GEOSPATIAL APPLICATIONS IN IDENTIFICATION AND SIMULATION OF RIVER EMBANKMENT LOCATIONS VULNERABLE TO BREACHING: A CASE STUDY IN SELECTED DISTRICTS OF ASSAM

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Abstract:

Floods, the most common devastating calamity in many parts of the world led to loss of life, property and resources. Flooding is a globally persistent hazard and is not just confined to certain regions of the world. India experiences one of the highest incidences of flood that occurs without an unfailing regularity. Among the several states prone to flooding, Assam is one of them which suffer from flood almost every year. Almost 60% of the districts get inundated during flood season causing untold human sufferings and heavy loss to animal lives, property and natural resources worth several million rupees. Embankments structures play a very important role in flood defense, while many are also used for water supply, power generation, transportation, sediment retention, and others. But these structures can sustain only limited safety levels and are subject to decay, they may fail due to various triggering mechanisms particularly with a high probability of failure under extreme conditions. Failure of these structures poses significant flood risks to people and property in the inundation area and cause interruption of services provided. Therefore, understanding and prediction of embankment failure processes are very much crucial for water infrastructure management. This study provides a geospatial approach in identifying the embankment locations vulnerable to breaching, observing dynamics of hydro geomorphology of the river system revealing the embankment locations closer to the continuous unidirectional changing river courses and non-parallel to the river course are prone to breaching. Further, this study also presents recent research into the use and applications of several dam breach parameter estimators to describe the physical characteristics of a dam breach, use of those parameters within the HEC-GeoRAS and the HEC-RAS environment, computation and analysis of the breach.

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Introduction

Floods are the most shattering, deadly, widespread and frequent among all the natural hazards of the globe has been creating worldwide damages to agriculture, environment, mankind and loss of human lives. In fact, floods are the most recurrent hydro-meteorological disaster that occurs in a domain of space and time. According to DMSG, 2001, floods are among the most devastating natural hazards in the world, widely distributed leading to significant economic and social damages than any other natural phenomenon. Under the influences of flood, a lot of roads were destroyed, they also influence on people's living near the rivers and coastlands. Flood is a recurring natural phenomenon usually brought about by heavy rains. Other causes of flooding include overflowing of river, inflow of tides, storm surges and other indirect source such as seismic activities. According to the statistics of many years it has been found that flood typically occurs either due to natural, human or agricultural activities. In most of the cases, flooding is caused mainly due to heavy rainfall and thunderstorms over a short period, due to prolonged, extensive rainfall or due to high tide combined with stormy conditions. Most commonly when water from heavy rainfall, from melting ice and snow, or from a combination of these exceeds the carrying capacity of the river system, lake, or ocean into which it runs, flood results. They also result in siltation of the reservoirs and hence limit the capacity of existing dams to control floods.

Flooding has always been an important issue because of the material and human damage that can be caused. Therefore, there is now a great need to control flood all over the world. Emphasis on enhancing flood management techniques with both structural and non-structural ways has been given to every flood prone regions. The river flow generates a very strong hydrodynamic force against the stream banks which results in the wearing away of the stream or the river banks leading to erosion. River meanders and changes its course due to erosion which is a main factor for flooding.

Different flood control structures such as Embankments including dams, dikes, levees, spurs, groynes, porcupines etc have been built along rivers, lakes and coastal lines to prevent floods. These structures are elongated, naturally occurring ridge or artificially constructed fill or wall, which regulates water levels. Artificial structures are mainly found along the sea, where dunes are not strong enough, along rivers for protection against high-floods, along lakes or along polders. But these structures were generally designed under given “extreme” conditions that are often no more representative of the recent extreme events. So, the likelihood of such structures to fail has significantly increased. The prediction of potential breaches and the consequent flooding are thus important steps in managing the risk from potential embankment failure. Therefore, understanding the fundamental processes of breaching is crucial for flood prediction, risk assessment and rescue planning.

