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Role of Satellite and Remote Sensing in Disaster Management: A Case Study of the Sina River Flood in Solapur District, Maharashtra

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Abstract

One of the most frequent and devastating natural calamities in India is floods which lead to devastating impact on life, property, agriculture and infrastructure. Heavy and extended rainfall in October 2025 caused heavy flooding on the Sina river in Solapur district of Maharashtra. This study explores the application of satellite remote sensing in disaster management in the context of flood monitoring, assessment and post disaster analysis of Sina River flood event. The satellite data helped to know the rain distribution, river over flow, inundation extent and affected areas in time, which was very important for the emergency response and the damage assessment. Using satellite data and Geographic Information Systems (GIS), accurate flood mapping and identification of potentially affected areas was possible. The outcomes emphasize the importance of the satellite-based observations in early warning, real-time monitoring and mitigation planning during flooding in flood-prone areas and their to play a crucial role in a flood disaster management strategy.

Keywords: *Satellite remote sensing, Flood disaster, Disaster management, Sina River.*

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Introduction

Natural disasters have a devastating effect on sustainable development, especially in developing nations such as India where population density and socio-economic vulnerability exacerbate the effects of natural disasters. Floods are the commonest and most devastating natural hazard of the year, resulting in unprecedented loss of lives, destruction of infrastructure, disruption of livelihoods and degradation of farm lands. Rapid urbanisation, encroachment of floodplains, deforestation of catchment areas, climate variability and poor drainage and flood control systems also aggravate the occurrence of floods. In extreme flood events, conventional ground-based monitoring methods like river gauge stations and field surveys have limited effectiveness in terms of providing timely information over large areas and real-time data, which constrains their use in disaster response and mitigation efforts.

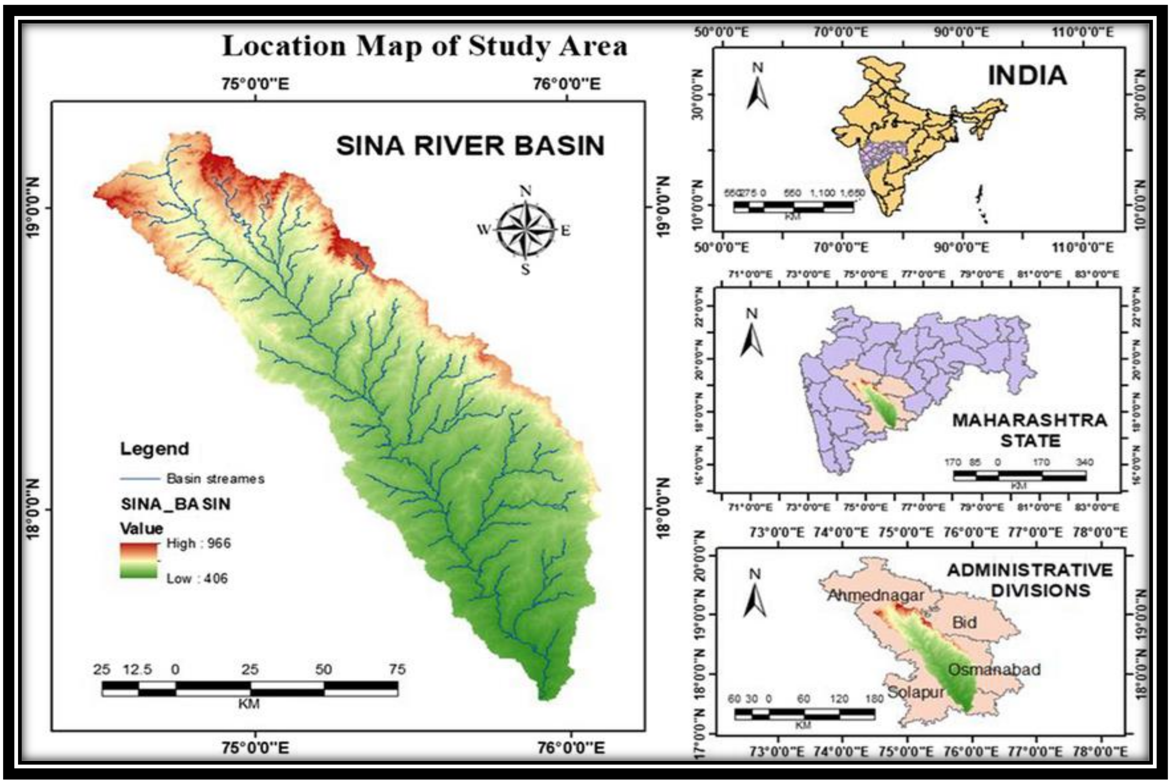
Satellite remote sensing has proven to be a valuable and invaluable tool in the management of disasters in recent decades because of its ability to provide synoptic, repetitive and near real-time observations of large spatial areas. Satellite data can be used throughout all phases of disaster management, in preparedness, early warning, response and post-disaster phases. Optical satellites offer high resolution data of land use, surface water distribution and damage assessment. Radar based satellites like the Synthetic Aperture Radar (SAR) are more useful for flood monitoring, while they can work day and night and can penetrate clouds. The following capabilities make satellite remote sensing particularly useful during flooding, when heavy clouds and precipitation are common:

