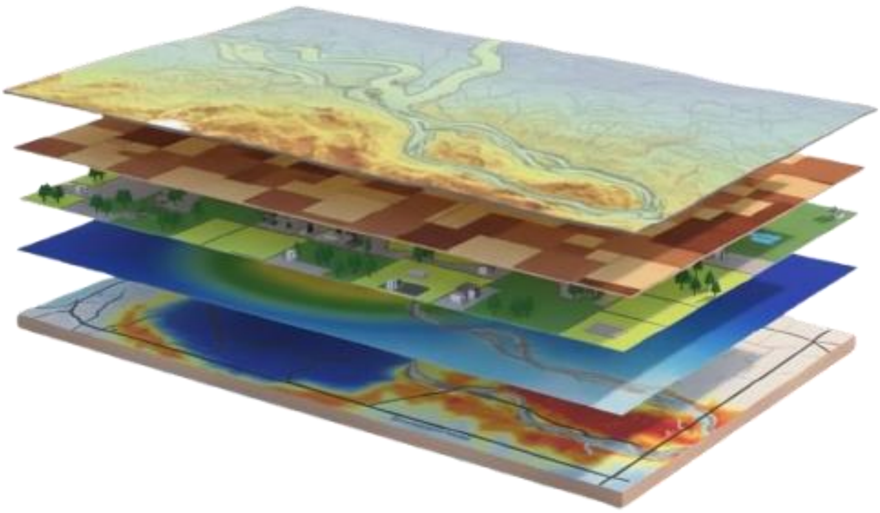
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Flood Hazard Model in Krishna River Basin



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National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

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Centres for Krishna River Basin Management Studies (cKrishna)

The Centres for Krishna River Basin Management Studies (cKrishna) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by NIT Warangal and NIT Surathkal, under the supervision of cGanga at IIT Kanpur, the center serves as a knowledge wing of the National River Conservation Directorate (NRCD). cKrishna is committed to restoring and conserving the Krishna River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

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Centre for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

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Acknowledgment

This report is a comprehensive outcome of the project jointly executed by NIT Warangal (Lead Institute) and NIT Surathkal (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

Disclaimer

This report is a preliminary version prepared as part of the ongoing Condition Assessment and Management Plan (CAMP) project. The analyses, interpretations and data presented in the report are subject to further validation and revision. Certain datasets or assessments may contain provisional or incomplete information, which will be updated and refined in the final version of the report after comprehensive review and verification.

Team

N V Umamahesh, cKrishna, NITW
M Chandrasekhar, cKrishna, NITW
K Venkata Reddy, cKrishna, NITW
Jew Das, cKrishna, NITW
Kamalini Devi, cKrishna, NITW
V Vamsi Krishna, cKrishna, NITW
Litan Kumar Ray, cKrishna, NITW
G Gowtham, cKrishna, NITW
Prasanta Majee, cKrishna, NITW
Eswar Sai Buri, cKrishna, NITW
Kandula Srikanth, cKrishna, NITW
B. Manu, cKrishna, NITK
S Shrihari, cKrishna, NITK
Dwarakish G S, cKrishna, NITK
Lakshman Nandagiri, cKrishna, NITK
Chandan Pradhan, cKrishna, NITK
Varija K, cKrishna, NITK
Vinod Tare, cGanga, IITK
Priyanka, cKrishna, NITK
Nishanth B, cKrishna, NITK
Karunasindhu, cKrishna, NITK
Vinod Tare, cGanga, IIT Kanpur

Preface

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policymaker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. It is our hope that this report will serve as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

Prof. N V Umamahesh
Centres for Krishna River Basin
Management and Studies (cKrishna)
NIT Warangal (Lead Institute), NIT Surathkal (Fellow Institute)

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Abbreviations

Abbreviation	Full Form
DEM	Digital Elevation Model
FHI	Flood Hazard Index
GIS	Geographic Information System
IMD	India Meteorological Department
KRB	Krishna River Basin
LULC	Land Use / Land Cover
MCE	Multi-Criteria Evaluation
NRSC	National Remote Sensing Centre
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SRTM	Shuttle Radar Topography Mission
SWAT	Soil and Water Assessment Tool
UTM	Universal Transverse Mercator
WGS 84	World Geodetic System 1984

1. Introduction

Floods are among the most frequent and destructive natural hazards affecting river basins across India, causing extensive damage to infrastructure, agriculture, livelihoods, and human life. In recent decades, the frequency and intensity of flood events have increased due to climatic variability, rapid urbanization, land-use changes, and altered river flow regimes, particularly in large river basins (Schumm, 1977; Jain et al., 2012). The Krishna River Basin (KRB), one of the major river basins of peninsular India, is especially vulnerable to flooding owing to its complex physiography, monsoon-dominated climate, dense drainage network, and extensive human interventions along river corridors.

Flood hazard assessment and mapping play a critical role in disaster risk reduction and integrated water resources management. Flood hazard maps provide spatially explicit information on areas prone to inundation, supporting land-use regulation, floodplain zoning, infrastructure planning, and emergency preparedness (Leopold et al., 1964; Brierley and Fryirs, 2005). Advances in geospatial technologies, remote sensing, and Geographic Information Systems (GIS) have significantly enhanced the ability to integrate multiple factors influencing flooding, such as topography, rainfall, soil characteristics, land use, and proximity to river networks, into scientifically robust flood hazard models (Farr et al., 2007).

The Krishna River Basin exhibits marked physiographic diversity, ranging from the steep, high-relief Western Ghats in the west to the gently sloping alluvial and deltaic plains in the eastern region. This variability strongly influences runoff generation, flow accumulation, drainage density, and flood propagation processes across the basin. The basin receives most of its annual rainfall during the Southwest Monsoon, often leading to sudden increases in river discharge and flooding along major tributaries such as the Bhima, Tungabhadra, Musi, and Munneru (IMD, 2020). In addition, reservoir operations, floodplain encroachments, road infrastructure, soil permeability, and land-use transformations further modify the basin's natural hydrological response, increasing flood susceptibility in several regions.

