensing applications starting from flood mapping, flood plain zoning, flood plain, etc. with higher number of works concentrated on post-disaster management. Post–disaster management have been carried out in flood prone West Bengal with works being carried out with objectives of delineating non-flooded areas from flooded areas, high flood depth zones and human settlements to help reduce the post-disaster stress.*

Key Words: **GIS, Remote sensing, Floods, Post-disaster management, Flood plain zoning**

1. INTRODUCTION

Floods are the most dangerous and destructive acts of nature. They cause widespread damage to agriculture, residences and public utilities and amount to loss of billions of dollars each year in addition to the loss of human as well as animal lives. Generally 'flooding' is caused by a river over-spilling its banks. This can be as a result of excessive precipitation combined with channels which don't have sufficient capacity. In Asia during the monsoon season, over 75% of annual precipitation is received in the four wet months from June to September. River flooding is of great concern in the Indian state of West Bengal. The state has about 37,660 km^2 of area which is flood prone. It is spread over 111 blocks with a total geographical area of about 88,752 km^2. It has been observed by the Department of Disaster Management of the West Bengal Government that from 1960 to 2000 there has been only five occasions when the state was not in grave danger from floods. The total area devastated crossed 20,000 km^2 in four different years and the floods of medium magnitude between 2,000 to 10,000 km^2 have occurred on ten occasions. It was also seen that 23756 km^2 of land area was inundated and 22.1 million people were gravely affected (Rudra, 2001) as a result of it.

However in the recent years, there has been renewed focus on assessing the vulnerability of the people at hand (Hewitt, 1997; Varley, 1994; Mitchell, 1999) with more priority given to management of the scenario after the occurrence of such an event. Cannon (2000) emphasized that natural disaster is a function of both natural hazard and vulnerable people. So the higher the probability of people being vulnerable, the more gruesome is the impact of a natural disaster. Vulnerability is generally defined as an amalgamation of exposure, susceptibility and resilience (Figure 1) with flood management practices being majorly concerned about reducing human losses and economic costs to an acceptable level.

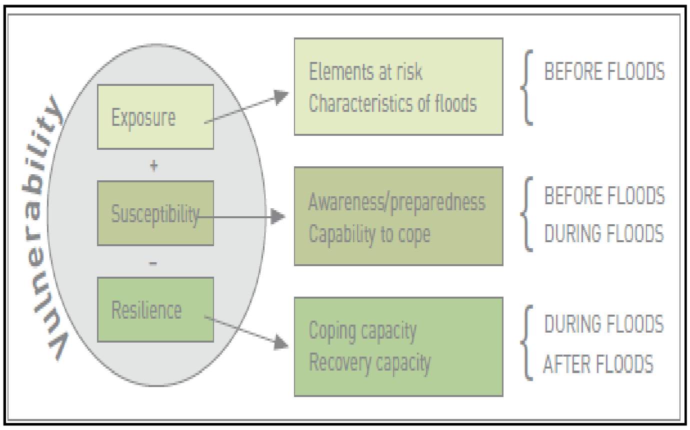

Fig-1: Vulnerability map (Source: Adapted from UNESCO Institute for Water Education)

According to the West Bengal Disaster Management Department, the causes for floods in West Bengal can be mainly attributed to: (i) Occurrence of excess rainfall in river catchments or high concentration of runoff from the river tributaries and rivers carrying flows more than their capacities (ii) Synchronization of flood peaks of the main rivers and its corresponding tributaries (iii) Landslides causing hindrance to flow and change in the river course as a result of it (iv) Poor drainage systems particularly natural (v) Cyclone accompanied by heavy rainfall.

Thereby, with each seasonal and un-seasonal advent of floods and high rate of persistent destruction, it becomes necessary to use GIS and remote sensing tools to measure the exact extent of destruction and carry forward the work of post-disaster management. Satellites thus provide comprehensive and multi-temporal coverage of large areas in real time and at equally frequent intervals and, have thus become extremely vital for monitoring of atmospheric as well as surface parameters related to flood. Satellites are generally designed to transmit remote sensing data to provide exhaustive multi-date and multi-spectral information on phenomena which are extremely dynamic in nature and cover very large, large as well as small river basins. They have also been found to be suited for mapping/monitoring and studying (i) flood inundated and water congested areas (ii) extent of damages to crops, structures, etc. (iii) changes in river configuration, deposition of silt, shoals etc. and areas vulnerable as a result of bank erosion (iv)watershed characteristics and land cover/land use in command areas. Flooded areas, which tend to extend over several thousands of square kilometers, could be mapped very effectively using the satellite data and are also used in delineation of boundaries of flood prone zones. This review study aims to provide a comprehensive analysis of post-disaster flood management works carried out in West Bengal primarily using remote sensing and GIS tools with the chief objective of reducing human and economic loss.

