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Flood Hazard Mapping Using Arcgis in Thiruvalla Taluk

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Abstract – Flooding is a natural hazard that happens in areas with a lot of rain and low-lying land with a lot of rivers. This study offers a GIS-based flood hazard assessment for Thiruvalla Taluk, Kerala, designed to identify and delineate areas susceptible to flooding. We applied GIS-based Weighted Overlay and Multi-Criteria Decision Analysis(MCDA) to integrate rainfall, terrain, and land-use land cover, soil, geology, geomorphology, and distance to river. Here Weighted Overlay Analysis to make a Flood Hazard map by creating thematic layers, standardising them through reclassification, and then combining them. The hazard map identifies six villages at extreme risk, providing a decision-support tool for planners. It shows areas that are more likely to flood because they are low-lying, near rivers, and have heavy rainfall. The methodology shows a systematic and cost-effective way to assess the risk of flooding in areas with little data. The outputs are very helpful for planning disaster management, regulating land use, and building infrastructure. The study stresses how important geospatial techniques are for getting ready for floods and making smart choices that will help the environment.

Keywords - Drainage density, Flood hazard mapping, GIS, Remote sensing, Weighted overlay analysis

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I. Introduction

Flooding is a frequent hydro-meteorological hazard that has a major effect on riverine and low-lying areas, especially in monsoon-dominated areas like Kerala. Because of its low elevation, heavy rainfall, extensive floodplains, and dense drainage system, Thiruvalla Taluk, which is situated between the Pamba and Manimala river systems, is extremely vulnerable to flooding. Despite recurring floods, no integrated hazard map exists for Thiruvalla Taluk. Therefore, precise delineation of flood-prone areas is crucial for efficient risk assessment and spatial planning.

The effective integration of multi-source spatial data for flood hazard assessment has been made possible by recent developments in Geographic Information Systems and Remote Sensing. Prior research has demonstrated the efficacy of multi-criteria decision-making approaches in hazard mapping by identifying flood susceptibility zones using methods like hydrological modelling and Weighted Overlay Analysis.

The main goal of this study is to create a GIS based flood hazard zonation map for Thiruvalla Taluk by combining important factors like rainfall, slope, drainage density, land use/land cover (LULC), soil, geology, geomorphology, and distance to river. A Weighted Overlay Analysis method is used to make a composite Flood Hazard Index and divide the study area into five different hazard zones like very high, high, moderate, low and very low.

This study provides a scalable GIS workflow for flood-prone regions with limited hydrological data. This makes it possible to assess flood hazards in areas with limited data in a costeffective and scalable way. The research offers a spatial decision-support instrument pinpointing susceptible area.

II. Scope

The main scope of the study is to integrate multi-source geospatial datasets using GIS-based Multi-Criteria Decision Analysis (MCDA). It also implements Weighted Overlay Analysis for quantitative flood susceptibility mapping. This study utilizes raster-based map algebra for pixel-level hazard computation. It derives hydrological parameters (slope, drainage density) from DEM-based terrain analysis. It applies standardized reclassification (1–9 scale) for data normalization. Consistency is ensured through weight normalization ($\Sigma W_i = 1$). It produces high-resolution flood hazard zonation maps (Very Low–Very High). This integrates topographic, hydrological, and land-use factors for comprehensive mapping. Other scopes are to enable predictive flood susceptibility assessment beyond historical data and provide scalable and reproducible GIS workflow for regional application. This supports decision-making in disaster management and land-use planning.

III. Objectives

The Main objectives of the study are to generate thematic layers (rainfall, DEM, slope, LULC, drainage, soil, geology, geomorphology, river proximity) and to develop a GIS-based flood hazard map for Thiruvalla Taluk using multi-source spatial data. This ensures to apply weighted overlay (MCDA) for flood hazard index computation and to delineate flood hazard zones (low to very high risk). The other objectives are to identify potential flood-prone zones using hydrotopographic parameters and to recommend mitigation and planning measures for flood risk reduction.

