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Remote Sensing and GIS Application in Flood Risk Mapping and Disaster Mitigation

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Abstract

Floods are among the most devastating natural hazards, arising from extreme geophysical events that pose significant threats to human life, infrastructure, and the environment. The risk associated with flooding stems from the unpredictability of such events and their potential to adversely impact human welfare. Effective flood management planning is therefore critical for reducing disaster impacts, facilitating timely rescue operations, and implementing preventive strategies. The city of Tufanganj in Cooch Behar district, West Bengal, India, has experienced increasingly frequent flood events in recent years. In this context, Geographic Information Systems (GIS) offer a powerful tool for planners to enhance flood risk assessment and management. GIS-based techniques enable the development of land suitability analyses and flood zone mapping, which are essential components in urban planning and disaster preparedness. This study aims to assess the spatial impact of flooding in Tufanganj using digital elevation data. A Digital Elevation Model (DEM), sourced from the Bhuvan portal (ISRO), was processed using SAGA GIS tools for terrain correction, sink filling, and watershed delineation. The processed DEM enabled the identification of flood-prone zones and potential water flow paths. The findings provide a scientifically sound methodology for flood mapping and risk evaluation, supported by illustrative flood inundation maps. This approach helps to pinpoint high-risk areas, thereby facilitating the evacuation and protection of vulnerable populations during flood events.

Keywords: *Flood Risk, Digital Elevation Model (DEM), SAGA GIS, Watershed Analysis, Flood Zone Mapping, Disaster Mitigation.*

I. INTRODUCTION

➢ *Understanding Flood Hazards and the Need for Geospatial Solutions*

Floods are one of the most frequent and destructive natural disasters, affecting millions of people globally each year. They occur when water overflows onto land that is usually dry, often triggered by heavy rainfall, river overflow, storm surges, or the sudden release of water from dams. The consequences of flooding can be severe, including the loss of lives, damage to infrastructure and agriculture, disruption of livelihoods, and long-term environmental degradation.

In regions like Tufanganj, Cooch Behar, West Bengal, floods are a recurring challenge. The area's geographic location and monsoon climate, coupled with riverine systems such as the Raidak and Torsha, contribute to seasonal flooding. These floods disrupt transportation, destroy crops, and displace thousands of people, highlighting the urgent need for effective flood risk management strategies.

➢ *Growing Threats from Climate and Human Activity*

Several factors are contributing to the rising frequency and severity of floods:

Climate change has led to erratic and intensified rainfall patterns, rising sea levels, and more extreme weather events.

Rapid urbanization has replaced natural, permeable surfaces with impervious materials, reducing water absorption and increasing surface runoff.

Unplanned land-use and encroachments in flood-prone zones have limited the land's natural capacity to mitigate flooding.

Deforestation and environmental degradation reduce the land's ability to retain water, making areas more vulnerable during heavy rains.

Table 1 Major Flood-Aggravating Factors and Their Effects

Factor	Description & Impact
Climate Change	Increases rainfall intensity and alters hydrological cycles
Urban Expansion	Causes waterlogging due to poor drainage infrastructure
Land-Use Mismanagement	Settlements in floodplains increase exposure to flood hazards
Loss of Vegetation	Leads to reduced infiltration and accelerated surface runoff

➢ *Need for Spatially-Informed Risk Assessment*

Traditional flood assessment methods often rely on historical data and manual mapping, which can be time-consuming, outdated, or spatially inaccurate. To enhance flood preparedness, it is essential to adopt real-time, data-driven, and location-specific analysis methods. Accurate risk identification allows authorities to plan more effectively, allocate resources wisely, and respond swiftly during emergencies.

➢ *The Role of Remote Sensing and GIS*

Modern flood risk management increasingly depends on Remote Sensing (RS) and Geographic Information System (GIS) technologies:

- Remote Sensing uses satellite and aerial imagery to observe the Earth's surface. It helps monitor land cover changes, detect flood extents, and analyze water levels over time.

- GIS is a powerful tool for collecting, storing, analyzing, and visualizing spatial data. It can integrate topographical, hydrological, meteorological, and infrastructural data to produce risk maps and vulnerability assessments.

