© April 2026 | IJIRT | Volume 12 Issue 11 | ISSN: 2349-6002

Flood Hazard and Risk Mapping Using GIS and Remote Sensing Techniques in the Downstream Krishna River Region, India

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***Abstract*—Flooding is a major natural hazard in India, causing significant damage to life, infrastructure, and agriculture. The downstream region of the Krishna River near Vijayawada is particularly prone to flooding during intense monsoon rainfall. This study aims to delineate flood-prone zones using Remote Sensing (RS), Geographic Information System (GIS), and the Analytical Hierarchy Process (AHP). Flood-influencing parameters were categorized into geomorphic (elevation, slope, soil type, drainage density, distance from river), hydrologic (rainfall, flow accumulation, topographic wetness index), and socio-economic (land use/land cover and population density) factors. All parameters were converted into thematic layers, reclassified, and assigned weights using AHP. A weighted overlay analysis was performed to generate flood hazard and vulnerability maps, which were integrated using raster calculator in ArcGIS 10.7 to produce the final flood risk map. The results indicate that 35.36% (366 km²) of the area falls under low risk, 42.22% (437 km²) under moderate risk, and 22.46% (232 km²) under high risk. High-risk zones are dominated by agricultural (22.5%) and urban areas (13.4%). The results provide a scientific basis for flood management and planning.**

***Index Terms*—Flood Risk Mapping, RS and GIS, Analytical Hierarchy Process, LULC, Krishna River Basin, Vijayawada.**

I. INTRODUCTION

Flooding is one of the most frequent and destructive natural hazards, causing widespread damage to human life, infrastructure, agriculture, and ecosystems (Büchele et al., 2006). In India, flood occurrences are largely driven by intense monsoonal rainfall, river overflow, and increasing anthropogenic interventions in natural drainage systems (Freni et al., 2016). Low-lying downstream regions of major rivers are particularly susceptible due to their geomorphic setting and high runoff accumulation potential (Debnath et al., 2017). The downstream stretch of the Krishna River near Vijayawada frequently experiences flooding during peak monsoon periods, leading to significant socio-economic disruptions (Lahon et al., 2023). Rapid urbanization and changes in land use/land cover (LULC) have further intensified flood vulnerability in such regions by altering natural infiltration and drainage characteristics (Haagos et al., 2022).

The application of Remote Sensing (RS) and Geographic Information System (GIS) has significantly enhanced flood hazard assessment by enabling the integration of spatial datasets and environmental variables (Clark, 1987). These geospatial techniques facilitate the analysis of terrain, hydrology, and land use patterns, which are essential for understanding flood behavior and extent (Ahmed et al., 2018). Multi-criteria decision-making approaches, particularly the Analytical Hierarchy Process (AHP), have been widely adopted to assign relative weights to flood-influencing parameters and to improve the reliability of flood zonation maps (Ghosh and Kar, 2018). The integration of RS, GIS, and AHP allows systematic evaluation of multiple factors such as elevation, slope, drainage density, rainfall, and LULC in a unified framework (Choubin et al., 2019). This approach has been successfully applied in various regions to delineate flood-prone zones and support disaster management planning (K.S. Vignesh et al., 2021).

Flood risk is governed by the combined influence of geomorphic, hydrologic, and socio-economic factors, which together determine hazard intensity and vulnerability levels (Debnath et al., 2017). Geomorphic parameters such as elevation, slope, soil characteristics, and proximity to river channels control runoff generation and water accumulation patterns (Ahmed et al., 2018). Hydrological factors including rainfall intensity, flow accumulation, and topographic wetness index (TWI) play a critical role in flood formation and propagation (Freni et al., 2016). In addition, socio-economic variables such as population density and LULC significantly influence exposure and potential damage during flood events (Haagos et al., 2022). Therefore, integrating these parameters within a GIS-based multi-criteria framework provides a comprehensive assessment of flood hazard and risk, which is essential for effective planning and mitigation strategies (Lahon et al., 2023).

