

Flood Vulnerability in India: A Remote Sensing and GIS Approach for Warning, Mitigation and Management

Sneh Gangwar*

*Assistant Professor, Department of Geography, Aditi Mahavidyalaya, University of Delhi

Abstract:

The conventional means to record hydrological parameters of a flood often fail to record an extreme event. Remote sensing technology along with geographic information system (GIS) has become the key tool for flood monitoring in recent years. Development in this field has evolved from optical to radar remote sensing, which has provided all weather capability compared to the optical sensors for the purpose of flood mapping. The central focus in this field revolves around delineation of flood zones and preparation of flood hazard maps for the vulnerable areas. In this exercise flood depth is considered crucial for flood hazard mapping and a digital elevation model (DEM) is considered to be the most effective means to estimate flood depth from remotely sensed or hydrological data. This paper presents a review of application of remote sensing and GIS in flood management with particular focus on the developing county like India.

Key words: flood, remote sensing, geographic information system, digital elevation model, hazard mapping, monsoon Asia

The Problem of Floods in India: An Introduction

Floods have been a recurrent phenomenon in India and cause huge losses to lives, properties, livelihood systems, infrastructure and public utilities. India's high risk and vulnerability is highlighted by the fact that 40 million hectares out of a geographical area of 3290 lakh hectares is prone to floods. On an average every year, 75 lakh hectares of land is affected, 1600 lives are lost and the damage caused to crops, houses and public utilities is Rs. 1805 crores due to floods. The maximum numbers of lives (11,316) were lost in the year 1977. The frequency of major floods is more than once in five years. Floods have also occurred in areas, which were earlier not considered flood prone. An effort has been made in these Guidelines to cover the entire gamut of Flood Management. Eighty percent of the precipitation takes place in the monsoon months from June to September. The rivers bring heavy sediment load from the catchments. These, coupled with inadequate carrying capacity of the rivers are responsible for causing floods, drainage congestion and erosion of river-banks

Flood is a state of high water level along a river channel or on coast that leads to inundation of land which is not normally submerged. Flood is an attribute of physical environment and thus is an important component of hydrological cycle of drainage basin. Flood is a natural phenomenon in response to heavy rainfall but it becomes a hazard when it inflicts loss to the lives and properties of the people.

The Rashtriya Barh Ayog, set by Government in 1976 put the country's flood prone area at about 40 mha. This report, thus, revealed a rapid increase in flood proneness in just over a decade. Most of these areas lie in Ganga basin, the Brahmaputra basin comprising the Barak, the Tista, the Torsa, the Sabarmati, the Sankosh, the Jaldhaka, the Dibang, the Dihang. The most flood prone basin are those of the Ganga and Brahmaputra in Uttar Pradesh, Bihar, West Bengal and Assam, followed by Baitarni, the Brahmani, and the Sunarnarekha basin in Orissa. These five states are the most flood prone. But the commission analyzed the share of damage went up from 25 to 50 percent of the total and chronically flood prone Bihar area has been increasing.

Framing Vulnerability

Vulnerability is the degree to which a system or unit is likely to experience harm due to exposure to perturbations or stress. The concept of vulnerability originated in research communities examining risks and hazards, climate impacts, and resilience. The vulnerability concept emerged from the recognition by these research communities that a focus on perturbations alone (environmental, socioeconomic, technological) was insufficient for understanding the responses of, and impacts on, systems (social groups, ecosystems, places) exposed to such perturbations. With the concept of vulnerability, it became clear that the ability of a system to attenuate stresses or cope with the consequences through various strategies or mechanisms constituted a key determinant of system response and, ultimately, of system impact. A clearer understanding of coping strategies or mechanisms can thus throw light on who and what are at risk from what, and how specific stresses and perturbations evolve into risks and impacts.

Vulnerability in the social sciences is typically identified in terms of three elements: system exposure to crises, stresses and shocks; inadequate system capacity to cope; and consequences and attendant risks of slow (or poor) system recovery. This perspective suggests that the most vulnerable individuals, groups, classes, and regions or places are those

that: experience the most exposure to perturbations or stresses; are the most sensitive to perturbations or stresses (i.e. most likely to suffer from exposure); and have the weakest capacity to respond and ability to recover.

Space Technology: A Review

The unique capabilities of satellites to provide comprehensive, synoptic and multi-temporal coverage of very large areas at regular interval and with quick turnaround time have been very valuable in monitoring and managing flood dynamics. In fact, it is only space technology, which has for the first time provided the basic information needed in the space, time and frequency domain. In order that the appropriate flood control and anti-erosion works are scientifically planned, executed, monitored and maintained as per the best standards, it is necessary to acquire timely and reliable information about the flooded areas, watershed areas, river behaviour and configurations, etc. prior to floods, during floods, and after floods. Such information is difficult to acquire in time for decision making from conventional ground survey methods in vogue, which are arduous, time consuming and beset with various limitations, especially while studying floods of large river basins.

The earth Observation satellites provide comprehensive, synoptic and multitemporal coverage of large areas in real time and at frequent intervals and, thus, have become valuable for continuous monitoring of atmospheric as well as surface parameters related to flood. Satellites, by virtue of their remote sensing and data transmission capabilities to provide comprehensive multi-date and multi-spectral information on dynamic phenomena covering very large as well as small river basins, have been found to be admirably suited for mapping/monitoring and studying (i) flood inundated and drainage congested areas, (ii) extent of damages to crops, structures etc. (iii) river configuration, silt deposits, shoals etc. and vulnerable areas of bank erosion (iv) watershed characteristics and land cover/land use in command areas and (v) hydrological and meteorological data transmission from data collection platforms. The flooded areas, which extend to several thousands of square kilometers, could be mapped very effectively using the satellite data. They are also useful in delineating the boundaries of flood prone zones. Digital analysis of satellite data can detect changes on the sections of the inundated flood plains as well as in water quality. The multi temporal data from satellites are proved to be very valuable in the identification of the site ideal for taking up structural measures to control floods.