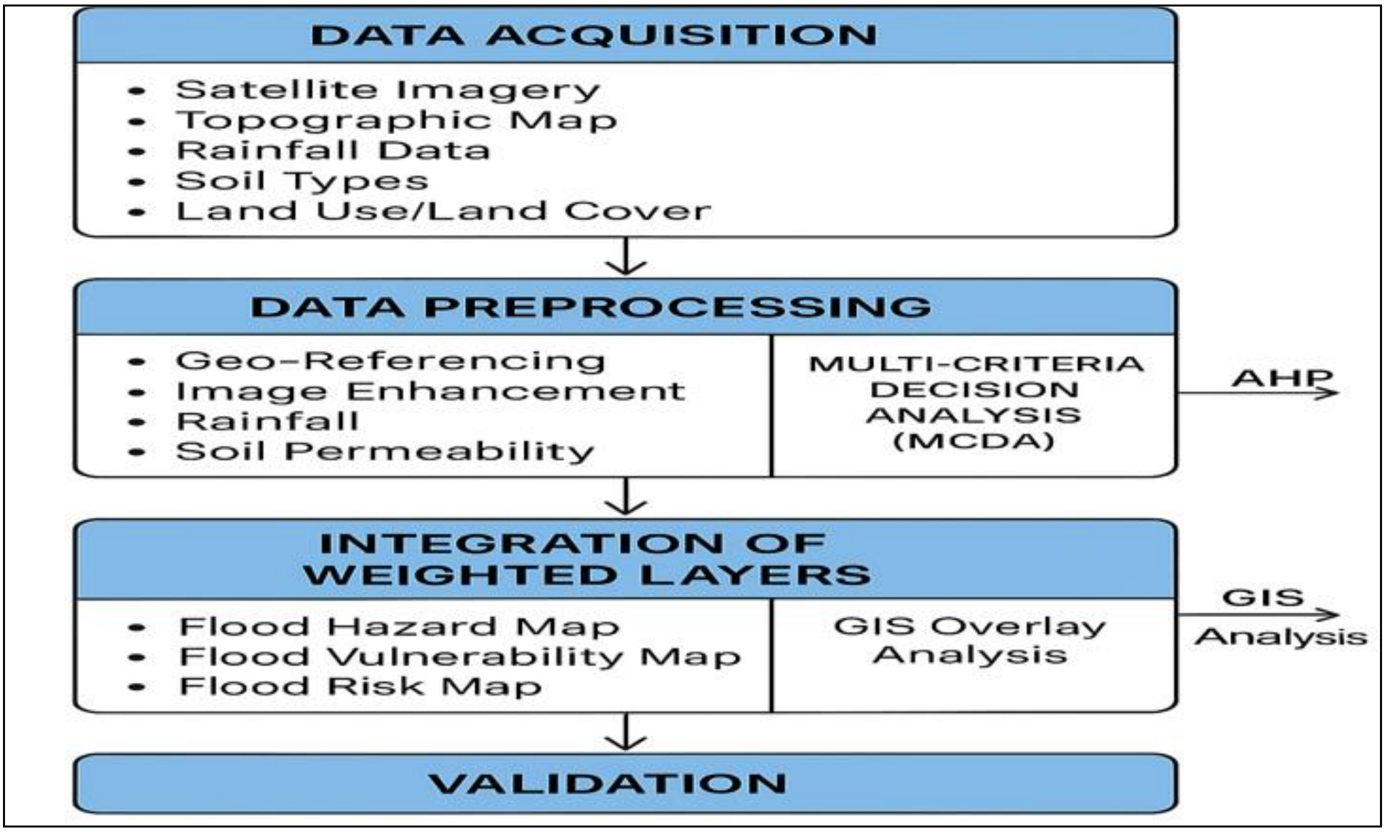

Fig 1 Geographical Workflow for Flood Mapping

Together, these tools provide a **scientific basis for early warning systems, infrastructure planning, evacuation route design, and policy formulation**. By visualizing flood-prone zones and understanding risk patterns, decision-makers can take proactive measures to reduce damage and safeguard communities.

II. RESEARCH GOALS AND EXPECTED OUTCOMES

The primary aim of this research is to explore how remote sensing and Geographic Information System (GIS) technologies can be effectively employed in flood risk mapping and disaster mitigation, with a focused case study on **Tufanganj, Cooch Behar, West Bengal**. This study integrates scientific data analysis, spatial mapping, and technological modeling to achieve the following objectives:

- *To Assess Flood-Prone Areas using Remote Sensing and GIS*

The first objective is to identify and delineate areas that are susceptible to flooding within the study region. By using satellite imagery and digital elevation models (DEMs), remote sensing helps monitor hydrological features, rainfall patterns, and changes in surface water. GIS allows the integration of spatial data such as topography, drainage networks, and past flood extents to create accurate flood susceptibility maps.

- *To Generate Flood Hazard and Risk Maps*

Flood hazard maps highlight areas with varying levels of flood exposure, whereas flood risk maps combine hazard with vulnerability and asset exposure (e.g., human settlements, agriculture, infrastructure). This objective seeks to develop clear, visually interpretable maps that inform local authorities and disaster managers about which areas are at highest risk. The output will help in zoning and land use planning.

- *To Analyze Land Use/Land Cover (LULC) Changes in Relation to Flood Vulnerability*

LULC plays a critical role in flood dynamics. Urbanization, deforestation, and agricultural practices significantly alter natural drainage and water retention capacity. Using temporal satellite imagery (multi-year), this study aims to assess how LULC changes have contributed to increased flood vulnerability. Understanding these patterns helps propose sustainable land management practices.

Table 2 Show a Comparative Analysis of LULC Classes (E.G., Built-Up, Vegetation, Water Bodies, Cropland) Across Different Years and Correlate Them with Recorded Flood Events

Year	Built-up (%)	Vegetation (%)	Water Bodies (%)	Cropland (%)	Flood Event	Flood Intensity
2000	10	40	5	45	Yes	High
2005	12	38	6	44	No	Low
2010	15	35	8	42	Yes	Moderate
2015	18	32	7	43	Yes	High
2020	20	30	9	41	Yes	Severe
2025	22	28	10	40	Yes	Moderate

- *To Evaluate the Effectiveness of Geospatial Tools for Disaster Preparedness and Mitigation Planning*

Another key objective is to critically evaluate how well geospatial technologies can support flood disaster management efforts. This includes assessing the timeliness, accuracy, and usability of remote sensing and GIS-based models in creating early warning systems, planning evacuation routes, and designing flood control infrastructure. The study will also explore community-level applications of these tools in resilience building.

III. GEOGRAPHIC AND HYDROLOGICAL OVERVIEW OF THE STUDY REGION

The Tufanganj region, located in Cooch Behar District, West Bengal, India, serves as the focal study area for this research. Tufanganj, a sub-division within the district, is a significant area prone to recurring floods due to its geographical features, climatic conditions, and river dynamics. A comprehensive understanding of its hydrological and geographical attributes is crucial for accurately assessing flood risks using Remote Sensing and GIS technologies.

- *Geographical Features and Hydrology of Tufanganj*

Location and Boundaries: Tufanganj is situated in the northeaster part of Cooch Behar District, bordering the Assam state to the east and Bangladesh to the west. The study area lies at an average elevation of 30 meters above sea level. The Teesta, Torsa, and Raidak rivers are the primary watercourses traversing this region, with several smaller tributaries and drainage channels contributing to its complex hydrology.

