Integrating Analytical Hierarchy Process and Geographical Information Systems for Comprehensive Flood Risk Evaluation in Upputhara, Kerala

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Abstract
Floods are among the most common and costly natural hazards worldwide, significantly impacting the environment by affecting water quality, biodiversity and increasing pollution levels. Upputhara, located in the Idukki district of Kerala, experiences frequent flooding due to its location in a V-shaped valley of the Periyar river, just below the Mullaiperiyar and Idukki reservoirs. The primary aim of this study is to delineate a flood hazard map for the Upputhara Grama Panchayat using a geospatial-based Analytical Hierarchy Process (AHP). The data sources for this study include Survey of India (SOI) topographical maps, ASTER DEM (30-meter resolution) and rainfall data from the Indian Meteorological Department (IMD). The flood hazard map was generated using nine spatial layers: vegetation condition, rainfall, geology, elevation, flow accumulation, topographic wetness index, drainage density, slope and soil texture.

The final map was produced through multi-criteria overlay analysis within a GIS environment, classifying the area into five flood hazard categories: very low (52%), low (28%), moderate (13%), high (5%) and very high (1.5%). Field data from flood-affected locations showed that the model has a 95% accuracy. While the majority of the study area faces a very low to moderate flood risk, about 17% of the region is at high to very high risk. This study demonstrates that geospatial technology-based flood hazard delineation is highly effective and supports sustainable development and planning. The generated map aids authorities responsible for flood protection by raising awareness about flood-prone areas and helping to reduce vulnerability.

Keywords: Periyar Basin, Flood Hazard, AHP, Geospatial Technique, Upputhara.

Introduction

Flood is a common natural disaster that affects all countries in the world. Floods can occur due to various factors such as intense rainstorms, coastal flooding and inland flooding[16]. Floods can have significant impacts including economic losses, damage to homes and infrastructure and negative effects on health and well-being[28]. Flood-related injuries and illnesses can persist over a long period. Governments and communities are increasingly focusing on building flood-resilient communities and implementing measures to reduce flood risk. Decision-making processes for flood control involve assessing multiple factors and uncertainties to create sustainable and resilient flood defence systems. Education and knowledge dissemination are important in managing flood disasters and reducing their impact on affected communities.

Floods are a natural occurrence that can happen almost anywhere, not necessarily near bodies of water, with heavy rains, poor drainage and nearby construction projects increasing the risk of flood damage. FEMA maintains flood maps to assess flood risk, showing the likelihood of an area flooding, with any place having a 1% chance or higher each year considered to be at high risk. These maps help communities to understand their flood risk and make informed decisions to mitigate potential damage. Floods have significant economic impacts, especially on vulnerable populations. Studies show that flooding affects the economic activities of coastal regions, leading to lower employment rates and longer work hours for the affected individuals.

Economic inequality exacerbates these impacts, as unequal societies are more susceptible to flood hazards due to physical marginalisation and inadequate infrastructure. Moreover, the economic system's focus on continuous growth contributes to environmental degradation, leading to climate crises that further intensify the economic repercussions of natural disasters like floods[29].In essence, floods not only disrupt economic activities but also highlight the interconnectedness between economic systems, environmental sustainability and societal resilience.

Flood and watershed management are crucial aspects in mitigating the impacts of natural disasters like floods. Various studies emphasise the importance of community involvement in flood disaster management efforts, highlighting the need to enhance community knowledge and skills through methods such as questionnaires, interviews and simulations[33]. Additionally, sustainable watershed-level planning approaches are utilised to develop flood-mitigation and storm water management plans, focusing on reducing flood volumes through activities like forest and land rehabilitation, erosion reduction and soil fertility enhancement[31]. The mismanagement of water resources due to anthropogenic changes in watersheds has led to increased runoff, stream bank erosion and degraded water quality, necessitating a holistic approach to watershed management using technological tools like GIS and hydrologic models[25].

Strategic action plans including flood hazard modelling and high-resolution spatial distribution maps, are essential for prioritising areas at high risk and implementing preventive measures to minimise human, economic and environmental losses from floods[8]. Flood risk management is a critical global concern, with flood impacts increasing despite risk reduction efforts[12]. The traditional approach of flood control is evolving towards flood adaptation due to intensifying and changing flood risks under climate change[14]. Multi-criteria decision-making (MCDM) methods play a crucial role in flood-risk management by evaluating various sustainability aspects like social, environmental, economic and technical criteria to aid decision-makers in selecting the best flood management alternatives[9].

However, challenges persist in effectively managing flood risks where institutional priorities, changing flood risk drivers and uncoordinated interventions hinder the effectiveness of flood policies despite financial investments in drainage infrastructure[14]. Integrating flexible, collaborative and inclusive approaches in flood risk management is essential to address the multidimensional impacts of floods and enhance adaptive capacity globally. Flood susceptibility can be accurately predicted using models and expanded flood inventory data obtained through remote sensing.