The Sina River flood happened in October 2025 in Solapur district of Maharashtra due to heavy and prolonged rainfall over the river basin that eventually caused overtopping of the river and the flooding of low-lying areas in the vicinity. The flood event heavily impacted agricultural lands, rural and urban infrastructure, and transportation, underscoring the impact of extreme hydrological events in the area and its susceptibility. This study seeks to utilize the role of satellite remote sensing for monitoring and managing Sina River flood with the mapping of flood extent, flood affected area estimation and disaster response support. The study highlights the role of the satellite based technology in reducing flood impacts, aid decision making and enhance the disaster management process in flood prone areas.

However, it was found that the study area was Sina River in Solapur District.

The Sina River is a tributary of the Bhima river and passes through the Solapur district of Maharashtra which is generally a drought prone area. It is a semi-arid climate with the rainfall concentrated in South-West monsoon.

In October 2025, unusually heavy rainfall was experienced over the river catchment which resulted in a sudden increase in river levels, resulting in low lying areas being flooded and overflowed.The study site consists of rural villages and agricultural areas along the riverbanks. The topography is flat and there is a lack of drainage capacity, making the area very susceptible to flooding.



Sina River Data Normal vs 2025 Flood Condition

The floods in late September 2025 reached record-breaking levels due to heavy rainfall and simultaneous dam discharges.

Metric	Normal Data	2025 Flood Peak
Rainfall	380mm–700mm annually	Over 103.57% above average since June
Peak Discharge	1,000 cusec (NimgaonGangarda dam)	2,12,651 cusecs (Record discharge)
Discharge (Dam)	581 m³/s (Wadakbal station)	27,800 cusecs (NimgaonGangarda peak)
Villages Affected	Historically low exposure	110 villages inundated
Affected People	Minimal historical impact	Over 5,500 people hit

Role of satellite in Disaster Management

Satellite remote sensing is an important tool for disaster management because of its ability to provide large-scale, timely, accurate data before, during and after a disaster event. Satellite data played an important role in providing early warning, flood monitoring, damage assessment and post disaster rehabilitation planning during the Sina River flood in October 2025 in Solapur district. Satellite's multi-temporal and multi-sensor observations enable continuous monitoring of the dynamic nature of floods, which could not be achieved by using the conventional ground-based method alone.

Early warning and monitoring

Meteorological Satellites are crucial for early warning and continuous observation of extreme weather events. These satellites monitor the characteristics of the atmosphere, including cloud cover, precipitation, humidity, etc. Pre-flood rainfall amounts were highly detected by satellite-based rainfall estimation methods before the October 2025 flood event in the Sina River catchment area. This information was useful in advance warning of a potential flood and provided disaster management authorities with useful information.

Satellite monitoring allows forecasting agencies to detect rainfall anomalies and saturation conditions in rivers basins well in advance. Satellite-derived early warning enables the authorities to start taking measures in preparation like reservoir regulation, evacuation, and public warnings, which helps to prevent loss of life and property.

Flood Mapping and Inundation Analysis

Satellite remote sensing is one of the most crucial applications used in disaster management including flood mapping. Satellite images were acquired both during and immediately after the flooding of the Sina River and used to identify flooded areas. The radar satellites were extremely effective, especially the synthetic aperture radar (SAR) which was able to operate under all weather and lighting conditions and to penetrate cloud cover.

Satellite-derived flood inundation maps clearly mapped out flooded farmland, residential areas, transportation structures and low-lying areas along river banks. The maps included spatial data on flood extent and depth, which helped authorities identify high-risk and heavily impacted areas.

Damage Assessment

Post flood damage assessment is an important determinant for relief planning and compensation estimation. Using satellite imagery, that collected after the flood was compared with imagery prior to the flood to determine the extent of land use change, crop damage, infrastructure loss and river morphology change. The analysis of vegetation indices was used to detect agricultural losses and spatial overlay analysis was conducted in GIS to identify damaged roads and settlements.

Satellite based damage assessment is a fast, cost effective and unbiased way of assessment as opposed to field surveys. It allows for measurements over large areas in a short time frame, a critical aspect during emergencies.

Relief and Rehabilitation Planning

Satellite-derived flood and damage maps are very important for relief/rehabilitation planning. Satellite data assisted disaster response agencies in the October 2025 flood to determine safe evacuation routes, find relief camps, and prioritise resource provision to areas of most significant disaster. The information also helped planners consider the needs of long-term rehabilitation, which involved the reconstruction of infrastructure, restoration of agriculture areas, and development of flood mitigation measures.