IV. Study Area

Thiruvalla Taluk, located in Pathanamthitta district of Kerala, represents a highly flood-prone fluvial landscape due to its distinct hydro-geomorphic setting and dense human habitation. The taluk covers a moderate geographical extent comprising predominantly land area interspersed with rivers, canals, wetlands, and paddy fields, where a significant portion of the terrain lies at low elevation within active floodplains. It is bounded and influenced by the Pamba and Manimala River systems, along with an intricate network of tributaries, resulting in a high drainage density and strong river–floodplain interaction. A considerable share of the area is intensively populated and utilized for agriculture, especially paddy cultivation, with settlements often located in close proximity to river channels and low-lying zones, thereby increasing exposure to flood hazards. The region experiences high-intensity monsoonal rainfall, which, combined with gentle slopes and poorly drained clayey alluvial soils, promotes rapid runoff generation and prolonged waterlogging. The presence of wetlands and water bodies contributes to temporary storage, but their reduction due to land-use changes and urbanization has altered natural drainage patterns. Additionally, built-up areas and infrastructure development have increased impervious surfaces, further aggravating flood susceptibility. The interaction of river-dominated hydrology, extensive inhabited floodplains, agricultural land use, and inadequate drainage conditions makes Thiruvalla Taluk highly vulnerable to recurrent flooding. These characteristics strongly justify the application of GIS-based multi-criteria flood hazard mapping, which enables spatial identification of risk zones and supports effective planning, mitigation, and disaster management strategies.

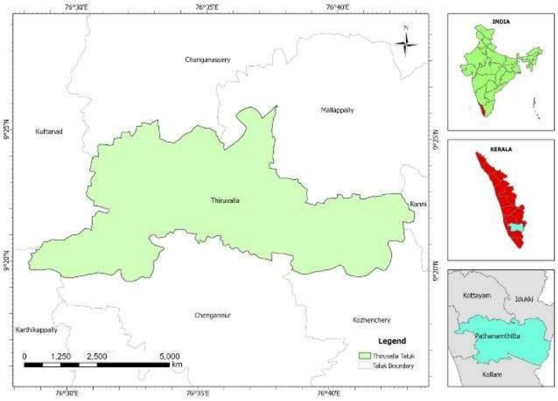


Figure 1 Layout of Study Area

V. Methodology

The methodology adopted in this study is designed to systematically integrate multiple flood-influencing factors within a geospatial framework to assess flood susceptibility in Thiruvalla Taluk. A GIS-based Multi-Criteria Decision Analysis (MCDA) approach was employed, enabling the combination of diverse spatial datasets such as rainfall, topography, land use/land cover, soil, geology, geomorphology, drainage characteristics, and river proximity. Initially, all datasets were pre-processed and standardized to ensure spatial consistency and analytical compatibility. Subsequently, thematic layers were generated and reclassified into uniform susceptibility scales to facilitate comparison and integration. A weighted overlay technique was then applied, assigning relative importance to each parameter based on its hydrological significance, leading to the computation of a composite Flood Hazard Index (FHI). Finally, the study area was categorized into distinct flood hazard zones, providing a clear spatial representation of risk levels. This structured methodology ensures a reliable, scalable, and data-driven approach for flood hazard assessment, particularly in regions with limited field data availability.

5.1 Data Acquisition and Preprocessing The Reliable secondary sources were used to gather multisource spatial datasets, such as the Digital Elevation Model (DEM), rainfall (CHIRPS), land use/land cover (Sentinel-2), soil, geology, geomorphology, drainage, and river proximity. To guarantee spatial uniformity and analytical compatibility, all datasets were imported into a GIS environment (ArcGIS Pro) and pre-processed using techniques like georeferencing, projection to a common coordinate system, clipping to the study area boundary, and conversion to raster format.