The combination of machine learning models and expanded flood inventory data has been shown to greatly improve the accuracy of flood susceptibility prediction, with improvements ranging from 1.14% to 19.74% based on the area under the receiver operating characteristic curve (AUC) [20]. Various machine learning algorithms, such as Random Forest, Gradient Boosting and Support Vector Machine, have been successfully applied to predict floods and non-flood regions, achieving high accuracy rates and low error rates[30]. Flood susceptibility modelling using hybrid machine learning models such as Fuzzy-ANN, Fuzzy-RBF and Fuzzy-SVM, has also been effective in identifying flood-prone areas and can be used for flood management planning and implementation[1]. Additionally, flood risk assessments combining geophysical and socio-economic datasets have been conducted to identify high-risk flood susceptibility zones and inform flood mitigation decisions.

The Analytical Hierarchy Process (AHP) method is a valuable tool for flood mapping, allowing for a systematic evaluation of various criteria to assess flood susceptibility in different regions. The AHP method integrates Geographic Information System (GIS) techniques to create flood susceptibility maps by considering multiple criteria and their relative importance in flood risk assessment. This approach involves the selection of criteria like elevation, slope, land cover and other relevant factors that significantly influence flood dynamics in a specific area.

Data Collection and Model Setup: The AHP-GIS-based flood mapping process involves collecting morphometric, topographic and variable data to create comprehensive flood risk maps. The selection of criteria is crucial and is based on their importance in producing floods in the study area.

Variable Analysis: Variables such as elevation, slope, soil types, rainfall distribution, land use/land cover and other factors are considered in flood susceptibility analysis using the AHP method. These variables are chosen based on their significance in flood hazard assessment and are supported by existing research.

Model Validation: The accuracy of flood susceptibility maps created using the AHP method is validated through methods like the area under the curve (AUC) analysis. This validation process compares the flood susceptibility map with historical flood data to assess the reliability and accuracy of the model. The AHP method, when combined with GIS techniques, provides a robust framework for flood risk assessment and mapping. It helps in identifying high-risk flood areas, understanding the factors contributing to flood susceptibility and guiding decision-making for flood management and disaster preparedness.

Flood History

The floods in Kerala in 2018 were catastrophic, affecting millions of people and causing over 400 deaths. The extreme rainfall during the monsoon season, with 53% above normal rainfall till August 21st, played a significant role in triggering the floods. Additionally, the State experienced 1, 2 and 3-day extreme rainfall events with return periods of 75, 200 and 100 years respectively. The situation was exacerbated by the fact that six out of seven major reservoirs were at more than 90% of their full capacity before the extreme rainfall hit Kerala.

The flooding in Kerala was worsened by the combination of above-normal seasonal rainfall, high reservoir storage levels and unprecedented extreme rainfall in the catchment areas of major reservoirs like Idukki, Kakki and Periyar. This led to a significant release of water in a short period, contributing to the severity of the flooding. The study suggests that improving reservoir operations with skilful forecasts of extreme rainfall at longer lead times (4-7 days) could help to mitigate the impact of such events in the future.

The flood risk in Idukki district, Kerala, is significant due to various factors such as heavy rainfall, steep terrain and the presence of major dams in the region. The district of Idukki has experienced severe flooding in the past, notably during the 2018 Kerala floods and the 2020 Kerala floods. These events were exacerbated by factors like abnormally high rainfall, landslides and the release of water from dams due to heavy precipitation in their catchment areas.

Idukki district is particularly vulnerable to flooding and landslides due to its undulating terrain and high-intensity storms during the monsoon months. The heavy precipitation in this region finds its way into the main rivers, leading to increased water discharges and flooding in downstream areas. The 2018 floods in Idukki were triggered by an abnormally high rainfall period from June to August, resulting in severe flooding across the State and causing significant damage to infrastructure and loss of lives.

Furthermore, the 2020 Kerala floods affected Idukki along with other districts, highlighting the recurring nature of flood risks in the region. The district witnessed landslides and flooding due to heavy rains during the monsoon season, leading to loss of lives, property damage and disruption of essential services. Idukki district in Kerala faces a high flood risk due to its geographical features, intense monsoon rainfall and the presence of major dams that can release water during heavy precipitation events. Understanding these risks is crucial for disaster preparedness, early warning systems and effective mitigation strategies to minimise the impact of future flood events in the region.