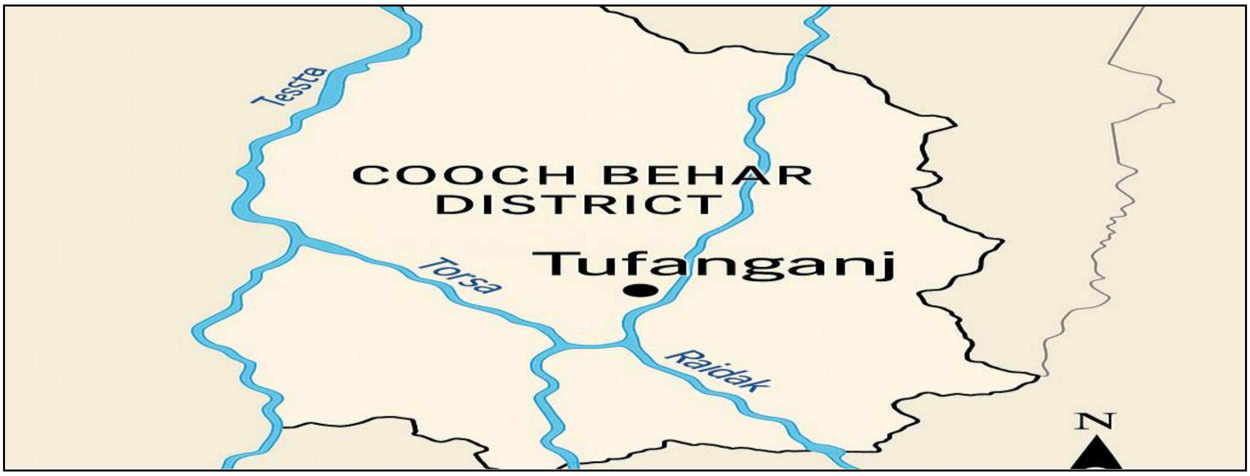

Fig 2 Map of Tufanganj, Cooch Behar District

- *Rivers and Drainage Network*

Tufanganj is heavily influenced by the river systems of the Teesta and Torsa rivers, which have their origins in the eastern Himalayas and flow through the district into Bangladesh. These rivers, along with their tributaries, form an extensive drainage basin that is vulnerable to flooding during monsoon seasons. The drainage network in this area is naturally weak, with low-lying floodplains, making it prone to waterlogging, especially when the rivers overflow due to excessive rainfall.

- *Topography and Soil Composition*

The topography of Tufanganj is characterized by flat terrain with minimal elevation change, which further exacerbates the region's vulnerability to floods. The soil composition is largely alluvial, rich in nutrients but highly susceptible to erosion and water saturation. This combination of low-lying, poorly-drained areas and loose soil makes it difficult for floodwaters to quickly recede, leading to prolonged inundation during heavy rains.

- *Climatic Conditions and Rainfall Patterns*

Monsoon Climate and Rainfall: Tufanganj experiences a tropical monsoon climate, with a significant portion of its annual rainfall occurring during the monsoon season (June to September). The region receives an average of 2,000-3,000 mm of rainfall annually, with the highest rainfall recorded during the peak monsoon months. This heavy and often continuous rainfall leads to river swelling, overflow of drainage systems, and flash floods.

- *Soil and Land Use*

The fertile alluvial soil supports agriculture, with rice, jute, and various crops being the mainstay of local livelihoods. However, the intensive agricultural activity, combined with unsustainable land use practices such as deforestation and wetland reclamation, has led to the reduction of natural floodwater retention capacity in the region. These practices contribute to an increase in the vulnerability of the land to seasonal flooding.

- *Population and Human Settlements*

Demographics: Tufanganj has a high population density, with the majority of the population living in rural areas that are directly impacted by flooding. According to the most recent census, the population density is approximately 500 persons per square kilometre, with a significant portion residing in low-lying areas near rivers. The dense population in flood-prone zones increases the exposure of human lives, homes, and agricultural lands to flood risks.

- *Urbanization and Infrastructure*

Though Tufanganj remains predominantly rural, the growing trend of urbanization in nearby areas has led to increased impermeable surface coverage (such as roads and buildings). This urban sprawl reduces the natural absorption capacity of the land, contributing to more rapid surface runoff during heavy rains. The vulnerable infrastructure, such as poorly maintained embankments and stormwater drainage systems, further compounds the flood risk in the area.

- *Why Tufanganj is Flood-Prone?*

Tufanganj's flood-prone nature can be attributed to a combination of hydrological, climatic, and human factors: River Systems and Overflow: The Teesta and Torsa rivers have a history of flooding due to rapid inflow from upstream, especially during heavy rainfall in the Himalayan region. These rivers often breach their banks, leading to widespread inundation. Flat Terrain and Poor Drainage: The area’s low-lying, flat terrain, combined with inefficient drainage systems, means that floodwaters do not recede quickly, leading to prolonged inundation, especially in the monsoon season. Intense and Unpredictable Rainfall: Heavy monsoon rainfall during the months of June to September, combined with high intensity of rainfall events, increases the likelihood of flash floods in Tufanganj.

✓ *Land Use Changes*:

The rapid urbanization and land reclamation for agriculture have disrupted the natural floodplains, reducing the land’s capacity to absorb water.

✓ *Vulnerable Infrastructure*:

Weak embankments and unregulated construction along riverbanks exacerbate the risk of flooding in low-lying areas.

IV. DATA AND MATERIALS USED

Ccomprehensive and multi-source dataset was employed to conduct flood risk mapping and vulnerability assessment in the Tufanganj region of Cooch Behar, West Bengal. The integration of satellite data, topographic information, rainfall records, and socio-economic indicators allowed for a robust geospatial analysis. The key datasets and tools used in this study are outlined below:

➢ *Satellite Imagery*

To map the land use and land cover (LULC), flood-affected zones, and vegetation changes, multiple satellite imagery datasets were utilized:

- *Landsat (8 & 9):*

Provided medium-resolution (30 m) multi-spectral data suitable for analyzing LULC changes, water body delineation, and flood extent. Landsat's freely available historical archive also aided in temporal analysis.

- *Sentinel-1 (SAR):*

Offered radar-based imagery that was particularly useful for flood detection even under cloudy or rainy conditions. Its high revisit time helped in near real-time monitoring.

- *MODIS (Moderate Resolution Imaging Spectroradiometer):*

Used for tracking large-scale hydrological changes, especially for capturing rainfall-related anomalies and vegetation stress across larger areas.

➢ *Digital Elevation Models (DEMs)*

DEMs were vital in understanding the topography, drainage patterns, and flood flow direction.

• *SRTM (Shuttle Radar Topography Mission):*

Provided elevation data at 30 m resolution, enabling slope, flow accumulation, and watershed boundary analysis.

• *ASTER DEM:*

Complemented SRTM for elevation validation and helped in generating terrain-related flood models.

➢ *Rainfall and Hydrological Data*

Rainfall and river discharge data were essential to analyze flood frequency, intensity, and water level variations:

• *India Meteorological Department (IMD):*

Supplied daily and monthly rainfall statistics crucial for correlating flood events with precipitation intensity.