2. AREAS OF OBSERVATION

Bera et al. (2012) considered Mongalkote block, the severe flood affected area of Burdwan district of West Bengal in Eastern India as their observational area. It lies between 23° 30′ 51″ N to 23° 40′ 37″ N latitude and 87° 53′ 28″ E to 88° 49′ 12″ E longitude. It extends over 364.90 km^2 area and has a population of 233,944 persons (Census, 2001) with a density of 641 per km^2. The entire block has been divided in 15 gram panchayats under which there are 164 villages. The study area had been largely affected by two rivers- Ajoy and Kunur.

The study area for Sanyal and Lu (2005) extended over three major river basins of southern West Bengal, namely Bhagirathi- Hoogly, Jalangi and Churni. All these three rivers are distributaries of the main branch of the River Ganga. The eastern parts of the districts of Bardhaman, Murshidabad and most of Nadia form the administrative entity for the area. The rivers such as Bhagirathi, Jalangi, Hoogly are the main affecting rivers.

3. OVERVIEW

Sanyal and Lu (2005) acquired Landsat ETMC images to identify the non-flooded areas within the flooded zone. ASTER digital elevation data were used to assess accuracy and rectify the classified image. ERS-1 synthetic aperture radar data were used for extracting the settlement areas surrounded by trees. At the end, all information extracted from satellite imageries were imported to ArcGIS, and spatial analysis was carried out to recognize the settlements which were vulnerable to river inundation.

Bera et al. (2012) carried out a planned and integrated management approach with the help of remote sensing and GIS and data on socio economic characteristics. Their study described an efficient and scientific approach with suitable illustrations of map and real time flood inundations. The areas which were flood affected, were delineated so that the flood affected people could be rescued from inundation and evacuated to safer regions.

4. WORK DONE

4.1 Delineation of Non-flooded Areas from Flooded Areas

Sanyal and Lu (2005) acquired two Landsat ETMC images of the study area at almost the peak of the flood. The scenes were corrected geometrically and radiometrically and were thereafter geo-referenced using GPS control points, which were collected during a field visit to the study area. TM bands 4, 3 and 2 were then projected in RGB to generate a standard false color composition (FCC) of the study area. And as asphalt road surfaces and rooftops yield very low reflectance to TM band 4, reflectance from water varies from roads and dark rooftops in Landsat band 7 (2.28–2.35 μm, mid infrared) thereby differentiating water and non-water bodies like in Fig 2(a).

However, overlapped areas were further dissolved to create one classified layer depicting the non-flooded areas. In this synthetic image, the advantages of band (4+7) and band (4/3) were included to extract the non-flooded area in the flood scene more precisely, as has been shown by the Fig 2(b). Bera et al. (2012) prepared in GIS field to determine the flood hazard region by using Arc GIS-3.2 software and using satellite image (Landsat ETM+, TM, LISS-III), SRTM image along with rainfall flood time photographs and other information at the time of the flood.

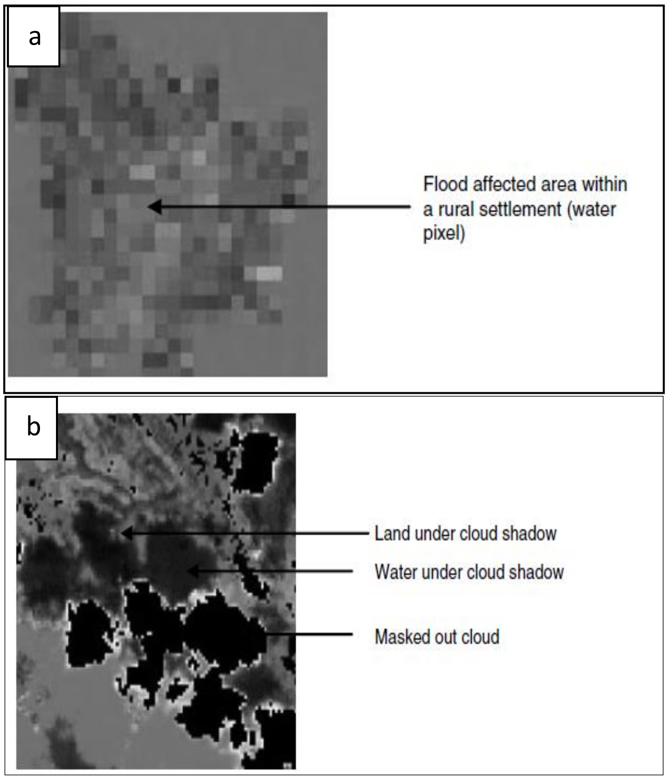

Fig-2: (a) Landsat ETMC FCC (zoomed eight times from optimum resolution) showing flooded area within a settlement and (b) FCC showing flooded and non-flooded areas under cloud shadow (Source: Sanyal and Lu, 2005)