Geostationary satellites provide continuous and synoptic observations over large areas on weather including cyclone monitoring. The use of meteorological satellites for forecasting heavy rainfall events, snowmelt runoff and monitoring of convective/frontal systems has improved the observational system greatly. The use of high resolution data from Indian Remote Sensing satellites has greatly contributed to our understanding of various parameters relevant to rainfall run-off analysis, flood forecasting and flood mapping including flood damage assessment. The vast capabilities of communication satellites are available for timely dissemination of early warning and real-time coordination of relief operations. Satellite communication capabilities, fixed and mobile, are vital for effective communication, especially in data collection, distress alerting, position location and co-ordinating relief operations in the field.

Space technology can play an important role in providing valuable information particularly useful in the flood assessment, mitigation and preparedness phases of floods besides weather monitoring and effective communication for early warning and management of the floods. Some of the applications of Space Technology are development of early warning systems, monitoring & assessment, preparation of developmental plans for relief, rehabilitation and post-flood assessment, apart from tele-medicinal services. Advancement in the sensor technologies and hydrological and hydraulic models has paved the tremendous scope for remote sensing to play a greater role in the field of flood management.

Remote Sensing and GIS in Flood Warning, Mitigation and Management

Advancements in the remote sensing technology and the Geographic Information Systems (GIS) help in real time monitoring, early warning and quick damage assessment of flood disasters. Geographic Information

System is a tool that can assist floodplain managers in identifying flood prone areas in their community. With a GIS, geographical information is stored in a database that can be queried and graphically displayed for analysis. By overlaying or intersecting different geographical layers, flood prone areas can be identified and targeted for mitigation or stricter floodplain management practices. Remote Sensing can be very effective for flood management in the following way:

- Detailed mapping that is required for the production of hazard assessment maps and for input to various types of hydrological models.
- Developing a larger scale view of the general flood situation within a river basin with the aim of identifying areas at greatest risk and in the need of immediate assistance.

Remote sensing and GIS technique has successfully established its application in following areas of flood management such as flood inundation mapping, flood plain zoning and river morphological studies. Remote sensing and GIS provides a data base from which the evidence left behind by disasters that have occurred before can be interpreted, and combined with other information to arrive at hazard maps, indicating which areas are potentially dangerous. The zonation of hazard must be the basis for any disaster management project and should supply planners and decision-makers with adequate and understandable information. Remote sensing data, such as satellite images and aerial photos allow us to map the variabilities of terrain properties, such as vegetation, water, and geology, both in space and time. Satellite images give a synoptic overview and provide very useful environmental information, for a wide range of scales, from entire continents to details of a few metres. Secondly, many types of disasters, such as floods, drought, cyclones, volcanic eruptions, etc. will have certain precursors. The satellites can detect the early stages of these events as anomalies in a time series. Images are available at regular short time intervals, and can be used for the prediction of both rapid and slow disasters. Then, when a disaster occurs, the speed of information collection from air and space borne platforms and the possibility of information dissemination with a matching swiftness make it possible to monitor the occurrence of the disaster. Many disasters may affect large areas and no other tool than remote sensing would provide a matching spatial coverage. Remote sensing also allows monitoring the event during the time of occurrence while the forces are in full swing. The vantage position of satellites makes it ideal for us to think of, plan for and operationally monitor the event. GIS is used as a tool for the planning of evacuation routes, for the design of centres for emergency operations, and for integration of satellite data with other relevant data in the design of disaster warning systems. In the disaster relief phase, GIS is extremely useful in combination with Global Positioning Systems (GPS) in search and rescue operations in areas that have been devastated and where it is difficult to orientate. The impact and departure of the disaster event leaves behind an area of immense devastation. Remote sensing can assist in damage assessment and aftermath monitoring, providing a quantitative base for relief operations.

Flood mapping during the flooding and flood plain mapping after the flood recedes is essential. One of the important information required is the nature and extent of the damage caused by floods in the flood prone areas. Satellite remote sensing provides synoptic view of the flood-affected areas at frequent intervals for assessing the progression and recession of the flood inundation in short span of time which can be used for planning and organizing the relief operations effectively. Remote sensing can effectively be used for mapping the flood-damaged areas. For mapping purposes, a pre-flood scene and a peak flood image would be compared to delineate the inundated area. Flood inundation maps can be used:

- To define spatial extent of flood inundation.
- To identify the worst flood affected areas.
- To evaluate impact of flooding on environmental concerns, such as, coastlines, forests, open space etc.
- To plan relief operation.
- To assess damage.

CONCLUSIONS

Floods are a natural phenomenon. Floods of varying intensity have been occurring in all the flood plains since time immemorial. However, the ever increasing occupation (or shall we call it encroachment?) of the flood-plains results in huge loss of life and damages, causing the floods to be termed as 'disasters'. The problem is intricate. The solution is equally intricate, if not elusive. Satellite Remote Sensing and GIS techniques have emerged as a powerful tool to deal with various aspects of flood management in prevention, warning, preparedness and relief management of flood disaster. They have greater role to play as an improvement over the existing methodologies.

References

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