In this context, the present study aims to develop a basin-scale Flood Hazard Model for the Krishna River Basin using a GIS-based multi-criteria weighted overlay approach. By integrating elevation, slope, rainfall, soil, land use/land cover, distance to rivers, and distance to roads, the study provides a comprehensive spatial assessment of flood hazard zones. The resulting flood hazard map serves as a valuable decision-support tool for policymakers, water managers, planners, and disaster management authorities to prioritize vulnerable areas, enhance flood mitigation strategies, and strengthen climate resilience within the Krishna River Basin.

2. Data Used

The Flood Hazard Model for the Krishna River Basin was developed using multiple spatial datasets representing topography, rainfall, land characteristics, soil information, and anthropogenic features. All datasets were processed in a GIS environment using ArcMap, ensuring consistent spatial extent, projection (WGS 84 / UTM Zone 44N or 43N), and uniform resolution. The following datasets were used in the study:

2.1 Digital Elevation Model (DEM)

- Source: Shuttle Radar Topography Mission (SRTM)
- Resolution: 30 m
- Purpose: Extraction of Elevation, Derivation of Slope, Hydrological pre-processing (drainage network, flow direction, flow accumulation). DEM played a crucial role in identifying low-lying flood-prone zones and understanding terrain influences on runoff.

2.2 Soil Data

- Source: SWAT India Dataset (https://swat.tamu.edu/data/india-dataset)
- Attributes Used: Soil texture (Clay, Clay Loam, Loam, Sandy Clay Loam, Sandy Loam)
- Purpose: Assessment of infiltration capacity, Identification of poorly drained soils, Classification of soil types based on runoff potential. The SWAT soil dataset provided standardized soil information for basin-scale flood modelling.

2.3 Rainfall Data

- Source: India Meteorological Department (IMD) Data
- Type: Long-term average annual rainfall (gridded dataset)
- Purpose: Identification of high rainfall zones, Understanding spatial rainfall variability across the Krishna Basin, Assessing rainfall-induced runoff potential. IMD data ensured reliable and climatologically representative rainfall values.

2.4 Land Use/Land Cover (LULC)

- Source: National Remote Sensing Centre (NRSC), Bhuvan
- Scale: 1:250,000 (250k LULC)
- Major Classes Used: Agriculture, Built-up, Forest, Grassland, Barren land, Water bodies

- Purpose: Evaluation of surface runoff potential, Identification of impervious and sensitive land cover zones. LULC was essential in understanding human influence and natural vegetation effects on flooding.

2.5 Distance to Roads

- Source: DivaGIS / GIS road layer
- Purpose: Assessment of drainage obstruction and local flood accumulation, Identification of roads acting as barriers or conduits for runoff, Roads were buffered and classified into distance-based susceptibility zones.

2.6 Distance to Rivers

- Source: DivaGIS river network / extracted from DEM
- Purpose: Proximity analysis of areas close to major rivers and tributaries, Identification of floodplain regions with higher inundation risk, Areas closer to rivers were assigned higher susceptibility values.

3. Methodology

The methodology for generating the Flood Hazard Map of the Krishna River Basin involves preparing thematic layers, standardizing datasets to a uniform spatial resolution, classifying flood-related parameters, and integrating them using a weighted-sum overlay approach in ArcMap. The step-by-step procedure is explained below.

3.1 Data Preparation and Standardization

All spatial datasets used in the study, including DEM, soil, rainfall, LULC, distance to rivers, and distance to roads, were pre-processed in ArcMap to ensure:

Uniform spatial resolution: All datasets were resampled to 30 × 30 m resolution using bilinear or nearest-neighbour resampling.

Common coordinate system: All layers were projected to WGS 84 UTM Zone 44N, ensuring spatial consistency.

Clipping to Basin Boundary: Using the Krishna River Basin boundary shapefile, all input rasters and vectors were clipped to maintain uniform extent.

This ensured that each parameter contributes equally within the same spatial framework in the weighted overlay process.

3.2 Preparation of Thematic Layers

Seven flood-influencing parameters were selected based on hydrological relevance and data availability. The layers prepared include: Slope (derived from SRTM DEM), Elevation (derived from SRTM DEM), Soil (SWAT India soil dataset), Rainfall (IMD long-term annual rainfall), Land Use/Land Cover (NRSC LULC 250k), Distance to Rivers (DivaGIS river network) and Distance to Roads (DivaGIS road network). Each layer was generated as a raster and further reclassified into susceptibility classes.

3.3 Classification of Thematic Layers

Each thematic raster was classified into five flood susceptibility classes according to the nature and influence of the parameter: Very High Susceptibility, High Susceptibility, Moderate Susceptibility, Low Susceptibility and Very Low Susceptibility. Reclassification was done using Natural Breaks, Quantile, threshold-based classification, or hydrological criteria, depending on the dataset. This standardization allowed comparison of different parameters within the same scale.

3.4 Assignment of Weights

Each parameter was assigned a weight based on its relative contribution to flood generation, following expert judgment and literature support.

Parameter	Weight (%)
Elevation	15%
Soil	10%
LULC	10%
Rainfall	25%
Slope	5%
Distance to Rivers	25%
Distance to Roads	10%

These weights reflect the dominance of rainfall and distance to rivers in determining flood hazard levels across the Krishna Basin.

3.5 Weighted Sum Overlay to Generate Flood Hazard Index

All seven classified layers were integrated using ArcMap's Weighted Sum tool. The Flood Hazard Index (FHI) was computed using:

$$FHI = \sum (W_i \times S_i)$$

Where,

W_i = Weight of the i^{th} parameter,

S_i = Susceptibility score (1-5) assigned during reclassification.

The weighted sum approach combines the relative influence of each flood-related factor to produce a cumulative hazard score for every 30 m pixel in the basin.

3.6 Classification of Final Flood Hazard Map

The final Flood Hazard Index raster was reclassified into five flood hazard zones: Very High Flood Hazard, High Flood Hazard, Moderate Flood Hazard, Low Flood Hazard, Very Low Flood Hazard. This final map represents the spatial distribution of flood susceptibility across the Krishna River Basin and highlights critical zones requiring flood management and mitigation strategies.