Objective and Scope:

i. Mapping of river courses using high resolution temporal satellite data.

ii. Identification of embankment locations vulnerable to breaching observing dynamics of hydro geomorphology of the river system.

iii. Simulation of embankment breaching at selected locations of the rivers for flood damage analysis in HEC-GeoRAS and HEC-RAS environment.

iv. To present a geospatial approach for flood risk analysis in order to mitigate flood problems.

Study site and its Description:

The study was Assam, in north-eastern part of India and is bounded by the kingdom of Bhutan and the state of Arunachal Pradesh to the north, by the states of Nagaland and Manipur to the east, Mizoram and Tripura to the south, and to the west by Bangladesh and the states of Meghalaya and West Bengal. Its capital is Dispur, a city located on the outskirts of its largest city, Guwahati.

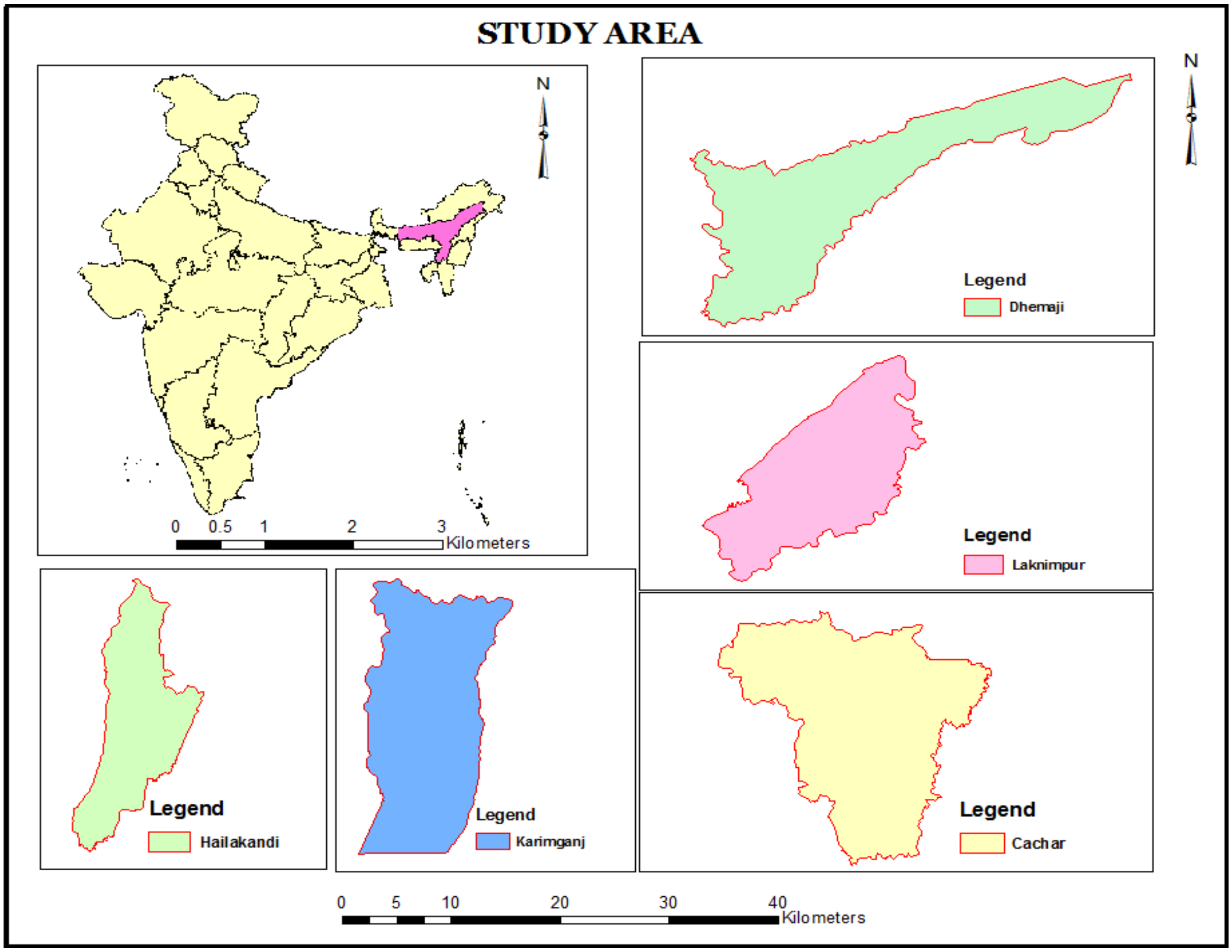
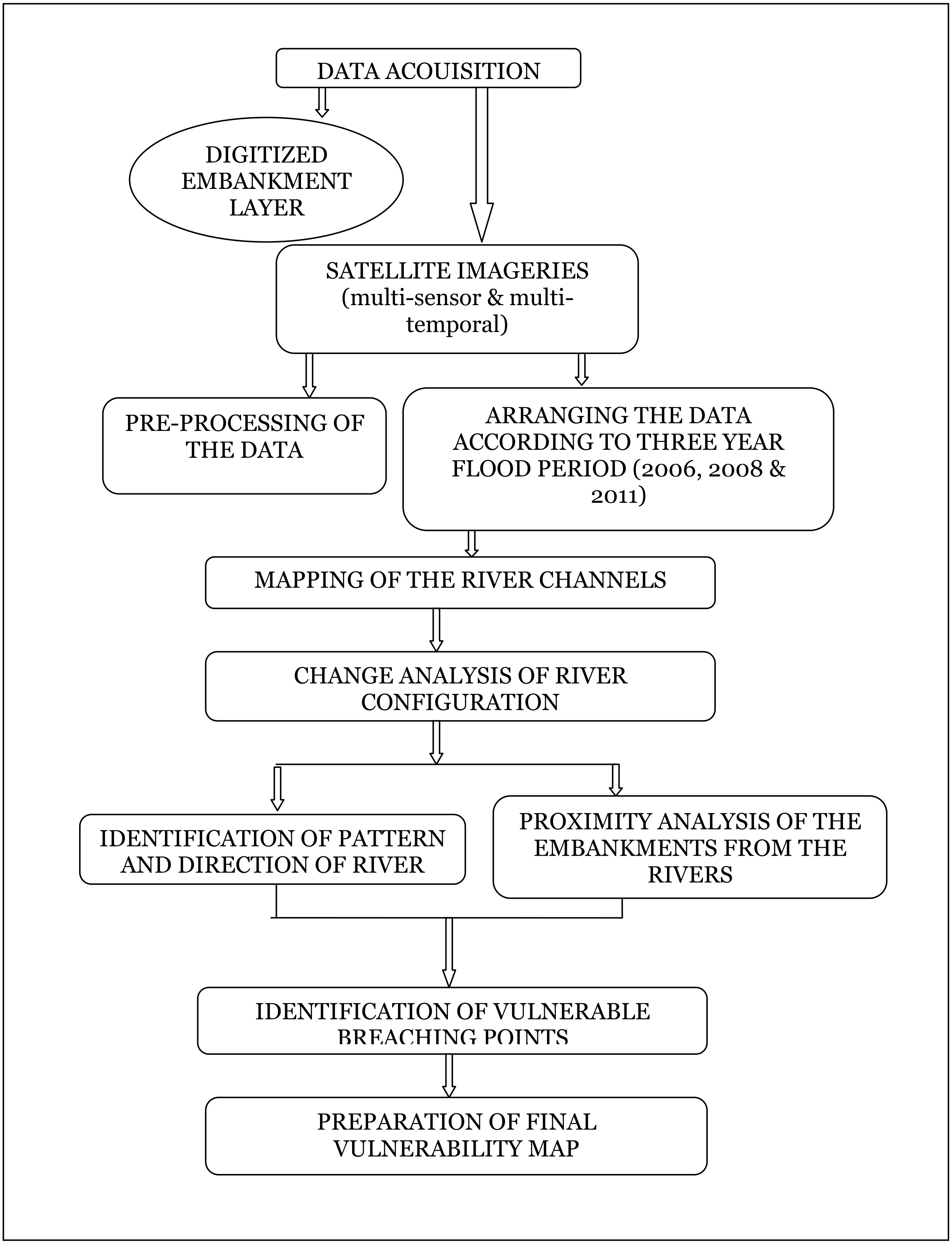
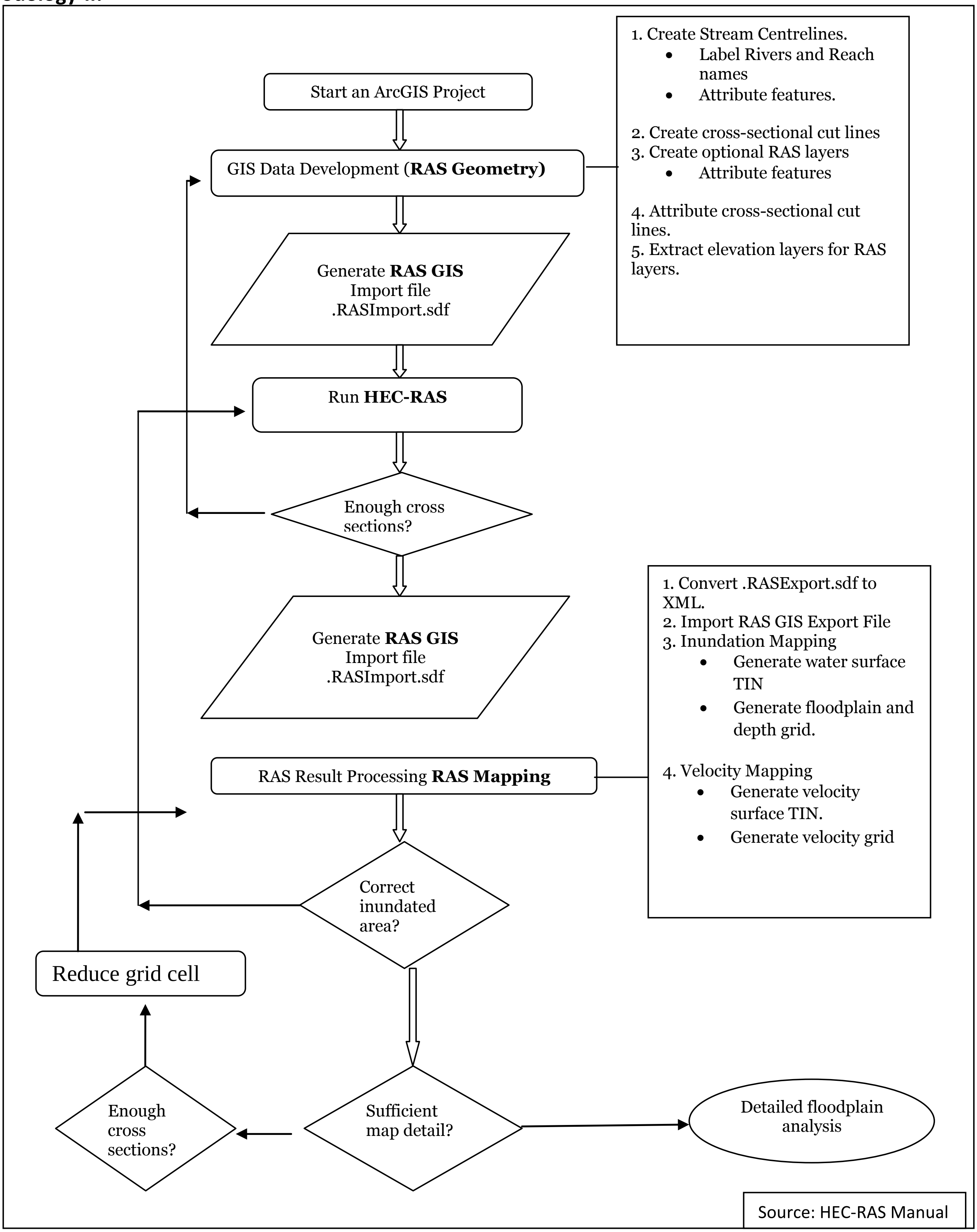