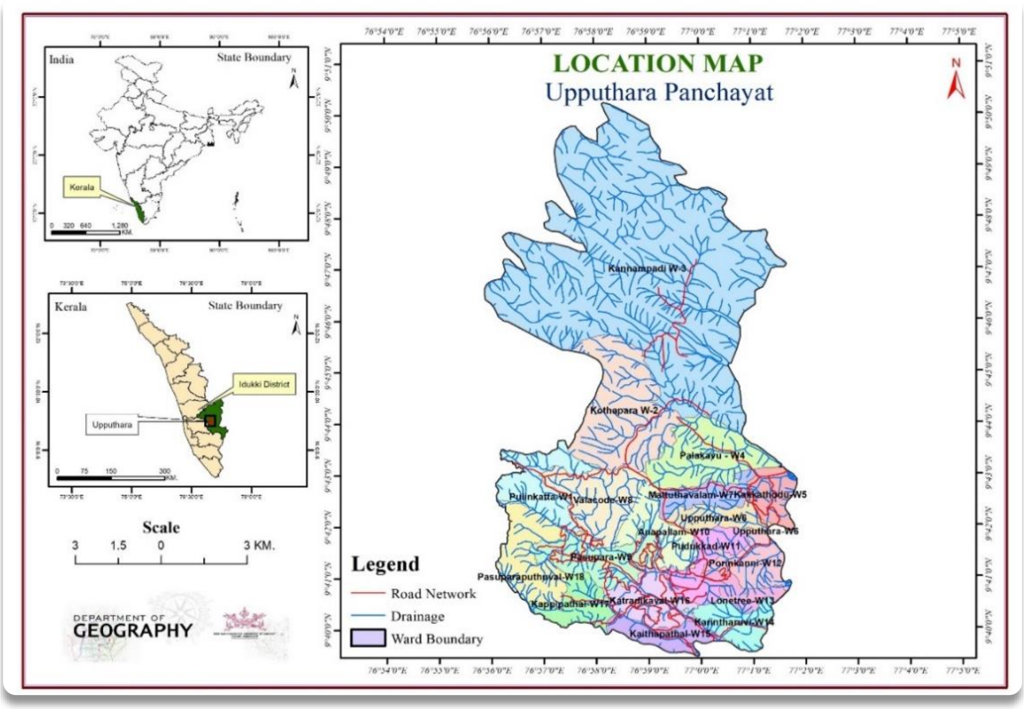

Figure 1: Study Area Location Map

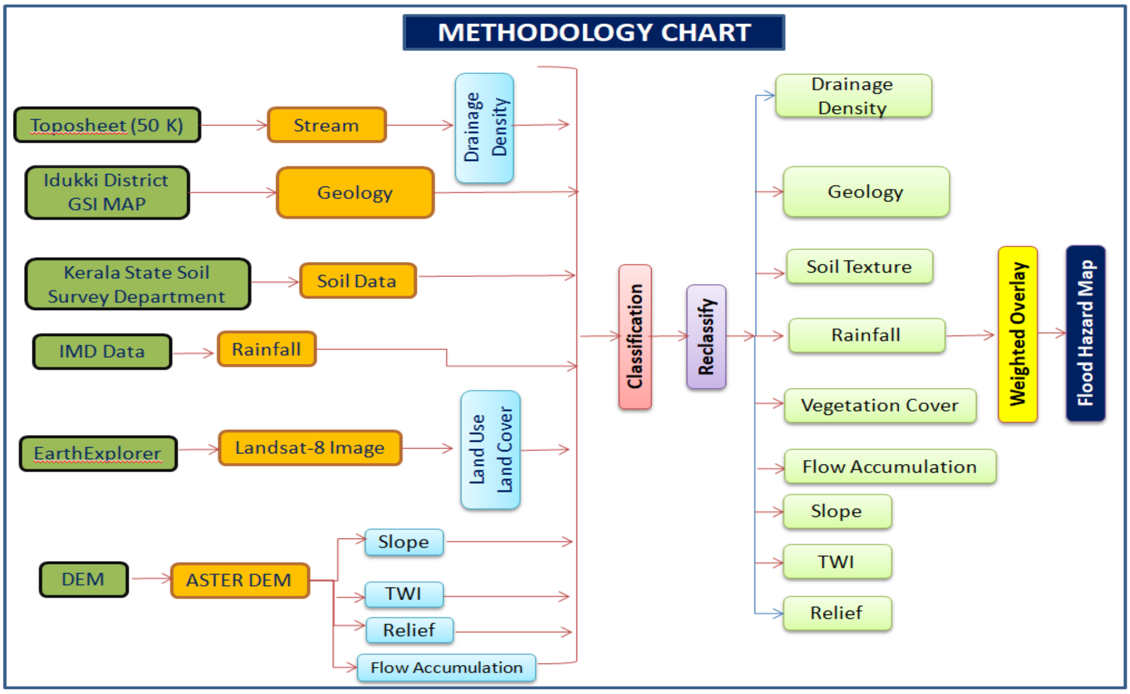

Figure 2: Schematic diagram of the methodology adopted in the study

Study Area

Upputhara Panchayat is in the Idukki district of Kerala. The geographic coordinates of Upputhara Panchayat are approximately 9.7735° N latitude and 76.9585° E longitude (Fig1). The total area of the panchayat is 135 sq. km. The total population of the study area is 26236. To the North is Vazhathope Panchayath and the Western and southern part of the panchayat cover Elappara Panchayat and the eastern side is Ayyapankovil Panchayath. According to the prepared DEM of the study area, the altitude varies from 712m to 1272m. Upputhara Panchayat was highly affected during the Kerala floods in 2018. Many bridges were destroyed during this period and a few deaths were reported due to landslides. High rainfall in the catchment area of the Idukki and Cheruthoni Dam causes more worries.