4. Result

4.1 Elevation

The Figure 4.1 illustrates the spatial distribution of elevation-derived flood susceptibility across the Krishna River Basin. Lower elevation areas (0-20 m and 20-100 m), marked in dark purple and yellow, represent Very High and High Susceptibility zones, respectively. These low-lying regions are vulnerable due to flat terrain and proximity to river plains. The mid-elevation range (100-300 m), shown in light blue, is classified as Moderate Susceptibility. The majority of the basin falls under Low Susceptibility (300-600 m), represented in red, indicating elevated plateaus and uplands. The highest elevation class (>600 m), shown in green, corresponds to Very Low Susceptibility, representing the Western Ghats and upland regions.

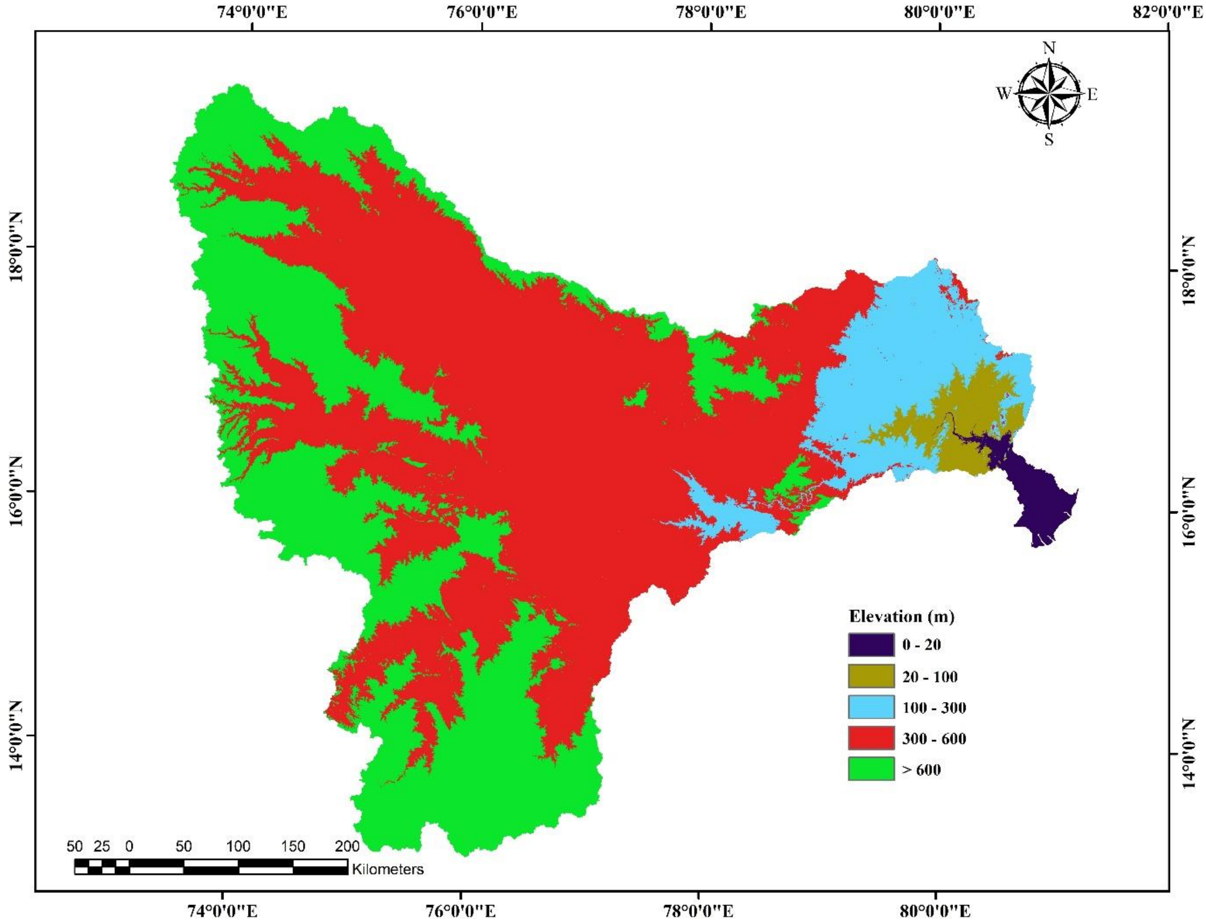

Figure 4. 1 Spatial distribution of soil textures and their associated flood susceptibility across Krishna River Basin

4.2 Slope

The slope map illustrates the spatial distribution of terrain steepness across the Krishna River Basin, classified into five slope categories (0-2°, 2-5°, 5-15°, 15-30°, and >30°). Gentle slopes (0-2°), shown in green, dominate the central and eastern parts of the basin and represent areas of Very High Susceptibility due to slow runoff and high potential for water accumulation. Moderately gentle slopes (2-5°), represented in purple, indicate High Susceptibility and are widely distributed throughout the basin. The moderately steep slopes (5-15°), shown in red, reflect Moderate Susceptibility regions. Steeper slopes (15-30°), marked in light blue, and very steep slopes (>30°), shown in brown, correspond to Low and Very Low Susceptibility zones, primarily located along the basin boundaries and hill regions. The map includes a legend, coordinate grid, scale bar, and north arrow for spatial reference.