II. STUDY AREA

The study area is situated in the downstream reach of the Krishna River near Vijayawada, within the state of Andhra Pradesh, forming a critical segment of the lower Krishna River basin (Central Water Commission, 2019). Geographically, the area extends approximately between latitudes 16°15′N to 16°45′N and longitudes 80°30′E to 81°00′E, covering a total extent of about 1035 km² (Survey of India, 2020). This region occupies a strategic position in the southeastern part of India and is characterized by low-lying alluvial plains that are highly susceptible to seasonal flooding (NRSC, 2018). The Krishna (Fig 1) River traverses this region before ultimately discharging into the Bay of Bengal, influencing the hydrological regime and sediment dynamics of the downstream floodplains (CGWB, 2017). The flow characteristics in this stretch are significantly regulated by major hydraulic infrastructures such as the Prakasam Barrage, which plays a vital role in irrigation management, water storage, and flood control (Irrigation Department Andhra Pradesh, 2021). The presence of such structures, along with extensive canal networks, modifies the natural flow pattern and contributes to both flood mitigation and localized flood risk under extreme rainfall conditions (Central Water Commission, 2019).

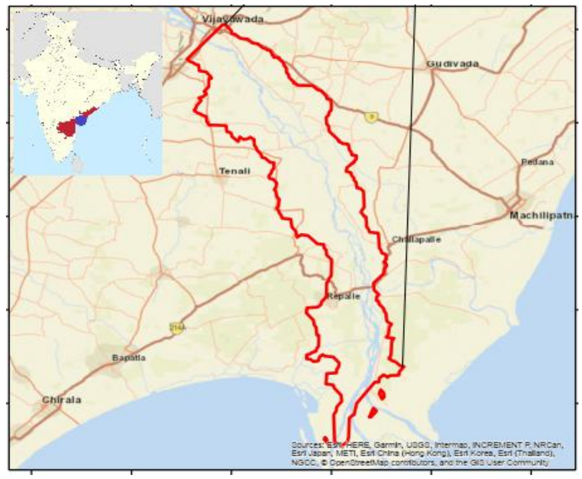


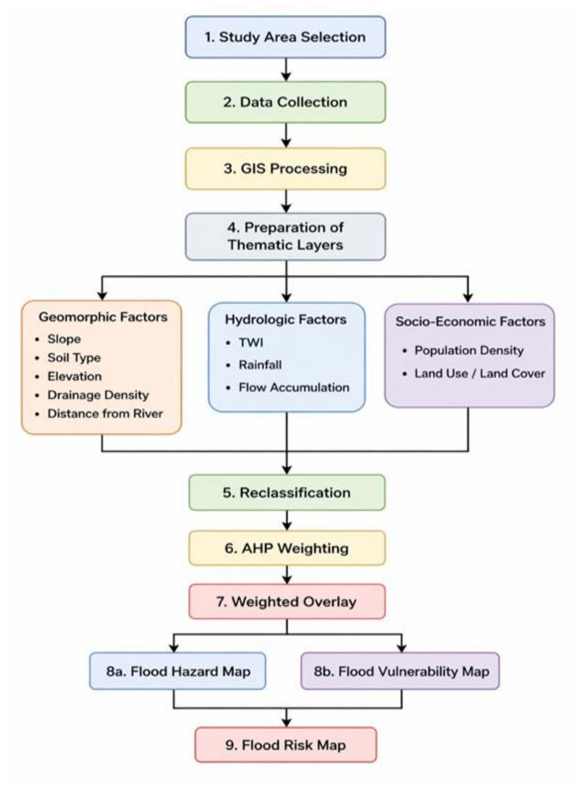
Fig.1 Study area

III. METHODOLOGY

The present study adopts an integrated (Fig 2) approach combining Remote Sensing (RS), Geographic Information System (GIS), and the Analytical Hierarchy Process (AHP) to assess flood hazard and risk in the downstream region of the Krishna River near Vijayawada. The overall workflow begins with the identification of the study area, followed by systematic data collection, processing, and analysis to derive flood hazard and risk zones (Ghosh and Kar, 2018).

Initially, relevant datasets such as Digital Elevation Model (DEM), rainfall records, soil maps, land use/land cover (LULC), and population data were collected from standard sources. These datasets were preprocessed in a GIS environment, which included projection correction, clipping to the study boundary, and ensuring uniform spatial resolution for accurate analysis (Clark, 1987). Based on these inputs, thematic layers representing flood-influencing parameters were generated and grouped into geomorphic, hydrologic, and socio-economic categories (Ahmed et al., 2018).

Fig 2. GIS–AHP Methodology for Flood Risk Assessment



Geomorphic factors such as elevation, slope, soil type, drainage density, and distance from the river were considered to understand terrain control over runoff and water accumulation (Debnath et al., 2017). Hydrologic factors including rainfall, flow accumulation, and Topographic Wetness Index (TWI) were used to represent water movement and flood generation processes (Freni et al., 2016). In addition, socio-economic factors such as LULC and population density were incorporated to capture the extent of human exposure and vulnerability (Haagos et al., 2022). Each thematic layer was reclassified into suitable classes based on its influence on flooding, allowing consistent comparison across all parameters (Choubin et al., 2019).