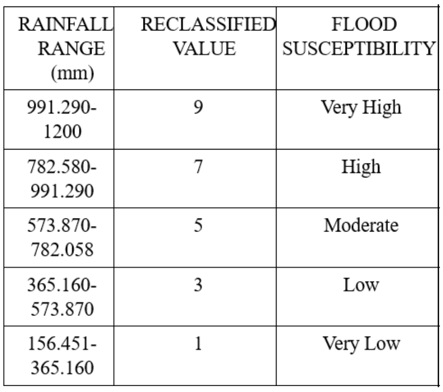
Table 1 Data Source

SL NO	DATA	SOURCE
1	Land Use Land Cover (LULC)	Esri Land Cover (Sentinel-2)
2	Elevation/Slope	Open Topography (NASADEM)
3	Geology	Geology survey of India
4	Geomorphology	Geology survey of India
5	Drainage	Extracted from DEM (Hydrology tool)
6	Road	Open Street Map (OSM)
7	Rainfall	CHIRPS
8	Soil	Benchmark soils of Kerala
9	Distance to River	Derived from ArcGIS Pro

5.2 Thematic Layer Generation and Reclassification

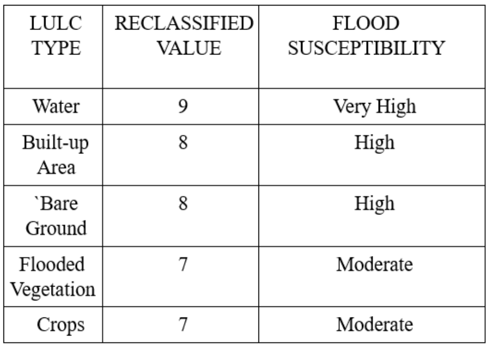
Slope and drainage density were obtained from the DEM using spatial analysis tools, and thematic layers representing important flood influencing factors were created. In order to normalise heterogeneous datasets for integrated analysis, each thematic layer was reclassified into standardised flood susceptibility classes (1–9) according to its relative contribution to flood occurrence.

Table 2 Reclassification Value of LULC



RAINFALL RANGE (mm)	RECLASSIFIED VALUE	FLOOD SUSCEPTIBILITY
991.290-1200	9	Very High
782.580-991.290	7	High
573.870-782.058	5	Moderate
365.160-573.870	3	Low
156.451-365.160	1	Very Low

Table 3 Reclassification Value of Rainfall



LULC TYPE	RECLASSIFIED VALUE	FLOOD SUSCEPTIBILITY
Water	9	Very High
Built-up Area	8	High
`Bare Ground	8	High
Flooded Vegetation	7	Moderate
Crops	7	Moderate

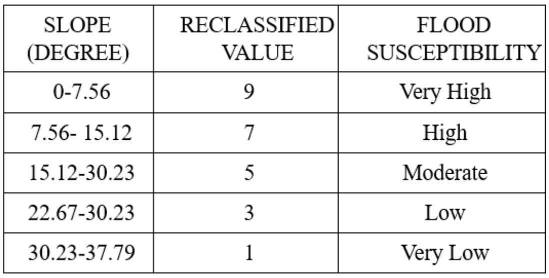
Table 4 Reclassification Value of Distance to River

DRAINAGE DENSITY RANGE	RECLASSIFIED VALUE	FLOOD SUSCEPTIBILITY
3.761738-4.702173	9	Very High
2.821304-3.761738	7	High
1.880869-2.821304	5	Moderate
0.940435-1.880869	3	Low
0-0.940435	1	Very Low

Table 5 Reclassification Value of Drainage Density

Alluvial Soil	5	Moderate
Plateau	4	Moderate
Pedi Plain	3	Low
Coastal Plain	2	Very Low

Table 6 Reclassification Value of Slope



SLOPE (DEGREE)	RECLASSIFIED VALUE	FLOOD SUSCEPTIBILITY
0-7.56	9	Very High
7.56- 15.12	7	High
15.12-30.23	5	Moderate
22.67-30.23	3	Low
30.23-37.79	1	Very Low