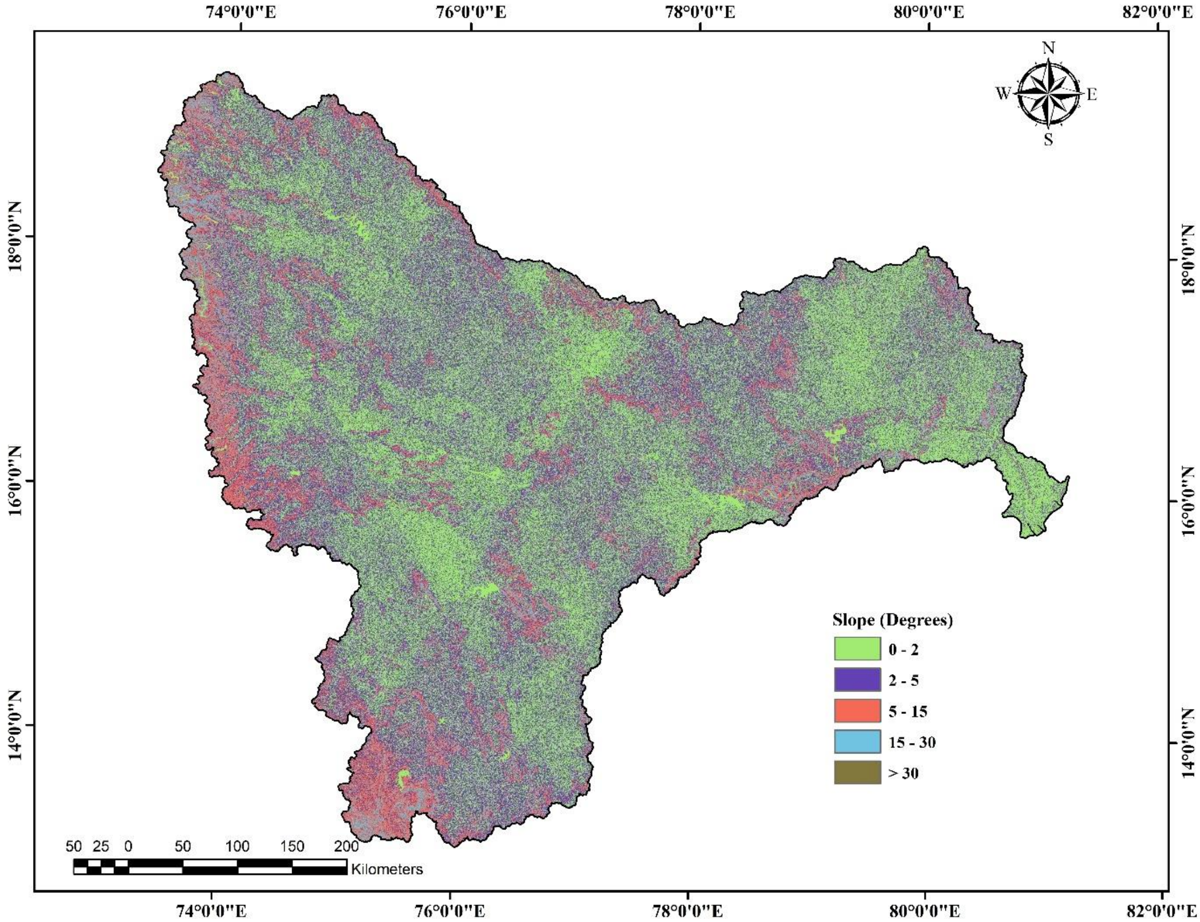

Figure 4. 2 Slope-Based Flood Susceptibility Classification of the Krishna River Basin across Krishna River Basin

4.3 Soil

The Figure 4.2 illustrates the spatial distribution of soil textures and their associated flood susceptibility across the basin. Clay soils (dark blue), representing Very High Susceptibility, dominate large areas in the central region due to their low permeability and high runoff potential. Clay loam soils (yellow), classified as High Susceptibility, cover extensive zones in the east and southeast. Loam (pink), sandy clay loam (red), and sandy loam (cyan) represent Moderate, Low, and Very Low Susceptibility, respectively, and are distributed in smaller patches. The map includes a legend, north arrow, coordinate grid, and scale bar for spatial interpretation.

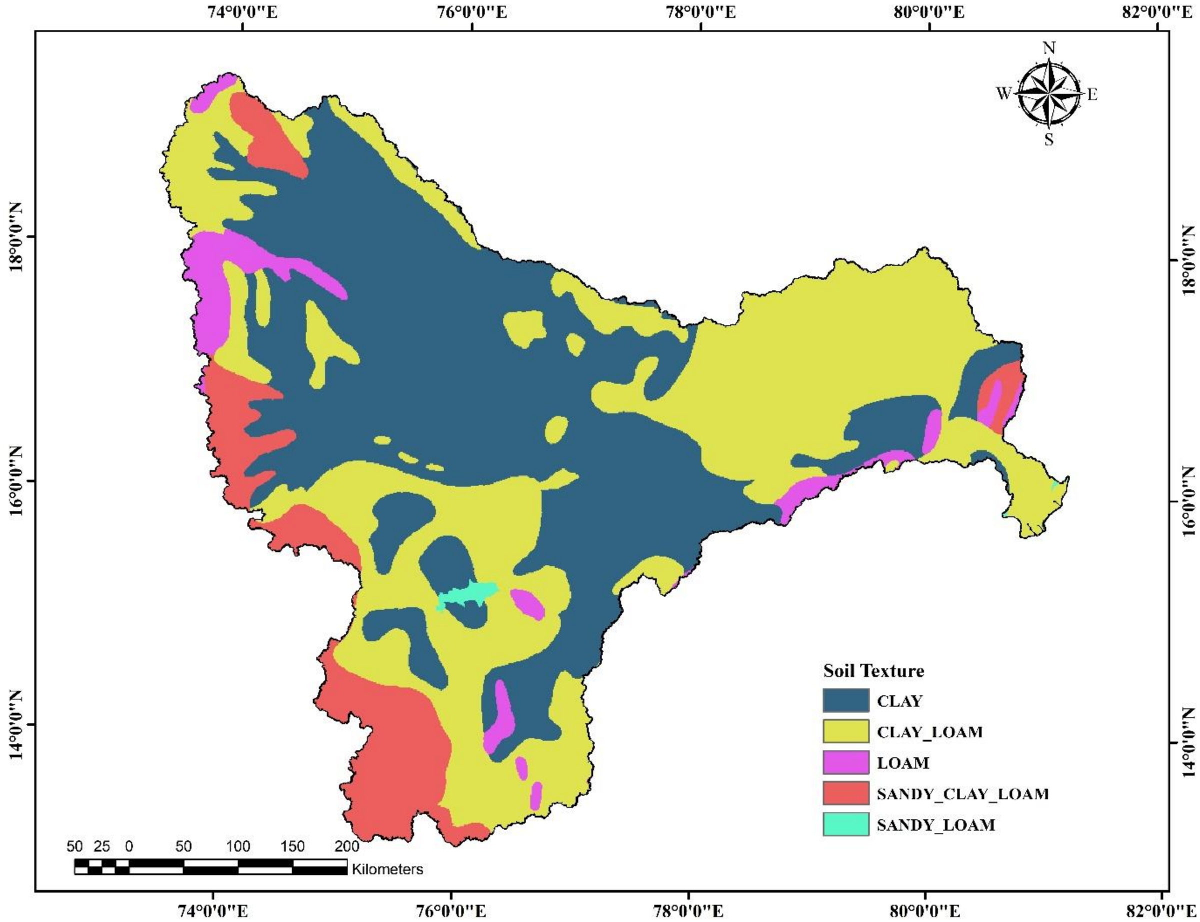

Figure 4. 3 Spatial distribution of soil textures and their associated flood susceptibility across Krishna River Basin