Fig:1 – Study Site

Methodology-I:



Methodology-II:



Source: HEC-RAS Manual

Analysis and Result:

Analysis of the river dynamics for the three temporal periods: The river dynamics was studied in GIS environment using overlay tools. All the three layers of river configuration from 2006-2011 and identifying the changes that occurred in the pattern of the river courses during this period of time.

These were the conditions on the basis of which we classified the river dynamics.

06_River	08_River	11_River	Class
River	River	River	No Change
	River	River	Channel Developed During 08
River			Sedimentation After 06
River	River		Sedimentation After 08
River		River	Highly Unstable Portion
		River	Increase during 06-11

The final river dynamic maps are presented below for each district:

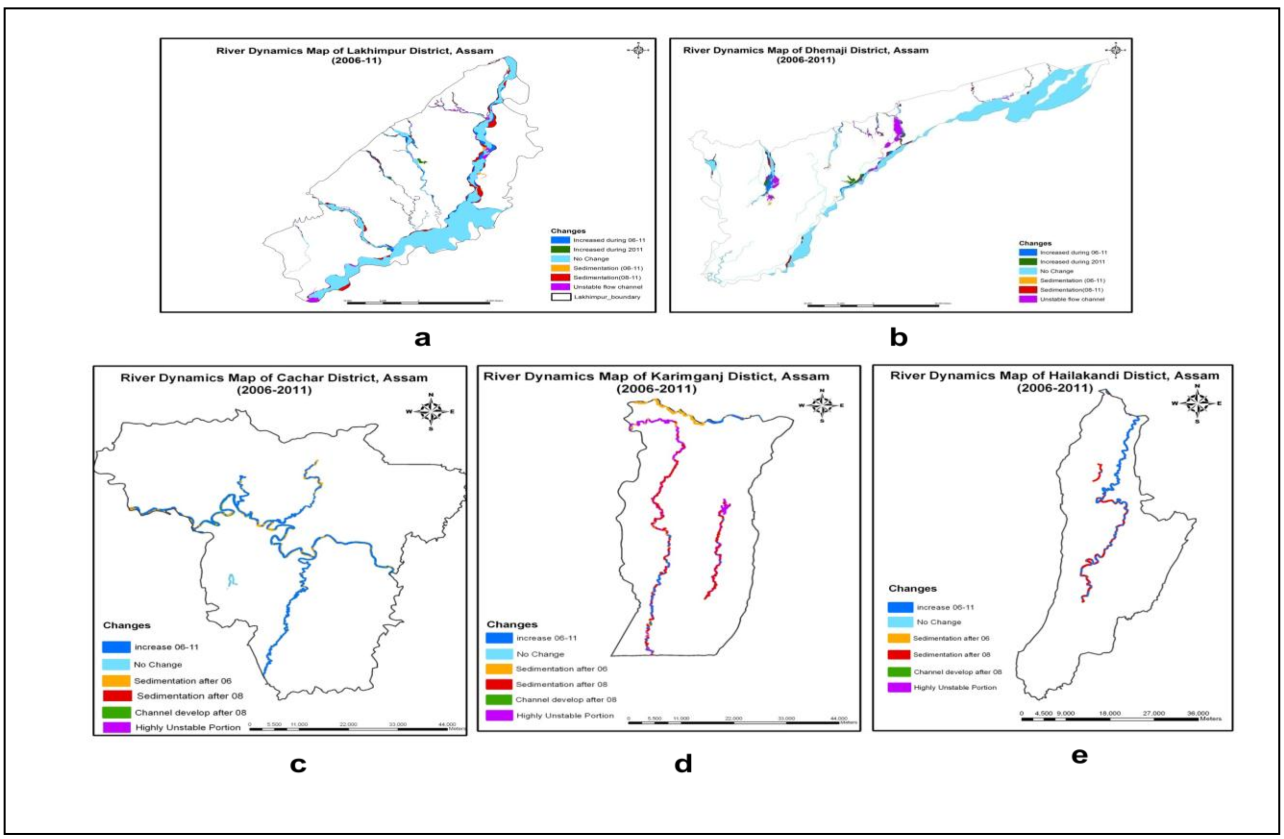


Fig 2: River Dynamics Map for (a) Lakhimpur (b) Dhemaji(c) Cachar (d) Hailakandi (e) Karimganj

Vulnerability Analysis of the embankments: On the basis of the following conditions, the final vulnerability maps were prepared.

Change	Distance from the embankment	Vulnerability
Increase during 06-11	Within 10m	Very high
Increase during 06-11	Within 20m	High
Increase during 06-11, Channel developed during 08, Highly unstable portion(Any increase)	Within 25m	High
Increase during 06-11, Channel developed during 08, Highly unstable portion(Any increase)	Within 30m	Moderate
Remaining(No Change and others)	Beyond 30m	Low