5.3 Weighted Overlay Analysis and Flood Hazard Index

Table 7 Reclassification Value of Soil (FHI)

SOIL TYPE	RECLASSIFIED VALUE	FLOOD SUSCEPTIBILITY
Clay	9	Very High
Gravelly Clay	6	High
Sandy	3	Low

The weighted overlay technique was used to implement a multi-criteria decision analysis (MCDA) approach. Each parameter was given relative weights based on its hydrological significance, Rainfall was assigned the highest weight (22%) due to its direct role in runoff generation, while geology received lower weight (5%) because of its indirect influence. The Flood Hazard Index (FHI), which provides a quantitative depiction of spatial flood susceptibility, was

Table 8 Reclassification Value of Geology calculated using map algebra by integrating all weighted thematic layers.

GEOLOGY TYPE	RECLASSIFIED VALUE	FLOOD SUSCEPTIBILITY
Charnockite group of rocks	9	Very High
Migmatite Complex	8	High
Acidic Rocks	7	High
Alkaline Rocks	7	High
Basic Rocks	5	Moderate
Laterite	3	Low
Sandstone and Clay with Lignite	2	Very Low
Sand and slit	1	Very Low

Table 9 Reclassification Value of Geomorphology

GEOMORPHOLOGY TYPE	RECLASSIFIED VALUE	FLOOD SUSCEPTIBILIT
Water Body	9	Very High
Rock Exposure	8	High
Residual Hill	8	High
Flood Plain	7	High

Table 10 Weightage of Parameters

SL NO	DATA	WEIGHTAGE
1	Rainfall	22
2	Distance To River	18
3	Drainage	15
4	LULC	12
5	Slope	12
6	Soil	9
7	Geomorphology	7
8	Geology	5

5.4 Flood Hazard Mapping

Using appropriate classification techniques, the calculated FHI values were divided into five different flood hazard zones: very low, low, moderate, high, and very high. In order to facilitate efficient planning and decision-making, the resulting zonation map was utilised to identify flood-prone areas and examine the spatial distribution of flood risk.

$$\text{Flood Hazard Index} = \sum(W_i \times R_i)$$

(W_i = weight, R_i = reclassified value).

VI. Result

The results present a spatially explicit evaluation of flood susceptibility in Thiruvalla Taluk using a GIS-based Weighted Overlay framework. The derived Flood Hazard Index (FHI) integrates multiple hydro-topographic and landuse parameters to delineate zones of varying risk. The analysis clearly identifies high-susceptibility regions concentrated in low-lying, river-proximal areas, demonstrating strong spatial variability in flood potential. These findings provide a robust basis for targeted flood risk management and evidence-based land-use planning.

6.1 Thematic Maps

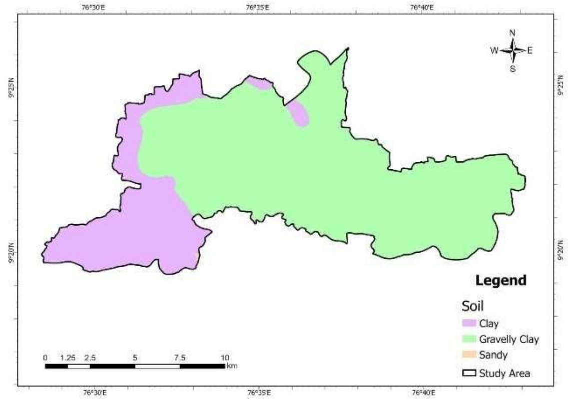


Figure 2 Thematic Map of Soil

Clay soils exhibit very high flood susceptibility due to low permeability, while sandy soils show low susceptibility owing to better drainage. Soil type thus directly influences infiltration and runoff.