4.4 LULC

The LULC map (Figure 4.4) illustrates the spatial distribution of major land-use and land-cover categories across the Krishna River Basin. The basin is predominantly covered by Agricultural Land (yellow), which accounts for the largest portion of the area and indicates intensive cultivation across the central, eastern, and southern regions. Built-up Areas (red) appear as concentrated patches around major towns and urban centres, especially in the northern and eastern parts of the basin, representing zones of high imperviousness and increased flood susceptibility. Barren Land (dark brown) is scattered throughout the basin, mainly on hilly terrain and in degraded landscapes. Forest Areas (green) are primarily concentrated along the Western Ghats in the western and southwestern parts of the basin, providing natural flood regulation through higher infiltration and vegetative cover. Water Bodies (blue), including reservoirs, lakes, and river stretches, are distributed throughout the basin, prominently visible in the central and southeastern regions.

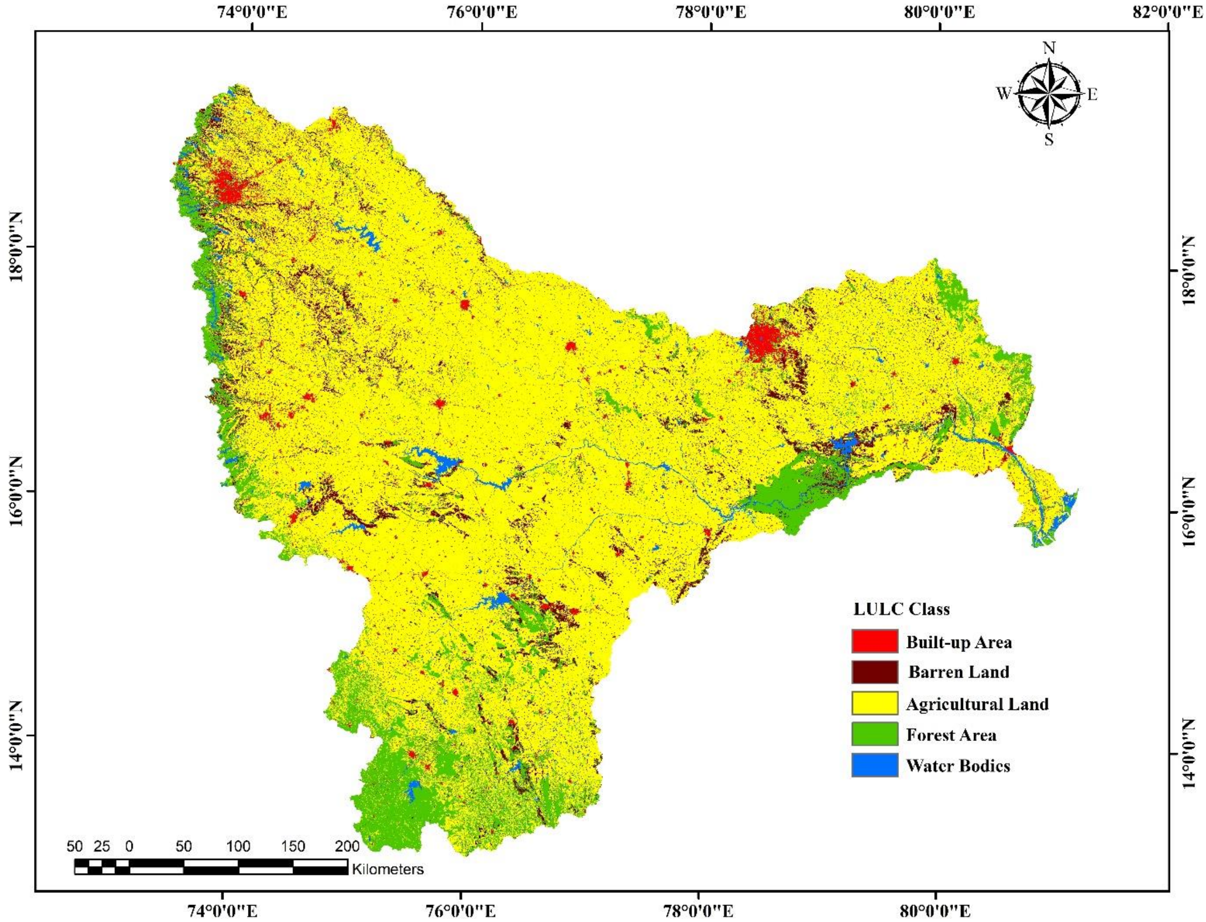

Figure 4. 4 Land Use/Land Cover (LULC) Classification of the Krishna River Basin

4.5 Rainfall

The rainfall map (Figure 4.5) illustrates the spatial variation of long-term average annual rainfall across the Krishna River Basin, classified into five rainfall zones. The highest rainfall areas (>2000 mm), shown in deep red, are concentrated in the extreme western part of the basin along the Western Ghats, where orographic lifting results in intense precipitation. Surrounding this core, the 1600-2000 mm zone (pink) forms a transitional belt, indicating regions receiving substantial seasonal rainfall. The 1300-1600 mm rainfall class (blue), though limited in extent, appears in scattered pockets across the basin and represents moderately high rainfall zones. The 800-1300 mm class (green) covers a large part of the central, eastern, and southern basin, representing regions with moderate rainfall influenced by monsoon variability. The 0-800 mm zone (light yellow) dominates the basin's interior and northeastern parts, indicating relatively dry regions with lower annual rainfall.