Table 1: Role of Satellite Remote Sensing at Different Stages of Disaster Management

Disaster Management Stage	Satellite Contribution	Key Outcomes
Early Warning & Monitoring	Rainfall estimation, storm tracking, cloud analysis	Timely flood alerts and preparedness
Flood Mapping	SAR and optical imagery for inundation mapping	Identification of flooded areas
Damage Assessment	Pre- and post-flood image comparison	Estimation of crop and infrastructure damage
Relief & Rehabilitation	GIS-based planning using flood maps	Efficient evacuation and resource allocation

Table 2: Types of Satellite Data Used in Flood Management

Satellite Type	Data Provided	Application
Meteorological Satellites	Rainfall, cloud cover, storm movement	Early warning
Optical Satellites	Land use, water spread	Flood extent mapping
Radar (SAR) Satellites	All-weather flood detection	Inundation analysis
GIS-integrated Satellite Data	Spatial analysis	Damage and relief planning

This case study on the 2025 Sina River Flood shows that satellite remote sensing is an indispensable tool for effective disaster management. It has been proved to offer early warning, flood map, rapid damage assessment, and decision making, which has greatly contributed to the disaster response and disaster resistance.

Methodology

In the present study, a satellite based remote sensing method is used for analysing flood event occurred on Sina river at Solapur district in October 2025. Pre-, in situ, and post-flood satellite images were employed to observe the flood dynamics, to map the extent of inundation, and to determine the extent of the flood-affected areas. The methodology aimed to guarantee the accuracy of flood mapping and the reliable interpretation by systematic data processing and spatial analysis.

Acquisition of satellite imagery

Satellite data were acquired for pre-flood, flood and post-flood periods to understand the temporal evolution of the flood event. Optical and radar data from satellites were both taken into account to alleviate the cloud cover limitation in heavy rainfall. The pre-flood images were used to provide baseline data, and the images during the flood period provided information on the amount of inundation. Post Flood images were used to provide damage assessment and validation of flood impact.

Pre-processing and Enhancement

The satellite images were pre-processed using standard processing methods to improve data quality and consistency. They consisted of geometric correction (which transforms images to real-world coordinates), radiometric corrections (which reduce the effects of the sensor and the atmosphere), and image enhancement (such as contrast stretching and filtering). Speckle noise reduction was used for radar data to improve the detection of water bodies. The images were then reprocessed and fed into GIS software for additional analysis.

Flood Boundary Extraction

Flood boundary extraction was performed to detect water areas and to be able to identify water covered areas during the flood. This was a step taken to differentiate flooded areas from unflooded land based on spectral and backscatter properties of water bodies. The water features were detected with the help of spectral thresholds in optical imagery and low backscatter values of water surfaces in radar imagery. The flood boundaries extracted were then converted to flood extent vector boundaries.

The site has been overlaid with Land-Use and Settlement Data.

The flood extent layer was added as a vector overlay to the land-use/land-cover (LULC) maps, settlement layers, transportation networks and agricultural boundaries in a GIS environment. An overlay analysis allowed affected land categories to be identified including croplands, residential, roads, and public infrastructure. Spatial statistics were created to estimate the level of damage at varying land-use categories.

Interpretation and Validation

The final step involved the interpretation of results and the validation of flood maps. Validation was performed using available ground reports, administrative records, and secondary data sources. The accuracy of flood delineation was assessed by cross-verifying satellite-derived inundation areas with reported flood-affected locations. The validated results were then used for impact assessment and disaster management planning.

Table 3: Methodology Steps and Description

Step No.	Methodological Stage	Description
1	Data Acquisition	Collection of multi-temporal satellite images
2	Preprocessing	Geometric and radiometric correction, enhancement
3	Flood Extraction	Identification and mapping of inundated areas
4	GIS Overlay Analysis	Assessment of affected land-use and settlements
5	Validation	Cross-checking with ground and secondary data

The overall process fuses the concept of satellite remote sensing and GIS, and systematically monitors the flood event starting from data acquisition to impact assessment. This methodology is reliable, efficient and scalable for flood disaster analysis and management.

Results and Discussion

The analysis of the flood event using the satellite data showed a large extent of flood inundation along the Sina River, inundation largely being localized in low-lying areas close to the river channel. The use of multi-temporal satellite imagery was very clear that agricultural lands were the most affected, since they are mainly located in the natural floodplain and are not protected by suitable infrastructure. Similarly, floodwaters have caused serious inundation of rural settlements close to the river banks, resulting in loss of life and property including damage to houses, roads and services. The inundated areas could be represented on a comprehensive spatial scale by flood extent maps, which were obtained from satellite data, and obtaining an accurate map of high risk and vulnerable areas in the Solapur district. The use of satellite imagery and GIS allowed for a successful overlay of land use and settlement data and the identification of the area affected by impacts on croplands, habitation areas and transportation networks. These spatial-based information enabled a quick determination of flood severity and enabled decision making by disaster management stakeholders. The results show that satellite remote sensing is a very quick and reliable as well as cost-effective tool for monitoring the flood event, especially in areas where ground-based observations are not possible or are difficult to take during the flood event. The overall conclusions are that satellite-based technologies play a vital role in improving the preparedness and efficiency of response to floods and long-term planning for disaster management.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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