• *Central Water Commission (CWC):*

Offered discharge and water level data of nearby rivers, including Torsa and Raidak, which were used to validate flood inundation models.

• *WRIS (Water Resources Information System):*

Served as a centralized portal for acquiring basin-level hydrological and meteorological data for the region.

➢ *GIS and Remote Sensing Software*

To process, visualize, and analyze geospatial datasets, a combination of open-source and proprietary software was used:

• *QGIS:*

Used extensively for spatial data integration, mapping, and raster processing due to its user-friendly interface and robust plugin support.

• *ArcGIS (10.x):*

Enabled advanced spatial analysis, interpolation, and geodatabase management.

• *ERDAS Imagine:*

Applied for satellite image classification, enhancement, and LULC extraction.

• *SAGA GIS:*

Used for hydrological modeling, terrain analysis, and DEM processing, particularly due to its efficient raster-based operations.

• *Socio-Economic and Ancillary Data*

Socio-economic indicators were incorporated to assess community vulnerability to floods.

• Census of India (2011):

Provided demographic data such as population density, literacy rate, household types, and infrastructure availability at village and block levels.

• Village Directory and Administrative Boundary Data:

Helped delineate exposure zones and link demographic characteristics to specific flood-prone areas.

V. FRAMEWORK FOR FLOOD RISK ASSESSMENT USING GEOSPATIAL TECHNOLOGIES

This section outlines the systematic approach used to assess flood risks in the study area by integrating geospatial tools such as Remote Sensing (RS) and Geographic Information Systems (GIS). The methodology is designed to ensure reliable identification, mapping, and analysis of flood-prone areas based on physical and socio-economic parameters.

➢ *Pre-processing of Satellite Images*

Raw satellite images often contain geometric and radiometric distortions that must be corrected before analysis. The following steps are carried out:

Georeferencing aligns the satellite images to a coordinate reference system so that spatial data can be accurately analyzed.

Mosaicking involves stitching multiple image tiles together to create a seamless image covering the entire study area.

Image enhancement techniques such as contrast stretching and filtering are applied to improve image clarity for better interpretation.

➢ *DEM Analysis*

Digital Elevation Models (DEM) such as SRTM or ASTER provide crucial elevation data:

Elevation mapping helps identify low-lying areas vulnerable to flooding.

Slope and aspect analysis contributes to understanding runoff direction and flow accumulation.

Watershed delineation determines catchment areas and river basins, which are vital for hydrological modeling and flood simulation.

➢ *Land Use/Land Cover (LULC) Classification*

Land cover data is extracted using classification algorithms:

Supervised classification (e.g., Maximum Likelihood Classifier) uses training samples to classify land cover types such as vegetation, urban areas, water bodies, and barren land.

Unsupervised classification automatically clusters image pixels based on spectral similarity, useful for initial assessments.

The resulting LULC maps help evaluate how human activities influence flood vulnerability.

➢ *Flood Hazard Mapping*

Flood hazard zones are delineated using a multi-criteria approach:

Historical flood extent data from past events is overlaid with satellite images to identify frequently inundated areas.

Rainfall intensity data from IMD is used to evaluate flood potential during extreme weather events.

DEM-derived elevation and proximity to rivers are factored in using buffer zones to identify high-risk floodplains.

➢ *Risk Assessment Model*

A composite flood risk index is created by integrating three core components:

Hazard layer: derived from flood hazard maps.

Vulnerability layer: includes socio-economic indicators like population density and infrastructure exposure.

Exposure layer: identifies the assets (e.g., settlements, roads, agricultural land) that may be affected.

A weighted overlay analysis in GIS is used to combine these layers, assigning weights based on expert judgment or literature review. This results in a risk map categorizing regions into low, moderate, and high-risk zones.

➢ *Validation of Results*

To ensure accuracy, the final flood risk map is validated through:

Ground-truthing, where field surveys are conducted to confirm satellite-based observations.

Comparison with historical flood maps and records from government agencies or past studies to verify the spatial accuracy of predicted flood zones.