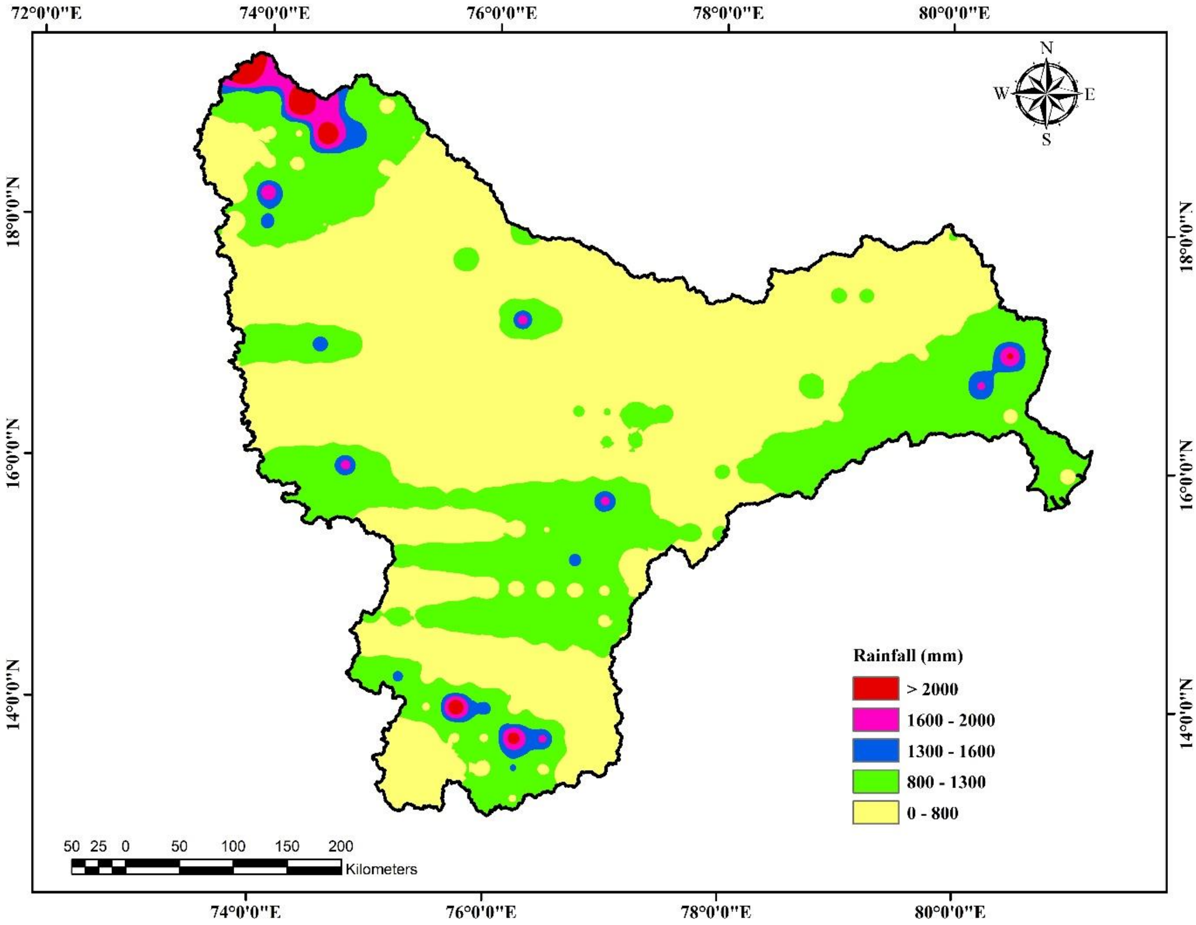

Figure 4. 5 Spatial Distribution of Average Annual Rainfall in the Krishna River Basin

4.6 Distance to River

The distance-to-river map (Figure 4.6) shows the spatial distribution of areas by their proximity to major rivers and tributaries within the Krishna River Basin. The map is classified into five distance ranges that reflect varying levels of flood susceptibility. The 0-100 m zone, shown in dark brown, represents areas immediately adjacent to river channels and denotes regions of Very High Flood Susceptibility due to direct exposure to river overflow. The 100-500 m buffer (green) indicates High Susceptibility, covering areas close to riverbanks where floodwater frequently spreads during high discharge events. Areas within 500-2000 m (light cyan) form a transitional belt representing Moderate Susceptibility, where occasional overbank flooding may occur depending on topography and rainfall intensity. The 2000-10000 m zone (blue) is classified as Low Susceptibility, lying farther from major river channels with reduced likelihood of inundation. Regions beyond 10,000 m (light brown) are considered Very Low Susceptibility, typically located in upland or interior basin regions with minimal direct flood influence from river systems.