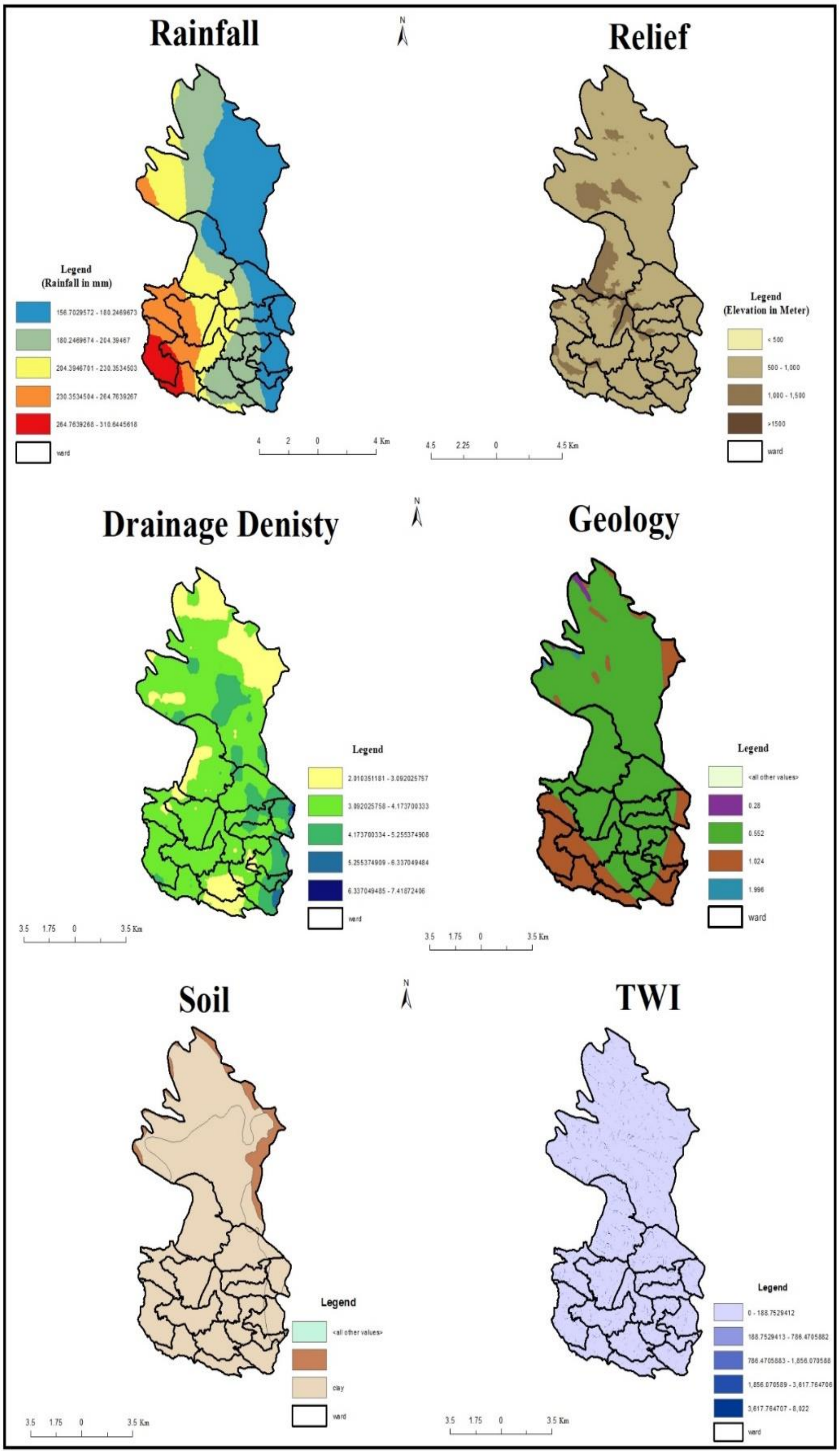

Fig. 3a: Flood Vulnerability inducing Factors

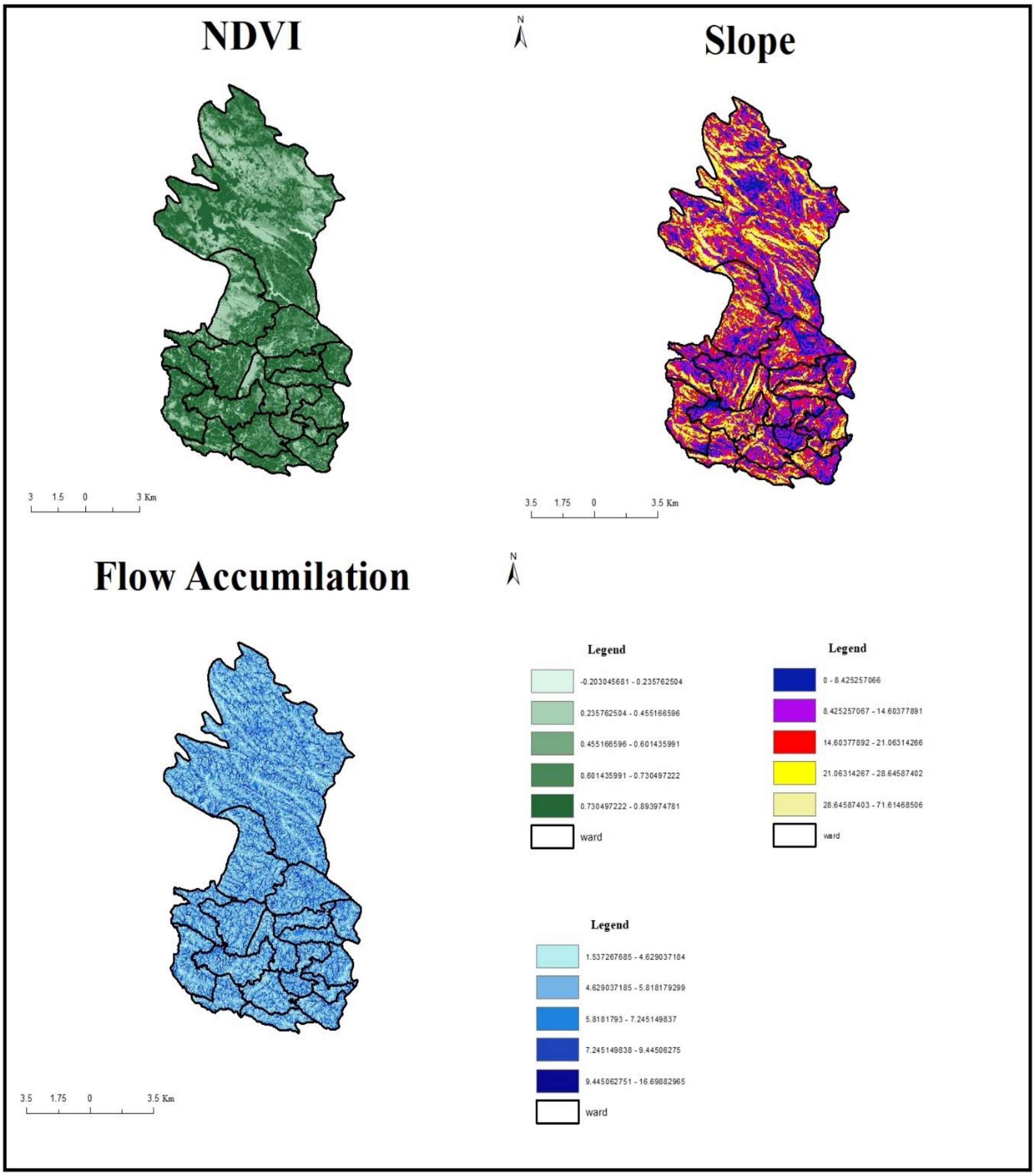

Fig. 3b: Flood Vulnerability Inducing Factors

Table 1
Parameters used for Flood risk assessment, their sources and details.

S.N.	Parameter	Data Source
1	Rainfall	https://cdsp.imdpune.gov.in
2	Elevation	ASTERDEM (30 Meter Resolution), www.earthdata.com
3	Slope	
4	Topographic Wetness Index	
5	Flow Accumulation	
6	NDVI	Landsat-8: OLI Image
7	Drainage	Survey of India (1:50,000)
9	Geology	Idukki District Resource Map (GSI 1: 2, 50,000)

Objectives

(i) To analyse the driving forces of flood hazard in the Upputhara

(ii) To delineate the flood hazard zone in the Upputhara

Material and Methods

The data source and methodological flow chart for the present study have been summarised and are given in table 1. To assess the flood risk of the Upputhara Panchayath, a total of nine parameters were selected. The nine parameters are related to flood conditioning or susceptibility factors viz. elevation, slope, drainage density, distance to rivers, geomorphology, rainfall, flow accumulation, topographic wetness index (TWI), geology and curvature. All the layers have been generated in the GIS environment based on an in-depth investigation and field observation.

Analytical hierarchy process method: The AHP method was developed by Saaty and due to its simplicity, efficiency and safety, it was used by scientists who dealt with decision-making processes[29]. Since EIA is a complex multi-dimensional process, involving multiple criteria and multiple actors, it was considered that the AHP is the most important multiple-criteria decision-making approach that facilitates adequate qualitative, quantitative, or combined decisions[29]. Through this method, combined quantitative and qualitative tools were used and it involved different groups of stakeholders and opinions expressed by many experts.

As a procedure, after having determined the assessment criteria and alternatives in the AHP, the next step is to conduct a comparison of paired criteria and to build a pairwise comparison matrix. The ratio of the row score to the column score in each cell is a pairwise comparison matrix[29]. To apply the method, each factor must be evaluated and rated against every other factor by assigning a relative dominant value between 1 and 9 (Tables 2 and 3).