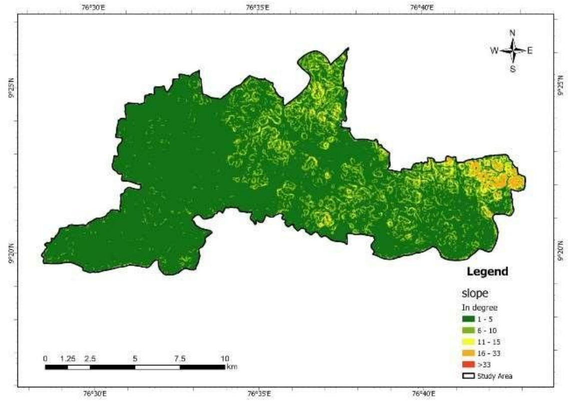


Figure 3 Thematic Map of Slope

Gentle slopes (0–7.56°) correspond to very high flood risk due to ponding and stagnation, whereas steeper slopes promote rapid runoff and lower susceptibility.

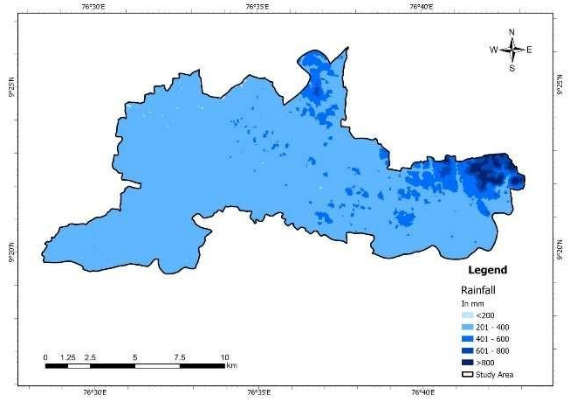


Figure 4 Thematic Map of Rainfall

Areas receiving >900 mm rainfall fall into high to very high susceptibility zones, confirming rainfall intensity as a key driver of flood occurrence.

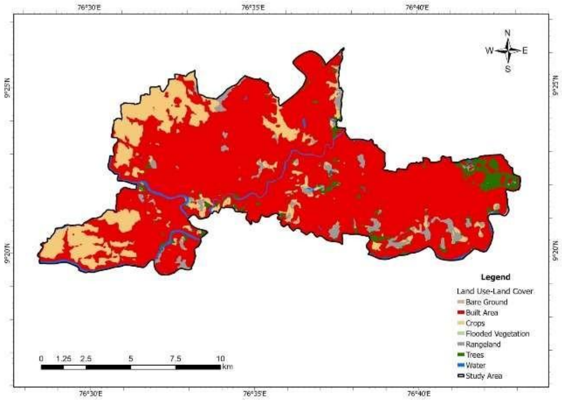


Figure 5 Thematic Map of Land Use Land Cover

Built-up areas and water bodies show high susceptibility due to reduced infiltration, while forested areas exhibit low susceptibility. Urbanization significantly increases flood risk.

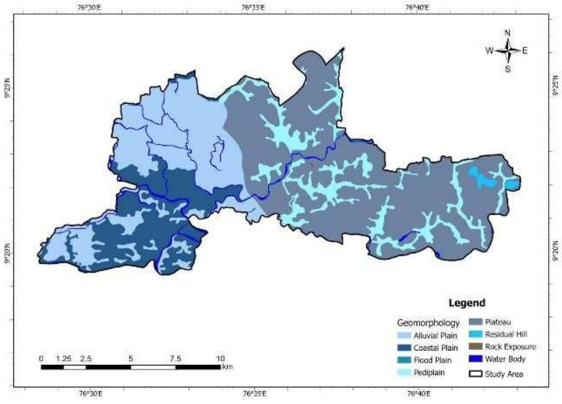


Figure 6 Thematic Map of Geomorphology

Floodplains and water bodies are highly susceptible, while pediplains and coastal plains show lower risk. Landform characteristics strongly influence flood inundation.