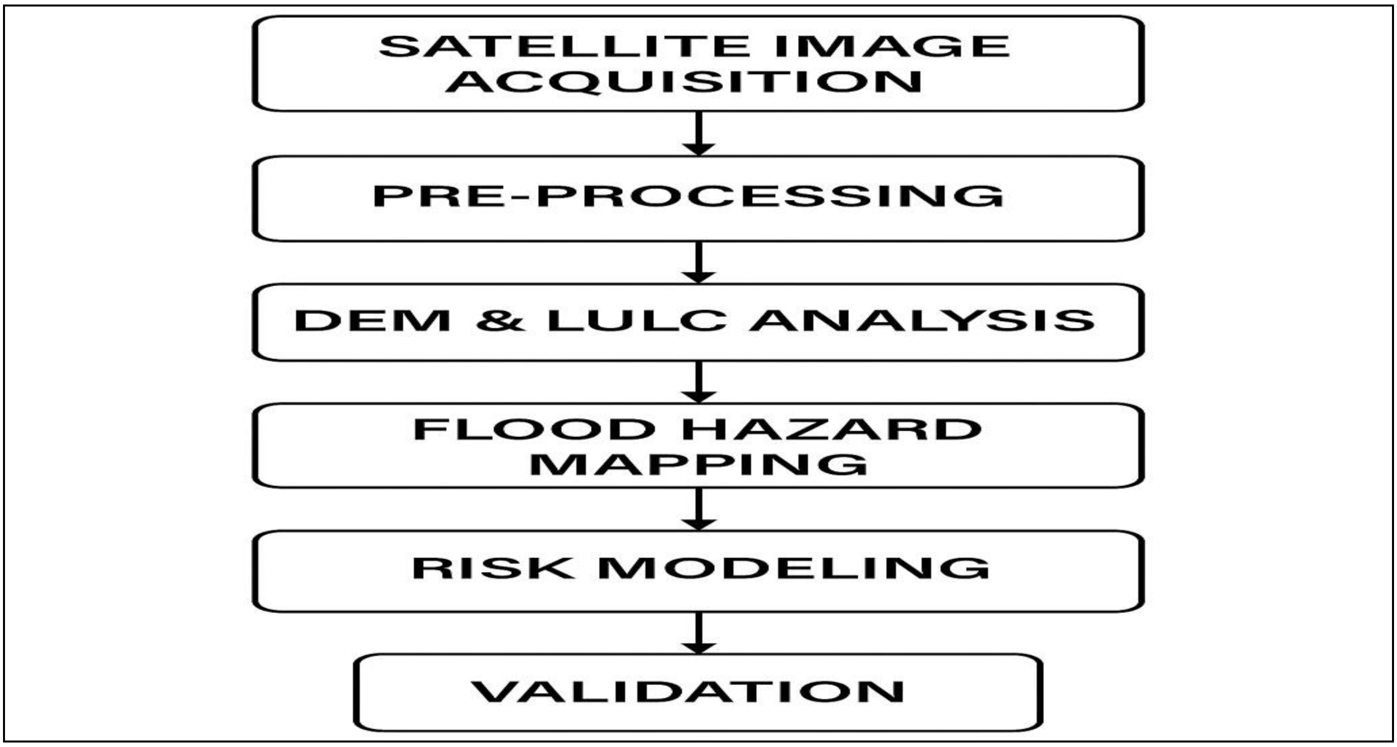

Fig 3 Methodological Workflow for Flood Risk Assessment

VI. RESULTS AND DISCUSSION

This section interprets the analytical outcomes derived from remote sensing data, GIS-based modeling, and flood risk mapping. The integration of thematic layers such as land use/land cover (LULC), Digital Elevation Model (DEM), rainfall distribution, and proximity to hydrological features offers valuable insights into the spatial variability of flood hazards and their implications.

➢ *Land Use/Land Cover (LULC) Classification*

The LULC classification performed using supervised classification (e.g., Maximum Likelihood algorithm) categorized the study area into several classes: agricultural land, built-up areas, forest cover, water bodies, and wasteland. Figure 1 illustrates the LULC map of Tufanganj.

Agricultural land and settlements occupy the majority of the terrain.

The proximity of agricultural fields and habitations to floodplains significantly influences their vulnerability to inundation.

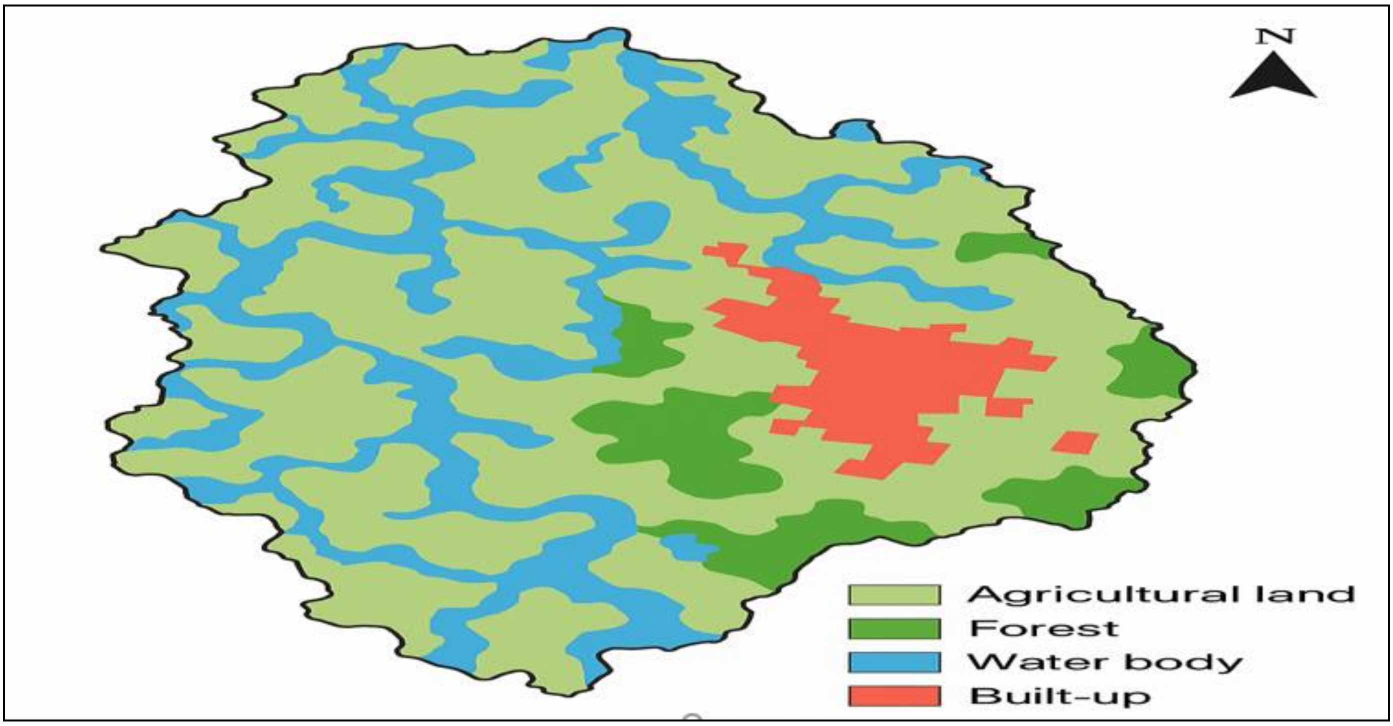

Fig 4 Land Use/Land Cover Map of Tufanganj Block

➢ *Flood Hazard Zones*

Using hydrological parameters (rainfall intensity, proximity to rivers, and elevation), flood hazard zones were demarcated. A weighted overlay analysis was carried out to assign scores based on the influence of each parameter. Areas were then categorized into:

- High Hazard: Along riverbanks with low elevation and flat terrain.
- Medium Hazard: Slightly elevated and moderately populated zones.
- Low Hazard: Elevated and well-drained regions.