The relative importance of each parameter was then determined using the AHP technique through pairwise comparison, ensuring a logical and consistent weighting scheme (Ghosh and Kar, 2018; Lahon et al., 2023). These weighted layers were integrated using a weighted overlay analysis to produce the Flood Hazard Map and Flood Vulnerability Map (K.S. Vignesh et al., 2021). Finally, both maps were combined using raster calculator tools in GIS to generate the Flood Risk Map, which represents the spatial distribution of flood risk by considering both hazard intensity and vulnerability (Büchele et al., 2006).

IV. RESULTS

The preparation of thematic maps is a fundamental step in flood risk assessment, as it represents the spatial variation of factors influencing flood occurrence. In the present study, thematic layers were categorized into flood hazard and flood vulnerability components. Further, flood hazard factors were subdivided into geomorphic and hydrological factors.

V. FLOOD HAZARD FACTORS

Flood hazard factors represent the natural characteristics of the study area that contribute to flood occurrence. These were classified into geomorphic and hydrological factors.

A. Geomorphic Factors

Geomorphic factors describe terrain characteristics that influence runoff and water accumulation.

Slope

Slope significantly influences the movement and accumulation of surface runoff. Areas with gentle slopes tend to retain water for longer durations, increasing flood susceptibility, whereas steep slopes allow rapid runoff and reduce the possibility of flooding. In the present study, the slope map was derived from the Digital Elevation Model using spatial analysis tools in GIS. The slope values in the study area range from 0° to 33°. The map is illustrated in Fig. 3 A.

Elevation

Elevation is an important factor influencing flood occurrence as water naturally flows from higher to lower elevations and tends to accumulate in low-lying areas. In the present study area along the downstream region of the Krishna River near Vijayawada, elevation ranges from 0 m to about 81 m above mean sea level. Lower elevation zones are mainly distributed along the river floodplain, which makes them more susceptible to flooding, whereas comparatively higher elevations occur toward the northern part of the study area. The map is illustrated in Fig. 3 B

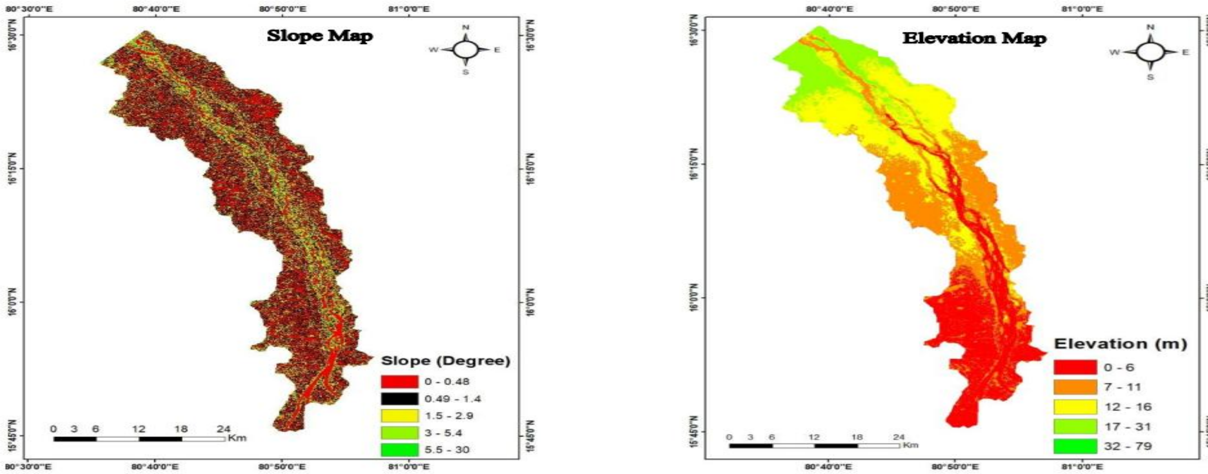


Fig 3 A) Slope map B) Elevation map

❖ Distance from River: Distance from river is a significant factor influencing flood susceptibility, as areas located closer to the river channel are more prone to flooding during periods of high discharge. In the present study area along the downstream region of the Krishna River near Vijayawada, the distance from river ranges from 0 to 12 km. The map is illustrated in Fig. 4 A.