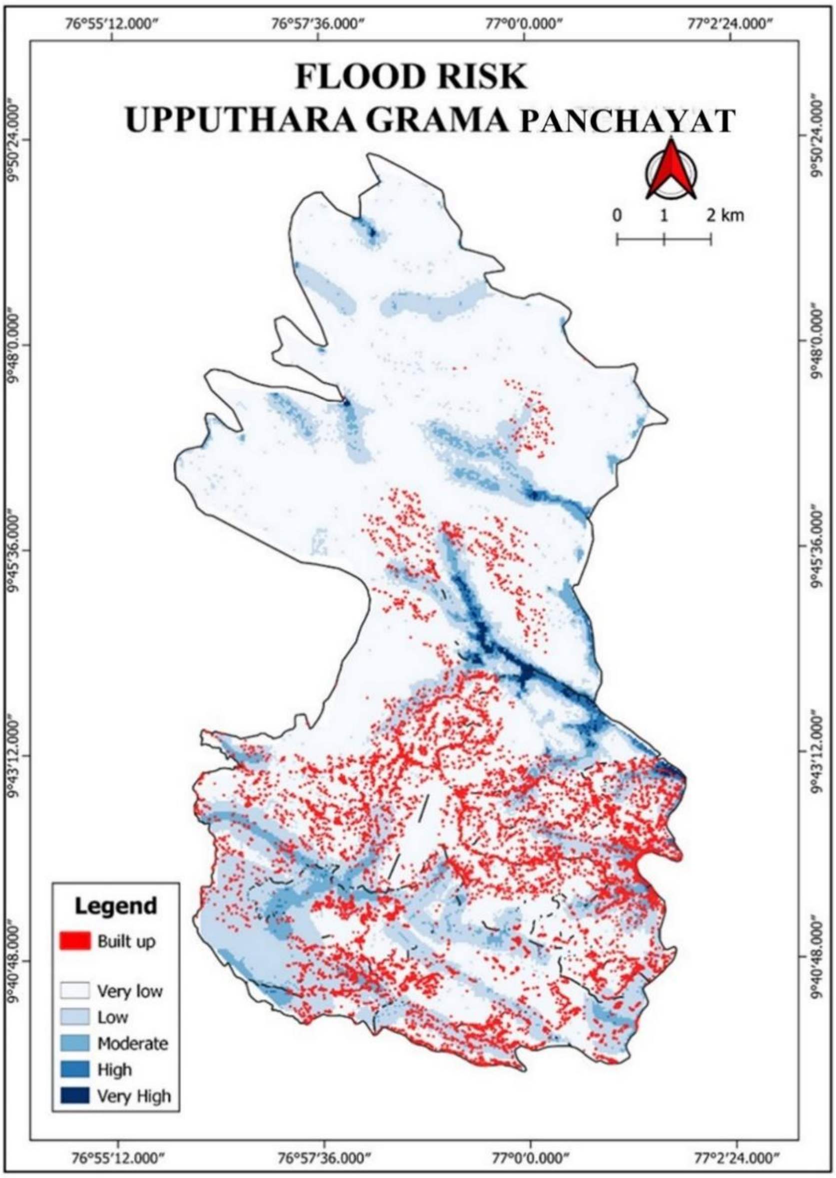

Figure 4: Flood Risk Map

Table 2
Comparison matrix and relative score of each parameter

Parameters	Elevation	Slope	Distance from the river	Rainfall	Flow Accumulation	Drainage Density	Geology	TWI	NDVI
Elevation	1	2	2	3	4	5	7	7	8
Slope	1/2	1	1	2	3	5	5	6	7
Distance from the river	1/2	1	1	2	3	5	6	7	7
Rainfall	1/3	1/2	1/2	1	2	3	4	6	7
Flow Accumulation	1/4	1/3	1/3	1/2	1	2	3	5	6
Drainage Density	1/5	1/5	1/5	1/3	1/2	1	2	4	6
Geology	1/7	1/5	1/6	1/4	1/3	1/2	1	3	4
TWI	1/7	1/6	1/7	1/6	1/5	1/4	1/3	1	3
NDVI	1/8	1/7	1/7	1/7	1/6	1/6	1/4	1/3	1

Table 3
Normalised-weight values in the standardised pairwise comparison matrix

Parameters	Elevation	Slope	Distance from the river	Rainfall	Drainage Density	Flow Accumulation	Geology	TWI	NDVI	Weights (Wi)
Elevation	0.085	0.066	0.069	0.039	0.024	0.014	0.010	0.005	0.003	***0.26***
Slope	0.043	0.033	0.034	0.026	0.018	0.014	0.007	0.004	0.003	***0.2***
Distance from the river	0.043	0.033	0.034	0.026	0.018	0.014	0.009	0.005	0.003	***0.19***
Rainfall	0.028	0.016	0.017	0.013	0.012	0.008	0.006	0.004	0.003	***0.13***
Drainage Density	0.021	0.011	0.011	0.007	0.006	0.006	0.004	0.003	0.002	***0.1***
Flow Accumulation	0.017	0.007	0.007	0.004	0.003	0.003	0.003	0.003	0.002	***0.05***
Geology	0.012	0.007	0.006	0.003	0.002	0.001	0.001	0.002	0.001	***0.04***
TWI	0.012	0.005	0.005	0.002	0.001	0.001	0.000	0.001	0.001	***0.02***
NDVI	0.011	0.005	0.005	0.002	0.001	0.000	0.000	0.000	0.000	***0.01***

CI = 0.10881

The following equation is used to model the FSI (Flood Susceptibility Index): n is the number of factors, W_i is the weight of each susceptibility parameter and R_i is the rank of each parameter. (Table 3).

Delineation of the Flood susceptibility and vulnerability map: After priority-based normalisation, the relative weights of each parameter were used to measure the flood susceptibility index in the GIS setting, which was calculated by multiplying the sum of weights by the rate of each factor.

Preparation of Flood Risk Map: Flood risk assessment is a critical task in managing and mitigating floods, particularly in flood-prone areas such as floodplains. This involves evaluating geo-environmental hazards and socio-economic factors to determine the cumulative risk assessment. The number of lives lost, people injured, property damaged and the overall adverse effects on economic growth due to natural disasters are considered as the cumulative risk assessment[27]. This assessment is a product of the possibility of a site experiencing regular flood events and the degree of instability of the system. Risk can be measured as a cross-cutting mix of hazard and vulnerability. Flood risk mapping of the Upputhara Panchayath has been calculated using the susceptibility index and vulnerability index in the raster calculator (Table 4).

The susceptibility index is a measure of the likelihood that a particular area will be flooded, while the vulnerability index assesses the potential consequences of a flood event on the affected population and their assets. By combining these two indices, a comprehensive flood risk assessment can be obtained which can then be used to develop appropriate mitigation and management strategies.