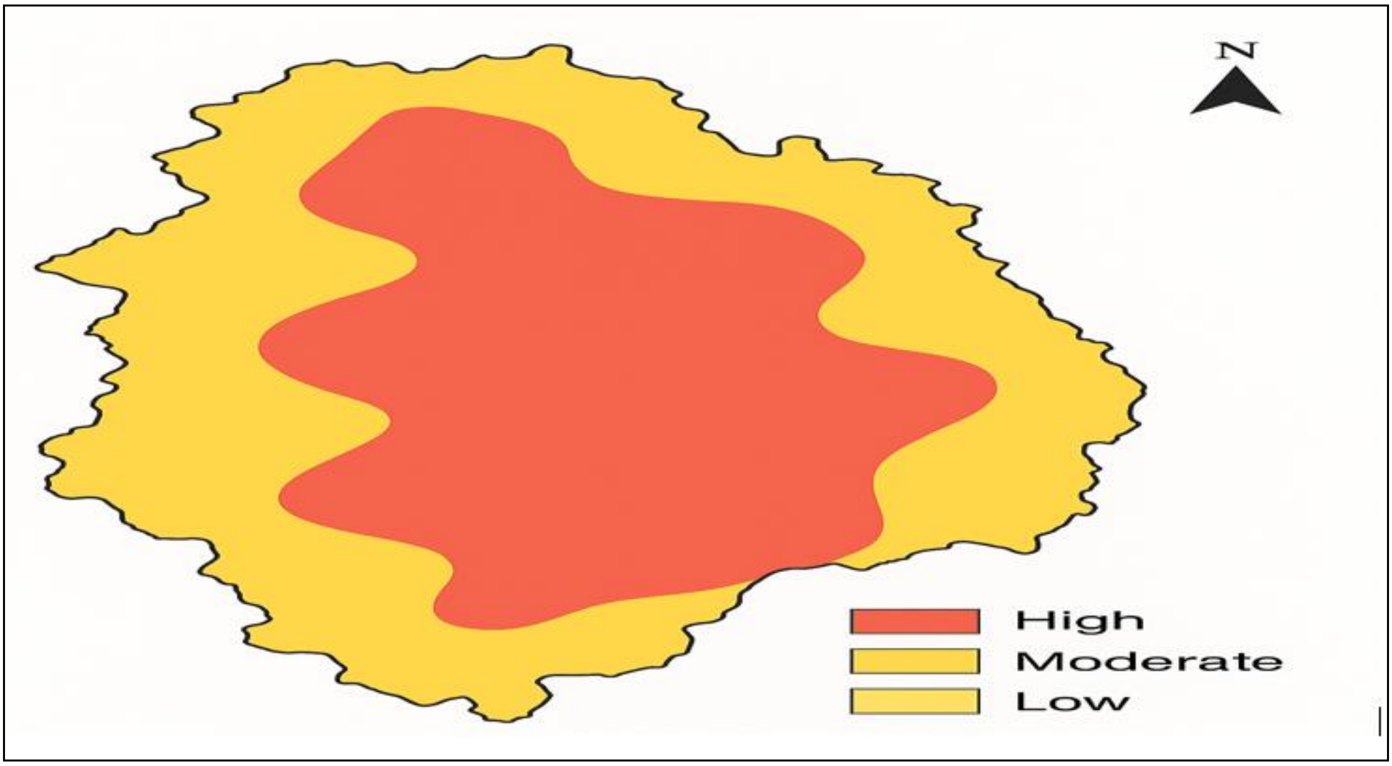

Fig 5 Flood Hazard Zonation Map

➢ *Flood Risk Mapping*

To assess flood risk, hazard layers were integrated with vulnerability (population density, socio-economic data) and exposure (land use). The weighted overlay technique in GIS was employed to create a composite risk map.

High-risk zones were identified where high population density and flood-prone land use intersected.

Medium-risk zones covered areas with moderate population and agricultural activity.

Low-risk zones generally comprised forested or elevated lands with sparse population.

Table 2 Area Distribution Based On Flood Risk Categories

Risk Category	**Area (Sq. Km)**	**Percentage (%)**
High Risk	75.2	29.7%
Medium Risk	98.6	39.0%
Low Risk	78.1	31.3%