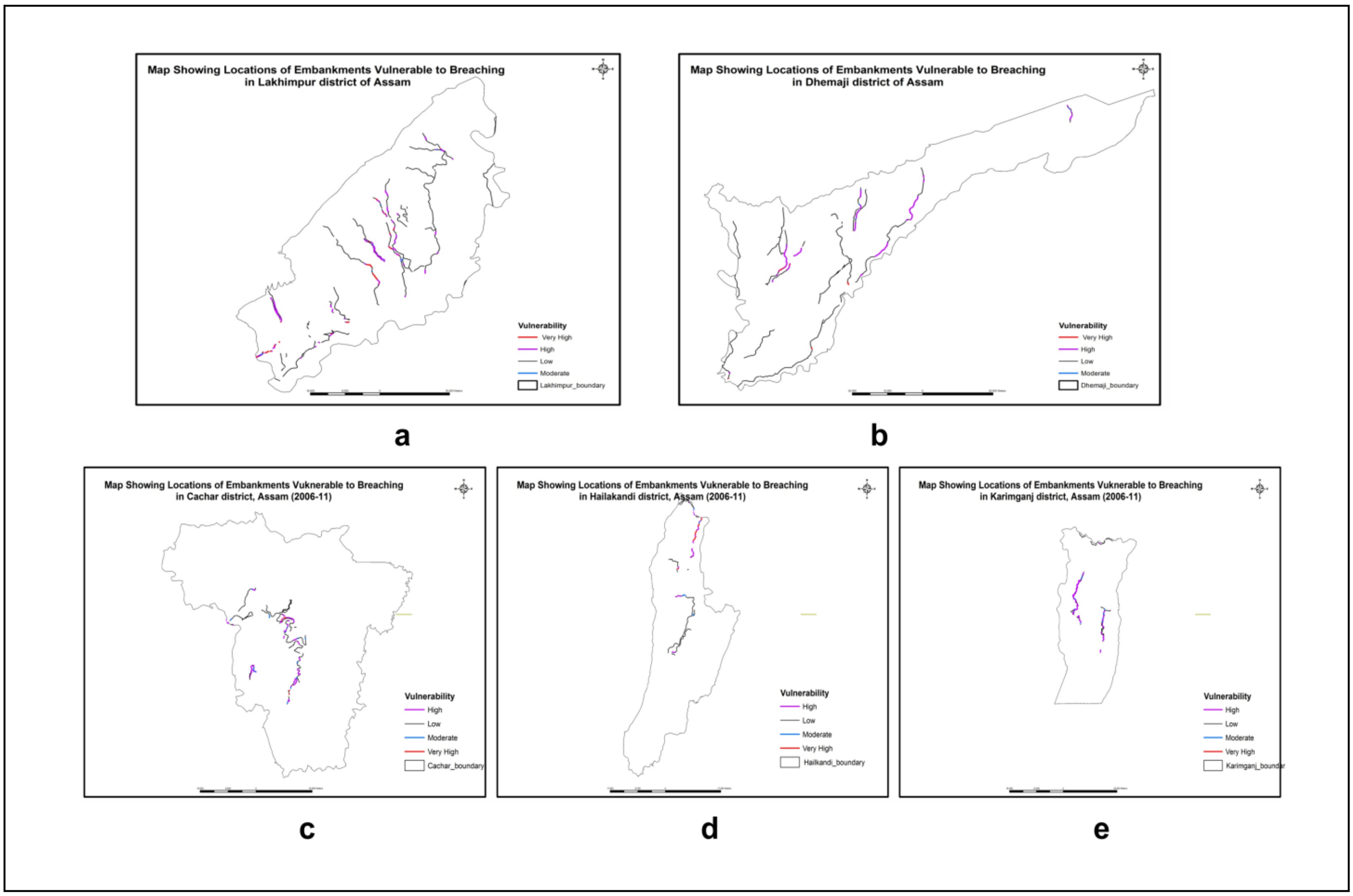


Fig 3: Final Vulnerability Map for (a) Lakhimpur (b) Dhemaji (c) Cachar (d) Hailakandi (e) Karimganj

Simulation of embankment breaching using HEC- GeoRAS and HEC-RAS:

For performing embankment breach, unsteady flow analysis was done because most of the rivers change with respect to time and cross- section. Boundary conditions were specified for upstream and downstream conditions. Stage hydrograph and normal depth was set as the boundary conditions for upstream and downstream areas respectively due to lack of discharge data and rating curves. Because of water stage errors in the upstream, some water stage refinement was made in the upstream boundary. Starting date for the simulation was taken as 1st June, 2012. Highest water level was allocated to 3rd June because rainfall intensity was highest on this date. The post processing is done and the breach is computed.