❖ Drainage Density

Drainage density represents the total length of streams per unit area and plays an important role in controlling surface runoff and flood potential. Areas with higher drainage density generally facilitate rapid runoff concentration, which may increase the likelihood of flooding. In the present study area along the downstream region of the Krishna River near Vijayawada, the drainage density ranges from 0 to 1.46 km/km². The map is illustrated in Fig. 4 B.

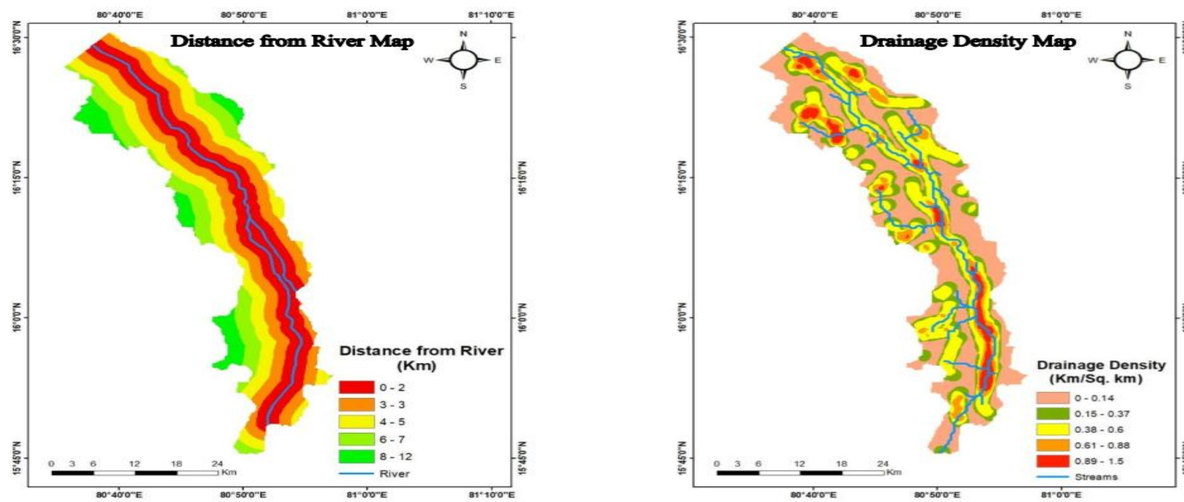


Fig 4 A) Distance from River map B) Drainage Density map

Flood Hazard Map

The flood hazard map was prepared by integrating two major categories of factors, namely geomorphic factors and hydrologic factors, which significantly influence flood occurrence. The Analytical Hierarchy Process (AHP) was used to assign weights to each factor based on their relative importance. These factors were combined using a weighted overlay analysis in a GIS environment to generate the flood hazard map. The resulting flood hazard map was classified into three categories: Low, Medium, and High hazard zones. The map is illustrated in Fig 5.

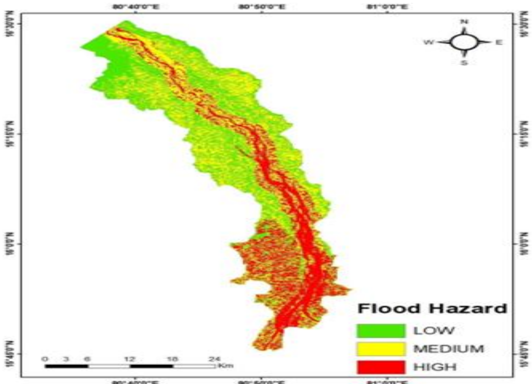


Fig 5 Flood Hazard Map of the Study Area

VI. CONCLUSION

The present study aimed to assess flood hazard, vulnerability, and risk in the study area using Remote Sensing (RS), Geographic Information System (GIS), and the Analytical Hierarchy Process (AHP). Various geomorphic, hydrologic, and socio-economic factors were integrated to prepare flood hazard, vulnerability, and risk maps.

The results of the study indicate that flood risk is unevenly distributed across the study area. The flood hazard analysis revealed that approximately 28% of the area falls under high hazard zones, mainly located in low-lying regions and near river channels. Similarly, the flood vulnerability assessment showed that about 17% of the area is highly vulnerable due to factors such as population density and land use patterns.

The flood risk map, which combines both hazard and vulnerability, indicates that around 22% of the total study area (232 sq.km) falls under high flood risk. These areas are predominantly concentrated along riverbanks and downstream regions, making them highly susceptible to flooding.

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