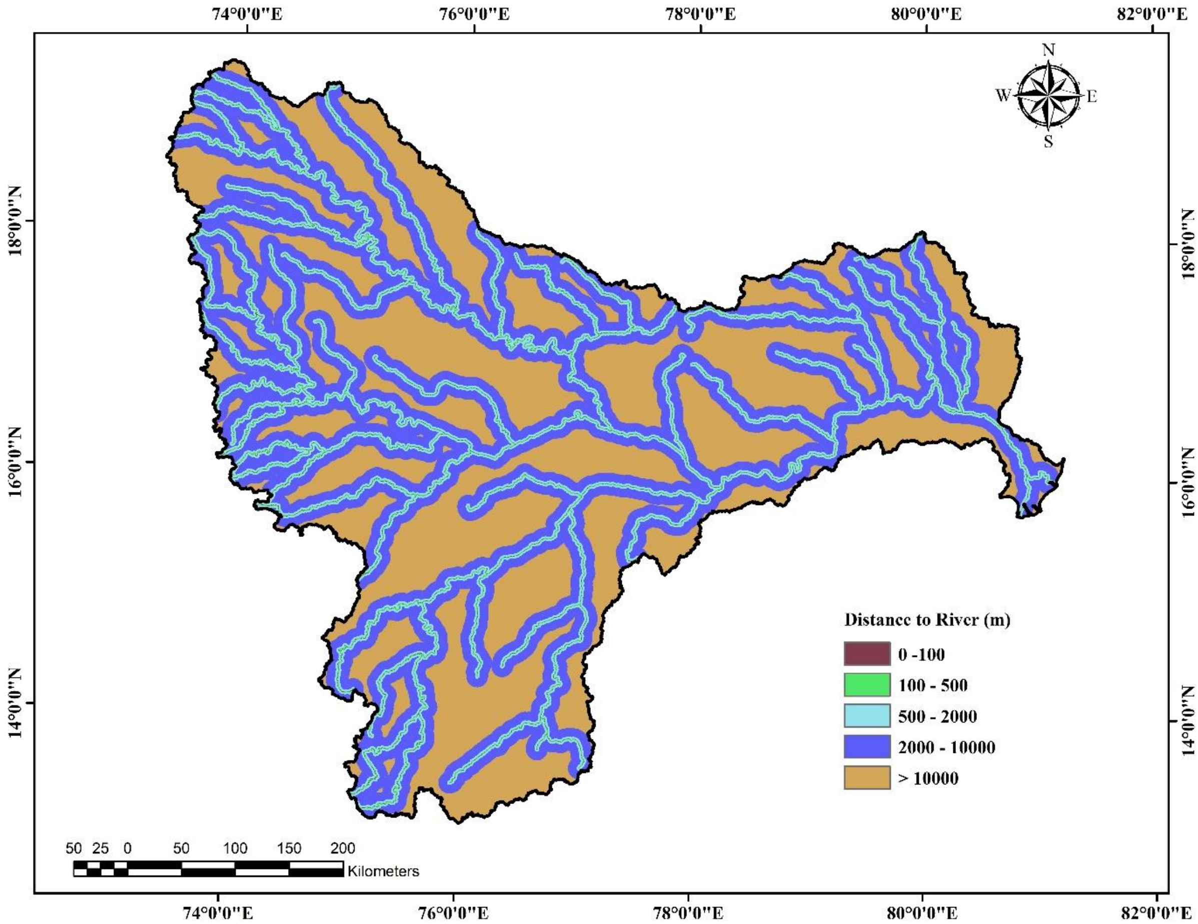

Figure 4. 6 Distance-to-River Classification Map of the Krishna River Basin

4.7 Distance to Road

The distance-to-road map (Figure 4.7) illustrates the spatial distribution of areas based on their proximity to the road network within the Krishna River Basin. The classification is divided into five distance zones that reflect the potential influence of roads on local hydrology and flood accumulation patterns. The 0-100 m buffer zone (dark brown) represents areas immediately adjacent to roads and corresponds to Very High Susceptibility, as road embankments often obstruct natural drainage and increase surface runoff accumulation. The 100-500 m zone (green) is classified as High Susceptibility, indicating areas still affected by altered flow patterns caused by nearby road infrastructure. The 500-2000 m distance class (blue) represents Moderate Susceptibility, where road influence exists but is less severe. The 2000-8000 m zone (light cyan) reflects Low Susceptibility, indicating areas largely unaffected by road-induced drainage disturbance. Regions located beyond 8000 m from roads (yellow) form the Very Low Susceptibility zone, as they remain distant from transportation corridors and experience minimal anthropogenic hydrological interference.