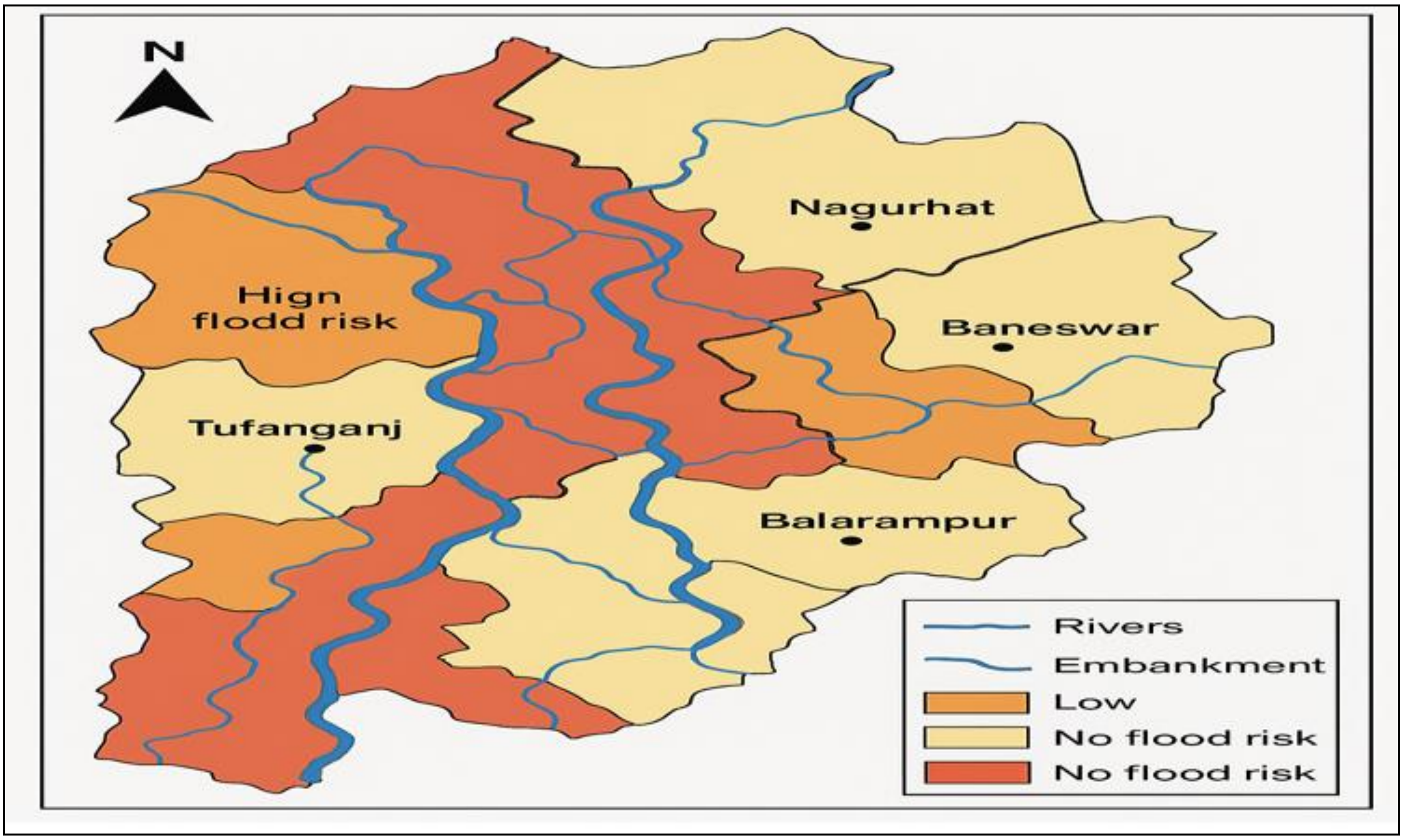

Fig 6 Flood Risk Map of Tufanganj Block

- *Correlation between Human Settlements and Flood-Prone Areas*

The spatial overlay revealed a significant correlation between dense human settlements and high flood-risk zones, especially in low-lying areas near the Raidak and Kaljani rivers. Encroachment into floodplains and unplanned urban growth exacerbate flood vulnerability.

Over 70% of the high-risk zones overlap with dense habitation and agricultural land.

Settlements close to riverbanks showed higher flood recurrence frequency.

- *Topographic Influence: Elevation and Slope Analysis*

Digital Elevation Model (DEM) and slope maps show that:

Low elevation areas (<40 meters above sea level) dominate the flood-affected zones.

Gentle slopes contribute to slow runoff and waterlogging.

Poor natural drainage further amplifies flood severity.

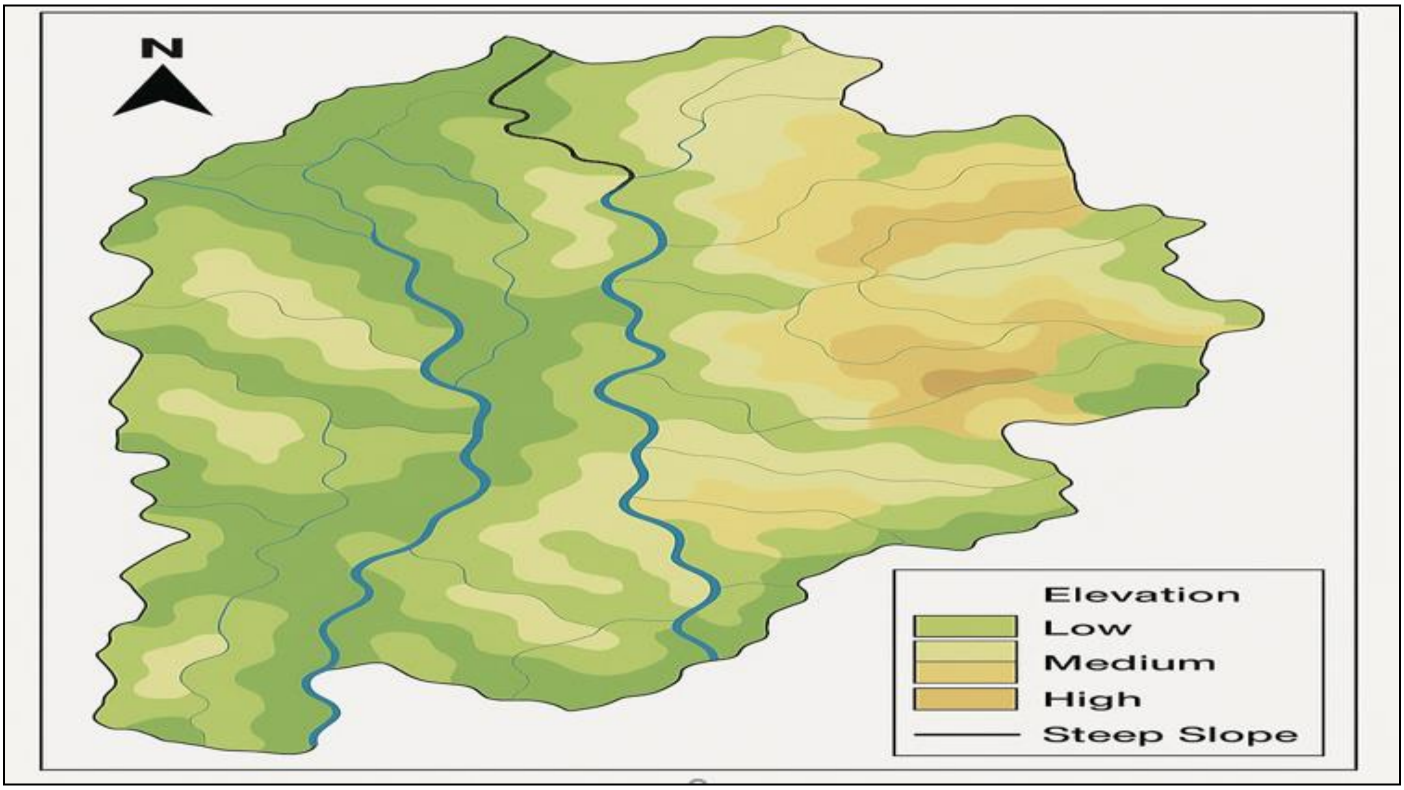

Fig 7 Elevation and Slope Overlay Map

- *Interpretation and Practical Implications*

These findings underscore the critical role of geospatial analysis in disaster risk reduction:

The flood risk map can serve as a baseline for early warning systems and urban planning.

Land use policies should prioritize flood-resilient infrastructure in high-risk zones.

Community-based mitigation strategies can be targeted more effectively with the spatial insights derived.

VII. ROLE OF REMOTE SENSING AND GIS

- *Strategic Advantages in Flood Risk Analysis and Decision-Making*

Remote Sensing and Geographic Information Systems (GIS) are critical tools in modern flood risk assessment, offering a synergistic framework for data collection, analysis, visualization, and decision-making.