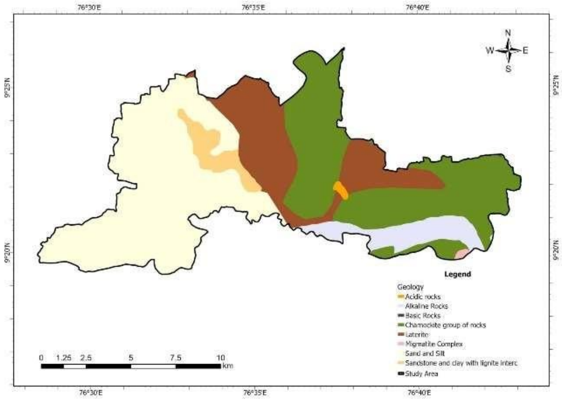


Figure 7 Thematic Map of Geology

Charnockite and migmatite complexes are highly susceptible due to poor permeability, whereas sandstone and alluvium show low susceptibility due to better infiltration.

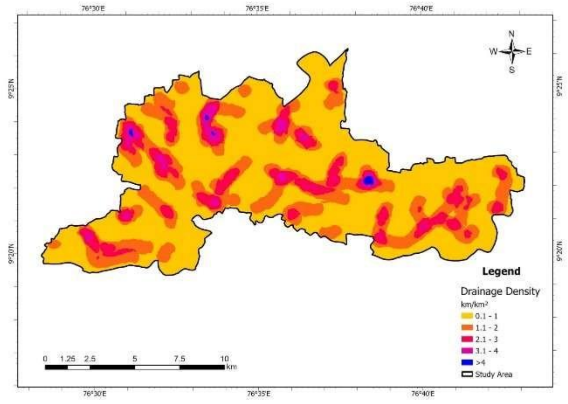


Figure 8 Thematic Map of Drainage Density

High drainage density areas concentrate runoff and are prone to flooding, while low-density areas show reduced susceptibility.

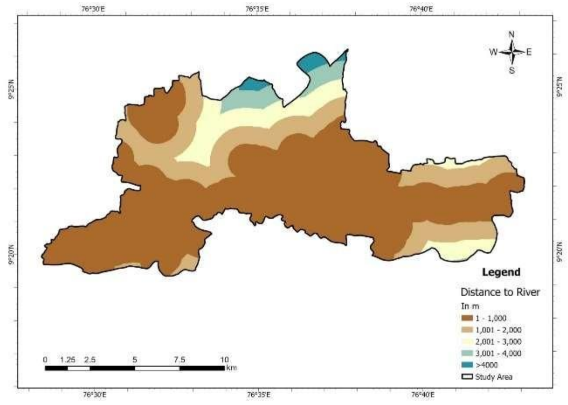


Figure 9 Thematic Map of Distance to River

Zones within 1 km of major rivers fall into very high susceptibility due to overflow and backwater effects, with risk decreasing as distance increases.

6.2 Inundation Maps

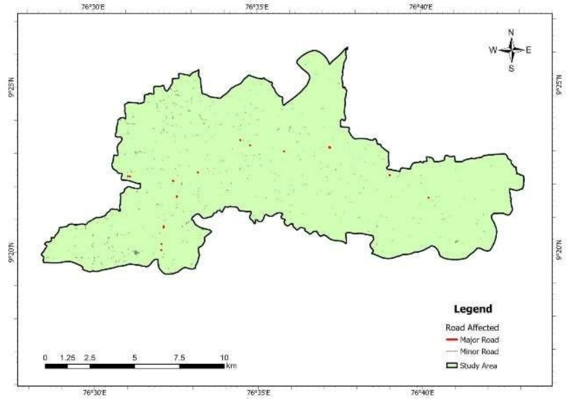


Figure 10 Inundation Map of Road Affected

Road networks along rivers are highly vulnerable, with ~30% intersecting high-risk zones.