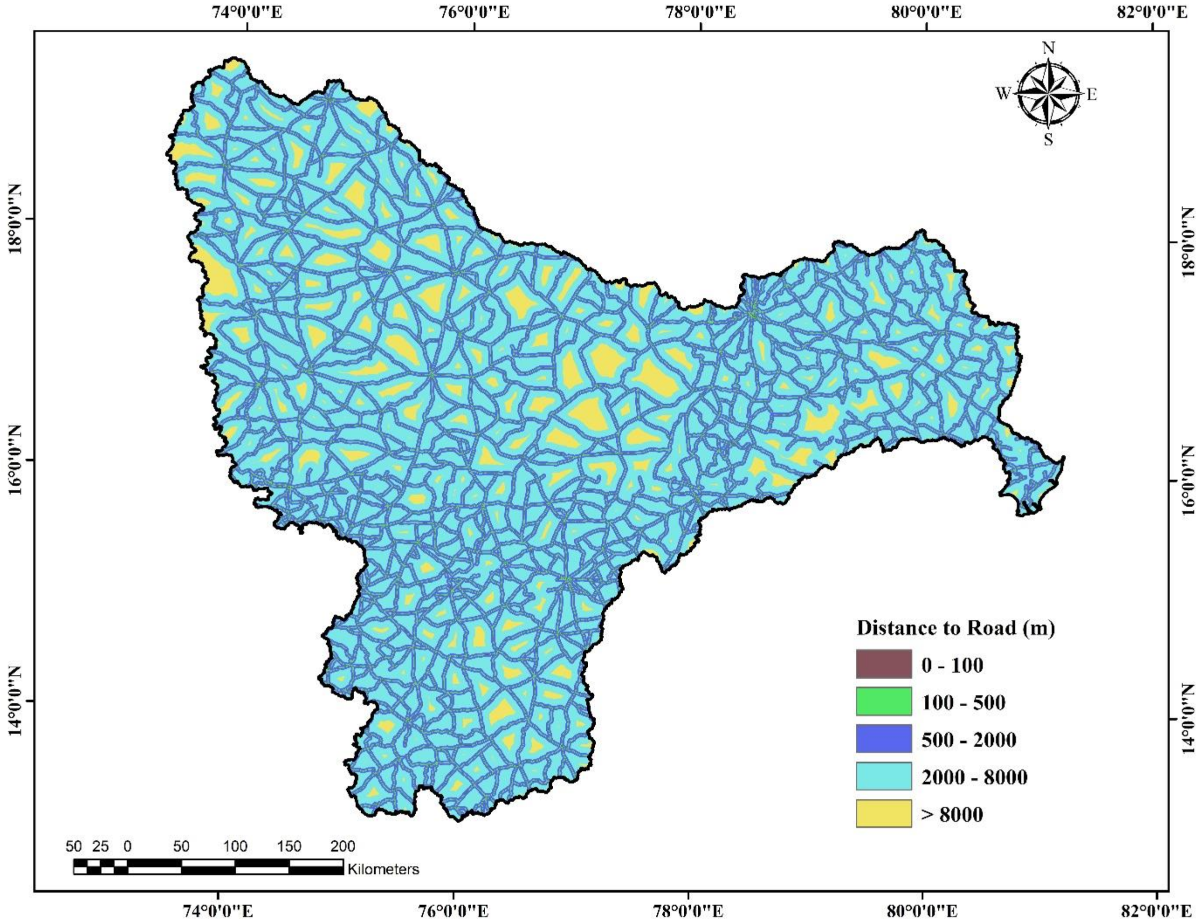

Figure 4. 7 Distance-to-Road Classification Map of the Krishna River Basin

4.8 Flood Hazard Map

The final Flood Hazard Map of the Krishna River Basin (Figure 4.8), generated through a GIS-based multi-criteria weighted overlay analysis using seven key parameters (slope, elevation, soil, rainfall, land use/land cover, distance to rivers, and distance to roads), clearly delineates the spatial distribution of flood susceptibility across the basin. The map classifies the region into five categories: Very High, High, Moderate, Low, and Very Low Flood Risk. Very high-risk zones, predominantly shown in red, are concentrated along major river corridors, low-lying floodplains, and the eastern deltaic portion of the basin, where flat terrain, low elevation, clayey soils, heavy rainfall, and close proximity to rivers make these areas extremely vulnerable to frequent inundation. Surrounding these are high-risk areas characterized by gently sloping terrain, agricultural land use, and moderate proximity to river channels. Moderate-risk zones, which form the largest portion of the basin, represent transitional landscapes with mixed soils, varied land cover, and intermediate rainfall conditions where localized flooding may occur during intense monsoon events. Low-risk regions occur mainly in upland areas with well-drained soils, higher slopes, and greater distance from rivers, resulting in reduced flood impact. The very low-risk zones are located in the high-elevation Western Ghats and southern uplands, where steep slopes, dense vegetation, and high elevations prevent flood accumulation. Overall, the map highlights the strong influence of physiography, hydrology, and land use on flood behaviour, providing essential spatial insights for flood risk management, mitigation planning, and climate-resilient development across the Krishna River Basin.

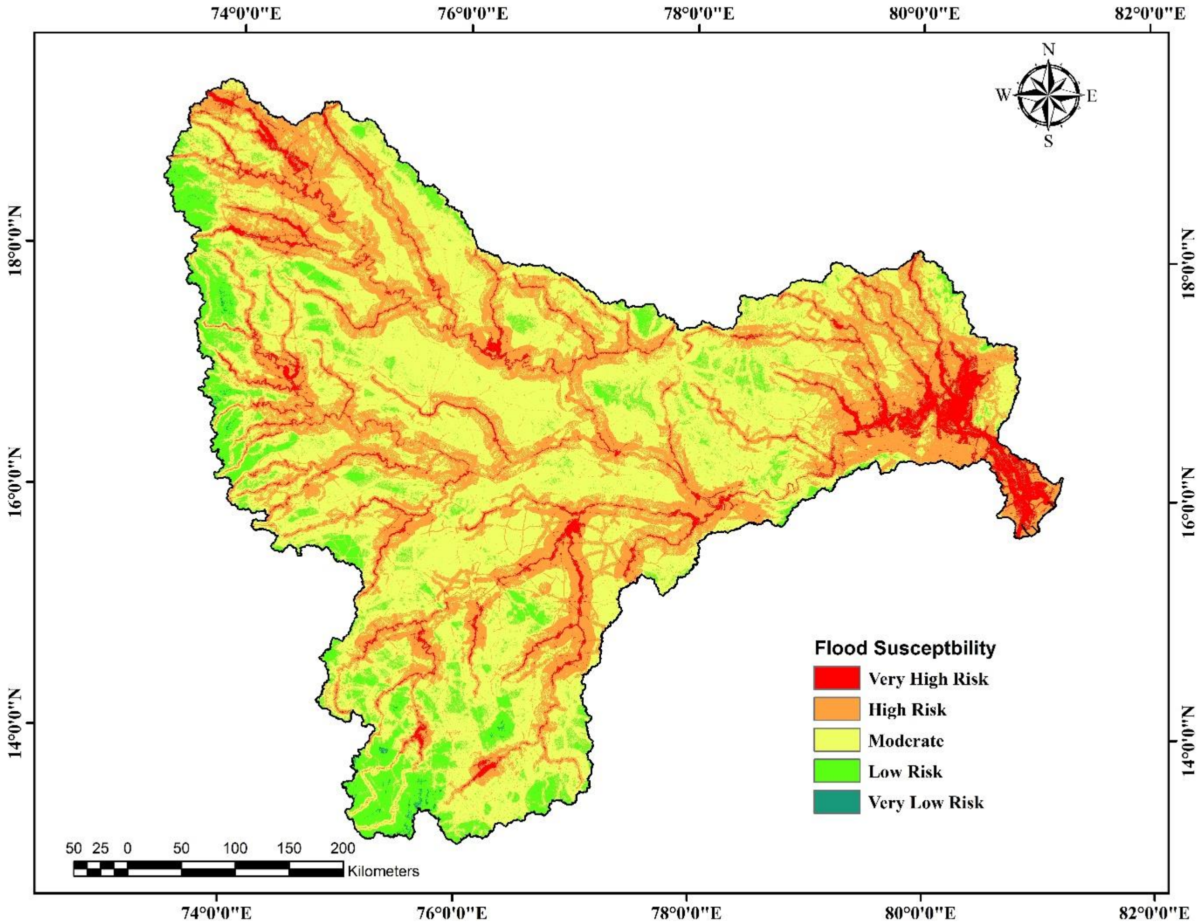

Figure 4. 8 Flood Hazard Map of the Krishna River Basin Derived Using Multi-Criteria Weighted Overlay Analysis

5. Conclusions

The Flood Hazard Assessment for the Krishna River Basin provides a comprehensive understanding of spatial flood susceptibility using a multi-criteria GIS-based approach that integrates topographic, hydrological, land use, soil, rainfall, and proximity parameters. The study effectively identifies zones ranging from very high to very low flood risk, highlighting how physiographic features, soil permeability, land cover patterns, and river proximity collectively shape flood behaviour across the basin. The results reveal that low-lying floodplains, deltaic regions, and areas near major rivers exhibit the highest flood susceptibility, while elevated terrain, forested regions, and the Western Ghats exhibit very low susceptibility. The weighted overlay method proved efficient at capturing the interactive influence of all seven input layers, producing a reliable flood hazard map that can support basin-level planning and disaster risk reduction strategies. This flood hazard assessment serves as an essential tool for water resource managers, urban planners, and policymakers in prioritizing vulnerable zones, planning resilient infrastructure, regulating land use in flood-sensitive areas, and strengthening early warning and mitigation measures. The study underscores the importance of integrating geospatial analysis with hydrological understanding to enhance climate resilience and sustainable flood management in the Krishna River Basin.

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