4.2 Delineation of High Flood-depth Zone

It was carried out to enhance contrast and facilitate classification. A PC transformation was applied over bands 2, 3, 4, 5 and 7 of the Landsat ETMC data acquired during the flood. The first three components that explained about 99.65% of the total variation were selected for further analysis. The other components were excluded from further analysis as their noise-to-signal ratio was found to be very high. Kunte and Wagle (2003) attempted to classify depth of water in the Gulf of Kutch and reported that the PC2 band is particularly sensitive to the concentration of suspended sediments and therefore, can be effectively used for broad classification of water depth. Thus taking this into consideration, Sanyal and Lu (2005) enhanced the amount of information and band combination of PC2, PC1 and PC3 were tried into RGB to create the best possible FCC. Fig 3 shows the turbidity concentration in the flooded zone.

4.3 Delineation of Human Settlements

The Landsat ETMC data obtained were geometrically corrected and further registered to 1:250000 land-use maps by Sanyal and Lu (2005). The radar data were obtained as a precision image (PRI). ERS SAR PRI products were then projected to ground range and resampled in 12.5 metre pixel

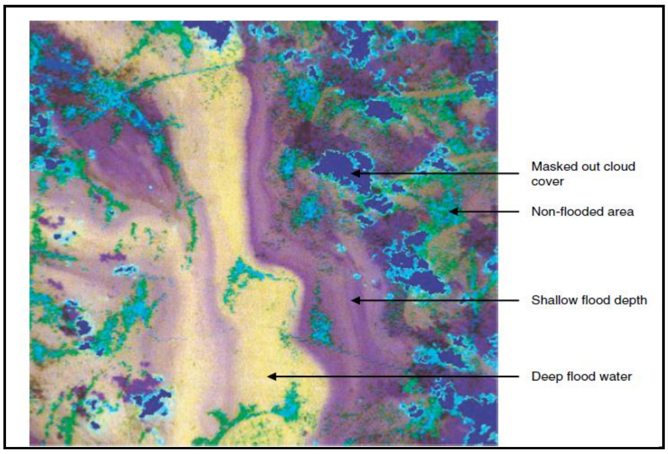

Fig-3: Different flood depth/turbidity zones identified over an FCC (PC2, PC1 and PC3 as RGB) (Source: Sanyal and Lu, 2005)

size. The PRIs were thereafter co registered with the land-use map with a root-mean-square error (RMSE) of 1.06 pixels. After geo-referencing, the SAR imageries were mosaicked and low-pass filter of a 5×5 pixel window was applied to it to reduce speckle and improve visual interpretability in order to identify settlements. After stacking TM bands 4, 3 and 2 in RGB, a colored image was generated by integrating with the processed radar image of 12.5 spatial resolutions though with the help of HSV sharpening tools with Fig 4 representing the study area where the small rural settlements are easily distinguishable by their bright appearance over a reddish background of vast cropland.

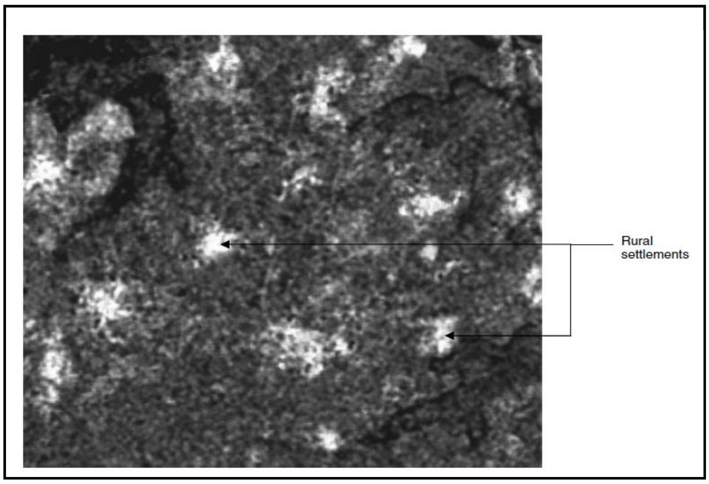

Fig-4: Landsat ETM bands 4, 3 and 2 merged with ERS SAR image to identify the rural settlements (Source: Sanyal and Lu, 2005)

5. CONCLUSION AND FUTURE PROSPECT

The studies demonstrate cost-effective and efficient ways to create a spatial database for identifying human settlements that are likely to be vulnerable to monsoon flooding. However it must be acknowledged that accuracy of the key information, past records of flooding, depends upon the map that represents them, particularly its scale. Although flooding is a natural phenomenon and one that cannot be stopped but can be minimized by better planning and management system, with more focus and research carried out in the area of data accumulation.

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