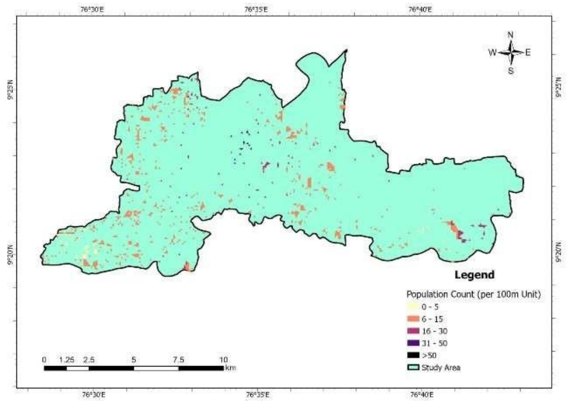


Figure 11 Inundation Map of Population Count

Densely populated settlements overlap with flood prone areas, increasing socio-economic vulnerability.

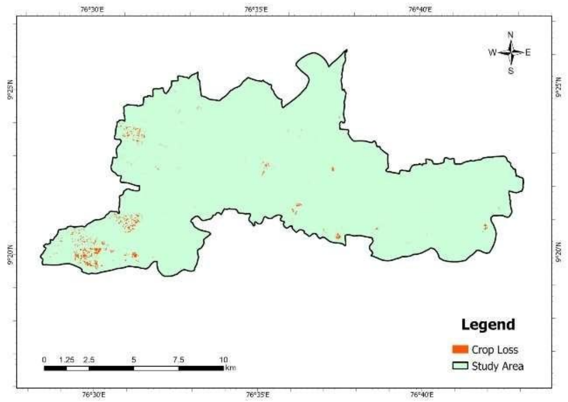


Figure 12 Inundation Map of Crop Loss

Paddy fields in floodplains face recurrent losses, underscoring the need for adaptive practices.

6.3 Flood Hazard Zonation Map

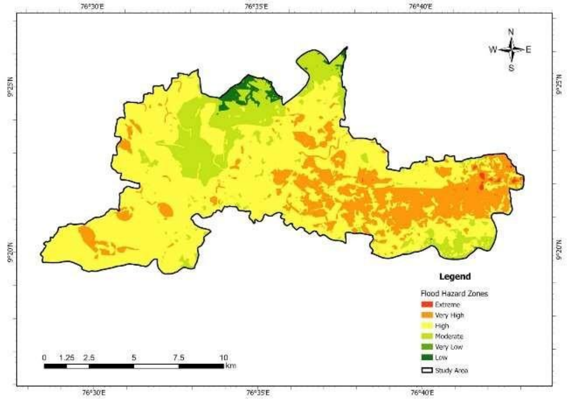


Figure 13 Flood Hazard Zonation Map

The flood hazard zonation map classifies Thiruvalla Taluk into five zones: very low, low, moderate, high, and very high. A substantial portion of the taluk, particularly riverbanks and low-lying floodplains, falls within moderate to high hazard zones. Villages such as Kaviyoor, Kuttoor, Niranam, Kadapra, Nedumpuram, Peringara, and parts of Thiruvalla town are identified as very high-risk areas due to low slopes (1–5°), high drainage density (>2.1 km/km²), clayey soils, and proximity to the Pamba River (<1000 m). In contrast, Eraviperoor, Koipuram, and Kunnamthanam exhibit moderate risk, while Kallissery and Pullad show lower susceptibility owing to higher elevation and greater distance from river channels.

VII. Conclusion

This study demonstrates the effectiveness of GIS-based Weighted Overlay and MCDA in delineating flood hazard zones in Thiruvalla Taluk.The high-risk areas include Kaviyoor, Kuttoor, Niranam, Kadapra, Nedumpuram,

Peringara, and parts of Thiruvalla town, primarily due to low slope, high drainage density, and proximity to rivers. The Limitations of this study include reliance on subjective weighting and absence of field validation, which may affect accuracy. So Future work should incorporate hydrological modeling, validation with flood records, and dynamic rainfall-runoff simulations.The resulting hazard maps provide a valuable decision-support tool for disaster management, land-use planning, and climate adaptation strategies.

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