Table 4
Sub-criteria of selected susceptibility parameters with their assigned and normalised ranks

S.N.	Factors	1	2	3	4	5	6	CR	Weight (Ri)
1	**Elevation**							0.062	
	<20	1							0.499
	20 – 100	1/3	1						0.256
	100 – 600	1/5	1/3	1					0.138
	600 – 1000	1/7	1/5	1/3	1				0.070
	>1000	1/8	1/6	1/5	1/3	1			0.038
2	**Slope**							0.060	
	0	1							0.445
	0 – 5	1/2	1						0.297
	5 – 15	1/4	1/3	1					0.147
	15 – 55	1/6	1/5	1/3	1				0.073
	>55	1/8	1/7	1/5	1/3	1			0.037
3	**Distance From River**							0.034	
	0.5	1							0.464
	0.5 – 1	1/2	1						0.264
	1 – 1.5	1/4	1/2	1					0.149
	1.5 – 2	1/6	1/4	1/2	1				0.083
	>2	1/8	1/6	1/5	1/3	1			0.040
4	**Rainfall**							0.083	
	<1500	1							0.464
	1500 – 2000	1/3	1						0.264
	2000 – 2500	1/5	1/3	1					0.149
	2500 – 3000	1/7	1/7	1/3	1				0.083
	>3000	1/9	1/9	1/5	1/3	1			0.040
5	**Flow Accumulation**							0.049	
	0	1							0.461
	0 – 21	1/2	1						0.262
	21 – 43	1/4	1/2	1					0.148
	43 – 108	1/6	1/4	1/2	1				0.091
	>108	1/8	1/6	1/5	1/4	1			0.038
6	**Drainage Density**							0.027	
	3.1	1							0.379
	3.2 – 4.2	1/2	1						0.249
	4.3 – 5.3	1/3	1/2	1					0.160
	5.4 – 6.3	1/4	1/3	1/2	1				0.102
	6.4 – 7.4	1/5	1/4	1/3	1/2	1			0.065
7	**Geology**							0.062	
	Charnockite group of rocks	1							0.499
	Peninsular Gneissic complex	1/3	1						0.256
	Basic rocks	1/5	1/3	1					0.138
	Migmatite Complex	1/7	1/5	1/3	1				0.070
	Low Grade Metasedimentary rocks	1/8	1/6	1/5	1/3	1			0.038
8	**TWI**							0.083	
	>16	1							0.503
	12 – 16	1/3	1						0.260
	8 – 12	1/5	1/3	1					0.134
	4-8	1/7	1/5	1/3	1				0.068
	<4	1/9	1/7	1/5	1/3	1			0.035
9	**NDVI**							0.083	
	-0.2 – 0.24	1							0.503
	0.25 – 0.46	1/3	1						0.260
	0.47 – 0.6	1/5	1/3	1					0.134
	0.61 – 0.73	1/7	1/5	1/3	1				0.068
	0.74 – 0.89	1/9	1/7	1/5	1/3	1			0.035

DEM (Digital Elevation Model): Elevation can be derived from DEM and this data is important for creating Flood susceptibility maps. In the field of flood mapping, the experts believe that the elevation of an area is the primary factor that controls the flood hazard.

Generally, the area located at a lower elevation is more prone to flooding compared to the area located at higher altitudes. Water tends to flow from a higher point to a lower area, and, consequently, lower areas with a flat surface are more likely to flood.

Slope: Slope is an important topographic component in hydrological studies because it regulates the flow of surface water. The slope of a canal in a region directly correlates with the flow speed. The flow speed increases proportionally to the slope angle. The infiltration process is also influenced by the slope angle. Increased slope angle reduces infiltration but increases surface runoff, resulting in stagnant water and flooding in areas where the gradient suddenly falls. This has a great impact on the flood formation as areas with high slopes are less exposed to flooding.

Rainfall: Rainfall is a critical conditioning factor for flood generation, influencing both the magnitude and frequency of flood events. Understanding the relationship between rainfall and flooding is essential for effective water resource management and flood risk mitigation. It is one of the most important parameters in the occurrence of floods. The development of floods and their potential damage are influenced by the rainfall and its intensity.

Flood condition indicators: (a) Elevation, (b) NDVI (c) Flow Accumulation, (d) Geology, (d) Drainage Density, (e) Distance from river, (f) Rainfall, (g) TWI, (h) Slope.

Flow accumulation: Flow accumulation is a concept used to quantify the amount of water that accumulates and contributes to the flow at a particular location in a drainage network. Flow accumulation is a critical factor in understanding flood dynamics, as it influences both the likelihood and duration of flooding events.

Research indicates that flow accumulation interacts with various environmental and atmospheric conditions to shape flood susceptibility.

Topographic wetness index (TWI): It is a widely used parameter for finding the location and extent of water-saturated regions. The Topographic wetness index (TWI) measures how topography affects runoff and flow accumulation in river catchments. Areas with greater TWI values are more prone to floods than those with lower TWI values. The Topographic wetness index (TWI) indicates the topography's effect on runoff and the amount of flow accumulation at any river catchment location. The area with a higher TWI value is more prone to flooding compared to lower TWI value.