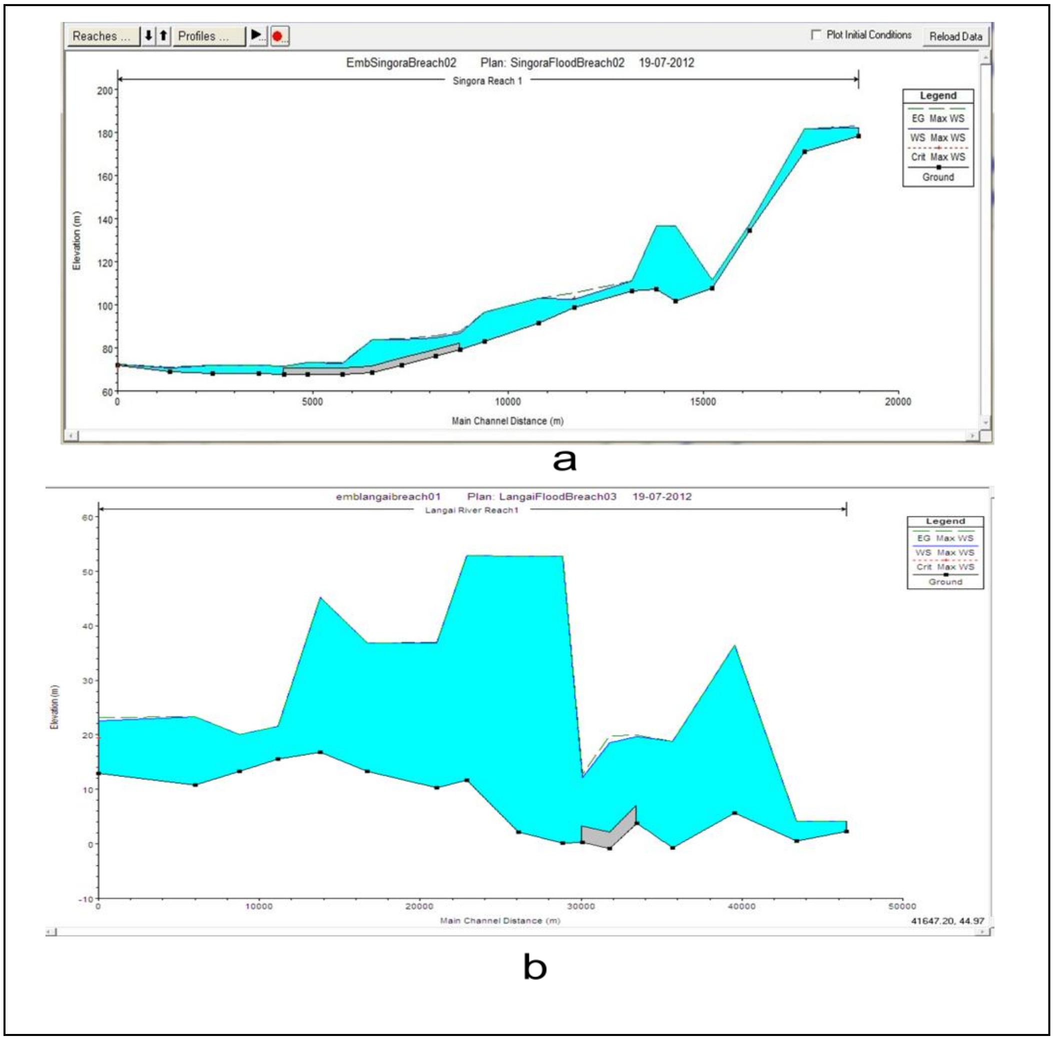


Fig 4: Profile plot of Water level post Breach (a) Singora River (b) Langai

Conclusion:

Flood, as everyone is aware of, is an unavoidable and life threatening disaster. Although it cannot be avoided, it can surely be mitigated to some extent. In this case study, for the districts of Cachar, Karimganj, and Hailakandi, which are together known as The Barak Valley, in South Assam, and the districts of Dhemaji and Lakhimpur in Upper Assam, which is our study area, flood has been a common and most frequent problem. Till now, several methodologies have been adopted in order to mitigate it and have been successful to reduce the problem to some extent. With time, more improved techniques have been adopted. Scientists are trying hard to discover better solutions by perceiving the various sides of these problems and understanding it better. But due to lack of data in these regions, a lot of obstructions are being faced. Especially for the Barak Valley region, data availability has been a real problem. But using high resolution CARTOSAT data and merged data of CARTOSAT and LISS IV, and some scenes of RESOURCESAT, of all the districts, this problem has been tackled to a large extent.