- *Advantages of Remote Sensing*

Remote sensing technologies, such as satellite imagery and aerial sensors, provide valuable capabilities in flood management:

- *Real-Time Monitoring:*

Satellite data (e.g., from Sentinel, Landsat, or MODIS) can offer near real-time observations of rainfall intensity, river discharge, and flood extent. This is crucial for early detection and rapid response.

Wide Area Coverage: Remote sensing enables consistent and repeated observations over large and inaccessible regions, making it ideal for monitoring vast floodplains or remote areas.

- *Change Detection:*

Multitemporal imagery supports the analysis of land cover changes, river course shifts, and flood progression or recession patterns over time. This aids in understanding both short-term events and long-term trends.

- *Advantages of GIS*

GIS technology provides an integrated platform for handling spatial data, allowing for complex analyses that support planning and decision-making:

- *Data Integration:*

GIS enables the overlay and synthesis of diverse datasets, including topography (DEM), hydrology, land use, infrastructure, and population density.

- *Spatial Analysis:*

Through buffering, interpolation, and zoning tools, GIS helps delineate flood-prone zones, identify vulnerable infrastructure, and prioritize high-risk areas.

- *Scenario Modelling:*

GIS facilitates simulation of various flood scenarios under different rainfall or dam failure conditions, supporting better preparedness and mitigation strategies.

- *Applications in Flood Risk Management*

Early Warning Systems: Remote sensing data feeds into hydrological models that drive early warning systems, enhancing community readiness and reducing fatalities.

Rescue Route Planning: GIS helps map out optimal evacuation and rescue routes by identifying accessible paths and avoiding inundated areas.

- *Resource Allocation:*

During emergencies, GIS supports the efficient deployment of relief materials, medical aid, and rescue personnel based on spatial need assessments.

- *Long-Term Strategic Role*

Beyond immediate response, GIS-based flood mapping tools are instrumental in long-term flood risk reduction strategies. Regularly updated flood hazard maps guide land-use planning, infrastructure development, and policy formulation. Moreover, integrating climate change projections with GIS can inform adaptive strategies for future flood resilience.

VIII. FLOOD DISASTER MITIGATION STRATEGIES

Policy Recommendations and Engineering Solutions Effective flood disaster mitigation requires a combination of engineering interventions, policy reforms, and community-based approaches. The following strategies address both structural and non-structural measures that can significantly reduce flood risk and enhance resilience.

- *Construction and Maintenance of Embankments and Levees*

Building and reinforcing embankments, levees, and floodwalls along rivers and vulnerable coastlines remain one of the most direct structural defenses against floodwaters. These barriers help contain river flows during peak discharge and prevent overflow into adjacent settlements and agricultural lands. Regular inspection and maintenance are essential to prevent breaches during extreme weather events.

- *Enhancement of Urban Drainage Systems and Flood Retention Basins*

Urban areas, with their high proportion of impervious surfaces, are particularly susceptible to waterlogging and flash floods. To address this, stormwater drainage systems must be upgraded to handle increased runoff volumes. Integrating flood retention basins, detention ponds, and pervious pavements can help temporarily store excess water and release it slowly, reducing peak flows and alleviating urban flood risks.

- *Afforestation and Watershed Management in Upstream Regions*

Vegetation cover in upstream catchments plays a critical role in regulating runoff and maintaining soil stability. Afforestation and reforestation initiatives can improve water infiltration, reduce surface runoff, and minimize sedimentation in rivers. Watershed management practices such as contour bunding, check dams, and controlled grazing also contribute to flood mitigation by enhancing natural water retention capacity in upland areas.

- *Relocation of High-Risk Settlements and Development of Flood-Resilient Infrastructure*

In cases where settlements are repeatedly affected by flooding, planned relocation to safer zones may be necessary. This must be supported by policies that ensure equitable compensation and social integration. Additionally, all new infrastructure in flood-prone regions should be designed with flood resilience in mind — including elevated structures, flood-proof materials, and decentralized energy and water systems that remain operational during disasters.

- *Implementation of Community-Based Disaster Risk Reduction (CBDRR) Programs*

Community engagement is vital for sustainable disaster risk reduction. CBDRR approaches empower local populations to participate in risk assessment, preparedness planning, and response efforts. Activities such as local hazard mapping, evacuation drills, early warning dissemination, and the formation of community response teams strengthen collective resilience and ensure that interventions are culturally and contextually appropriate.

- *Integration of Real-Time Flood Forecasting and GIS-Based Early Warning Systems*

Modern flood mitigation is increasingly reliant on technology. The integration of real-time hydrological data, weather forecasts, and remote sensing inputs into GIS platforms enables the creation of dynamic flood forecasting models. These systems can predict flood events with improved accuracy and provide timely alerts to vulnerable communities, allowing for proactive evacuation and resource mobilization.

IX. CONCLUSION

The study demonstrates the transformative role of Remote Sensing and GIS technologies in flood risk assessment, mapping, and disaster mitigation, particularly in vulnerable regions like Tufanganj, Cooch Behar District, West Bengal. By integrating satellite imagery, Digital Elevation Models (DEM), hydrological data, and socio-economic parameters, the research successfully delineated flood-prone zones and identified critical risk hotspots.

Key findings show that low-lying areas with poor natural drainage and proximity to rivers are consistently the most affected. Land use changes, especially increased urbanization and deforestation, have intensified flood vulnerability over time. GIS-based flood risk maps clearly illustrate the spatial correlation between human settlements, infrastructure, and high-risk flood zones, providing a practical tool for emergency planning and resource allocation.

Furthermore, the study outlines a comprehensive set of flood disaster mitigation strategies, combining structural measures—such as embankments, drainage improvements, and flood retention systems—with non-structural approaches including afforestation, community-based disaster risk reduction (CBDRR), and GIS-enabled early warning systems. These strategies are essential not only for reducing immediate flood impacts but also for guiding sustainable development and long-term resilience planning.

In conclusion, the integration of Remote Sensing and GIS serves as a scientific and strategic foundation for informed decision-making in flood-prone areas. It enables proactive intervention, enhances situational awareness, and supports both short-term emergency response and long-term policy formulation. For regions like Tufanganj, such data-driven, spatially explicit methodologies are indispensable for building adaptive and resilient communities in the face of escalating climate-related hazards.

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