Geology: Geology plays a significant role in flood susceptibility, influencing various hydrological processes and sediment stability. Understanding these geological factors is crucial for effective flood management and mitigation strategies. It is significant in the formation of drainage patterns and is associated with accumulation patterns of water.

NDVI: The Normalised Difference Vegetation Index (NDVI) is an important metric for flood monitoring since it can identify inundated areas from other forms of land cover. Integrating NDVI into flood risk assessment models improves urban planning and disaster preparedness by assessing potential consequences to vegetation and land use. The NDVI's capacity to reflect changes in vegetation cover is critical for disaster response and recovery, allowing authorities to identify areas that require immediate attention and resources.

Distance from the river: The likelihood of flooding generally increases as one moves closer to the river. Flood-prone areas, especially those near the riverbanks, may experience more frequent flooding events.

Drainage density: Higher drainage density implies a more interconnected and concentrated flow network, increasing the chance of flooding. Flooding is likely to occur more frequently in areas with high drainage density than in areas with low drainage density. Higher drainage density leads to erosion and sedimentation in the catchment region, affecting the lower ground. Drainage densities play a crucial role in controlling dangers by indicating the soil's qualities.

Results and Discussion

Assessment of flood potential: The primary purpose of the present study is to model the flood susceptibility areas in Upputhara Grama Panchayat. The multi-criteria analysis approach in this study utilises various factors: Elevation, Slope, Distance from river, Rainfall, Flow Accumulation, Land use, Geology, TWI, Curvature and integrates these with building data to identify the vulnerable population of the study area. The resultant flood susceptibility map shows various values categorised into five classes. The classes are very low, low, medium, high and very high probability of flood, comprising of 52.1 %, 27.7%, 13.3 %, 5.2% and 1.4% respectively. The high flood-risk zones are in the Southern and Eastern parts of the panchayat and mainly along the banks of the Periyar River. The areas of lower flood risk are high-slope regions. A total of 20% of the area comes under the medium to very high flood risk zone.

The wards Mattuthavalam, Upputhara, Kappipathal and Porikanni face the highest threats. After integrating the flood risk map with building data, it was found that about 902 (8.5%) buildings come under the flood-prone region. Geospatial mapping can be improved by using high-resolution spatial information, accurate conventional data and advanced factor ranking methods. Field validation improves accuracy by comparing outcomes and assisting decision-makers and administrative bodies in effective planning and management. The map highlights regions with high flood susceptibility, but other places must also be considered.

This study conducted fieldwork in high flood zones and validated findings through conversations with adjacent villagers. Although floods are not disastrous in this region, they do cause significant damage to agriculture. Policymakers should employ strict steps to prevent uncontrolled urbanisation and the settlement of areas near rivers and choked water routes.

Identifying high-risk locations requires extensive mapping using high-resolution satellite photos to improve and to refine research findings. This study demonstrates the dependability and importance of geo-information approaches in natural catastrophe assessment which involves multi-source data.

Conclusion and Suggestions

Periyar is one of the largest west-flowing perennial rivers, covering more than 5,000 km² in central Kerala. It traverses through the Idukki and Ernakulam districts before joining the Arabian Sea. The Periyar river basin is often affected by seasonal floods. The history of flooding in Idukki and the Periyar river basin highlights a consistent pattern of severe flood events, mainly due to intense southwest monsoon rainfall and the management of water releases from the major reservoirs of Idukki and Mullaperiyar. Catastrophic floods such as those in 1924 (Great Flood of 99), 2018 (Kerala Floods) and 2019, have caused extensive damage, revealing the region's susceptibility due to its terrain including V-shaped valleys and broad floodplains.

The recent increase in flood events suggests shifts in rainfall patterns, with rainfall sometimes exceeding 300 mm in 24 hours. IMD data indicates that whenever rainfall exceeds 280 mm in a day, it triggers spates in the Periyar basin. The study area, Upputhara, is also situated along the Periyar river basin, just below the Idukki reservoir, which faces a flood threat every year. This area is particularly vulnerable due to the Mullaiperiyar dam, which was commissioned in 1895 and constructed with lime surki mortar. The Periyar basin is structurally controlled, with a major lineament passing across the basin.

This research demonstrates the effectiveness of integrating the Analytical Hierarchy Process (AHP) and Geographic Information Systems (GIS) in mapping flood susceptibility in Upputhara Panchayat, Kerala. By utilising nine key factors such as elevation, slope, rainfall and distance from rivers, the flood hazard map provides a detailed understanding of flood risks across different areas.

The results reveal that about 20% of the region is at moderate to very high flood risk, particularly along the Periyar river and low-lying areas. The study's 95% accuracy, validated through field data, underscores the reliability of the geospatial approach. This research highlights the significance of accurate flood mapping for effective disaster management, helping authorities to focus on vulnerable zones and better allocate resources.

By identifying areas with high flood susceptibility and integrating these insights with building data, it provides a critical resource for flood risk mitigation and planning. Furthermore, the study suggests that geospatial mapping can be enhanced through high-resolution spatial data and robust field validation. Such approaches can support sustainable development efforts, reduce vulnerability and guide strategic interventions against uncontrolled urbanisation in flood-prone areas.

This study also demonstrates the urgent need for early warning systems and sustainable approaches to flood control, better water management and the protection of infrastructure, agriculture and local livelihoods.

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