Embankment breaching can occur due to piping or overtopping. But in this study, embankment breaching due to piping, i.e., failure mode due to piping is being concentrated. Vulnerability maps have been successfully produced by mapping the major rivers in these districts and then carrying out change analysis in the river configurations during the period of 2006-2011 and computing the distance of the embankments from the river channel. Further simulation of the breaching was done by using the HEC-GeoRAS and HEC-RAS software for two rivers which are LANGAI in Karimganj district and SINGORA in Lakhimpur district. Firstly, using HEC-GeoRAS, the RAS layers, which include the stream centre line, the left and the right banks, the flow paths, levees and XS cut lines were prepared for both the rivers. The 3D profiles were also generated. This data was exported to HEC-RAS using the GIS format which was followed by further processing in HEC-RAS using the boundary conditions as stage hydrograph for upstream conditions due to lack of discharge data. For downstream conditions normal depth was calculated and set as the boundary condition due to lack of rating curves. The simulation date taken was 3rd June 2012.

This analytical method is very helpful and useful in quasi- forecasting conditions.

References:

1. DMSG, 2001. The Use of Earth Observing Satellites for Hazard Support: Assessments & Scenarios. Committee on Earth Observation Satellites Disaster Management Support Group, Final Report, NOAA, Dept Commerce, USA.
2. River Mechanics, Pierre Y. Julien. Cambridge University Press 2002.