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Using Remote Sensing and Geographic Information System Methods, a Flood Hazard Zone was Defined in the Vamanapuram River Basin in Trivandrum, India.

Rosemary Noble [1], Reshma J.K[2] , Rajesh Raghunath[3] & Vineetha P[4]

Abstract

The frequency, severity, and economic toll of floods—the most prevalent kind of natural disaster—are all on the increase throughout the globe. A flood is "a natural phenomenon that results in the temporary submerging with water of a land that does not occur under normal conditions," as stated by the European Commission in 2007. When it comes to weather-related calamities, flash floods are among the worst that may occur. They are risky because they may occur suddenly and unexpectedly after short periods of heavy rain. The Vamanapuram River basin in Kerala State, India, is a problematic location due to the risk of frequent flash floods. The purpose of this research was to use a multi-criteria evaluation based on remote sensing and GIS methods to identify possible flood danger regions in the Vamanapuram River Basin. This research uses a multi-criteria approach based on the Ranking technique to suggest a Flood Hazard Map that takes into account elements such as slope, land use land cover, soil, drainage density, yearly rainfall, and roadways per micro-watershed. The majority of the basin was found to be in a moderate to very high flood danger zone, according to the estimated flood hazard zones. Only a small percentage (8%), however, was determined to be immune to flood risk. However, a third of the basin was located in a zone with very high risk. The findings were verified to provide a budget-friendly option for strategic flood risk management strategy.

Keywords: *Flood Hazard Zonation, GIS, Weighted Overlay Analysis, Multi Criteria Assessment*.

1. Introduction

A natural disaster is defined by the UN as: "the consequences of events triggered by natural hazards that overwhelm local response capacity and seriously affect the social and economic development of a region."[1] . The term natural hazard implies the occurrence of a natural condition or phenomenon, which threatens or acts hazardously in a defined space and time. Different conceptualizations of natural hazards have not only evolved in time, they also reflect the approach of the different disciplines involved in their study. In this sense, a natural hazard has been expressed as the elements in the physical environment harmful to man [4]; an interaction of people and nature [7]; the probability of occurrence of a potentially damaging phenomenon [20]; and as a physical event which makes an impact on human beings and their environment [2]. According to [12], floods are among the most recurring and devastating natural hazards, impacting upon human lives and causing severe economic damage throughout the world. It is understood that flood risks will not subside in the future, and with the onset of climate change, flood intensity and frequency will threaten many regions of the world [13].Flood has always been a recurrent phenomenon in India with more than 12 percent of the total land area in India is prone to recurrent flood. India receives 75% of rains during the monsoon season (June – September). As a result almost all the rivers are flooded during this time resulting in to the intense and recurrent floods. Flood hazard mapping is a vital component for appropriate land use in flood areas. It creates easily read, rapidly accessible charts and maps [3] which facilitates the identification of risk areas and prioritize their mitigation effects. A primary issue for flood management is to identify the area having higher hazard potential. The purpose of flood hazard assessment is to tag the areas within a development plan that are at risk of flooding based on factors that are applicable to flood risks. Policies are then sketched to be applied to such areas to minimize and manage such risk. Flood risk mapping using GIS and multi-criteria methods have been applied in various case studies [5],[14],[19]. The criteria used in this study were selected due to their relevance in the study area.This study deals with the first component of flood risk management, i.e. the definition of flood hazard areas in a specific region. The aim is to identify flood hazard zones, where mitigation measures should be taken. Thus, a spatial, multi-criteria index has been presented to delineate such areas.

1.1 Background: literature review

Forkuo (2011) generated an efficient and cost effective methodology for preparing flood hazard maps in Ghana. Bhadra et al.,(2011)showed that GIS technique is effective in extracting the flood inundation extent in a time and cost effective manner for the remotely located hilly basin of Dikrong, where conducting conventional surveys is very difficult. Thilagavathi (2011) used GIS to demarcate the flood hazard prone areas in the Papanasam Taluk into five zones of varying degrees of flooding. Furthermore, Orok (2011)directed that a flood risk map should be able to identify the areas that are most vulnerable to flooding and estimate the number of people that will be affected by floods in a particular area.

The matter of preparing a reliable hazard map is one of the latest concerns within the subject of flood management. In a series of studies (Forkuo E.K 2011, Islam and Sado 2000, Orok, H.I 2011, Sinhaet al., 2008) various methodologies for creating flood hazard maps are presented. Rejesk (1993) introduced three different methods for hazard zoning. His first method describes a

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binary model which evaluates if the hazard is present or not in a particular raster cell. The second method involves ranking different locations of an area depending upon the intensity of the hazard present. In the third approach some 'hazard' values have been assigned to each of the raster cells based on the results of a multivariate model which were built up on a host of variables related to river flooding and associated hazards.

2. Study area

Geographically the Vamanapuram river basin lies between 80^0 35′ to 80^0 50′ North latitudes and 76^0 40′ to 77^0 15′ East longitudes and is spread over the districts of Thiruvananthapuram and Kollam of Kerala State. The watershed has a total area of 766.89 sq.km (76689 ha) covering 31 villages spread over 33 panchayats, 8 blocks and two distri

46.12km and 171.84km respectively Schumm (1956). Form factor value is 0.31 ie, basin is elongated in shape (Horton;1932). The major river draining through the watershed is the Vamanapuram River, 88 km long. It starts from Chemmunji Motai and flows westward to fall into the Anjengolake. The climate of the area is between a tropical savanna climate and a tropical monsoon climate hence it does not experience distinct seasons. The average temperature ranges from 34 °C to 21 °C. The humidity is high and rises to 90% during the monsoon season. The major soil texture types found in Vamanapuram are clay, gravelly clay, loam and gravelly loam. The area has Built Up, Agriculture, Evergreen and Deciduous forests, Wastelands and Water Body. Figure I depict the spatial representation of the study

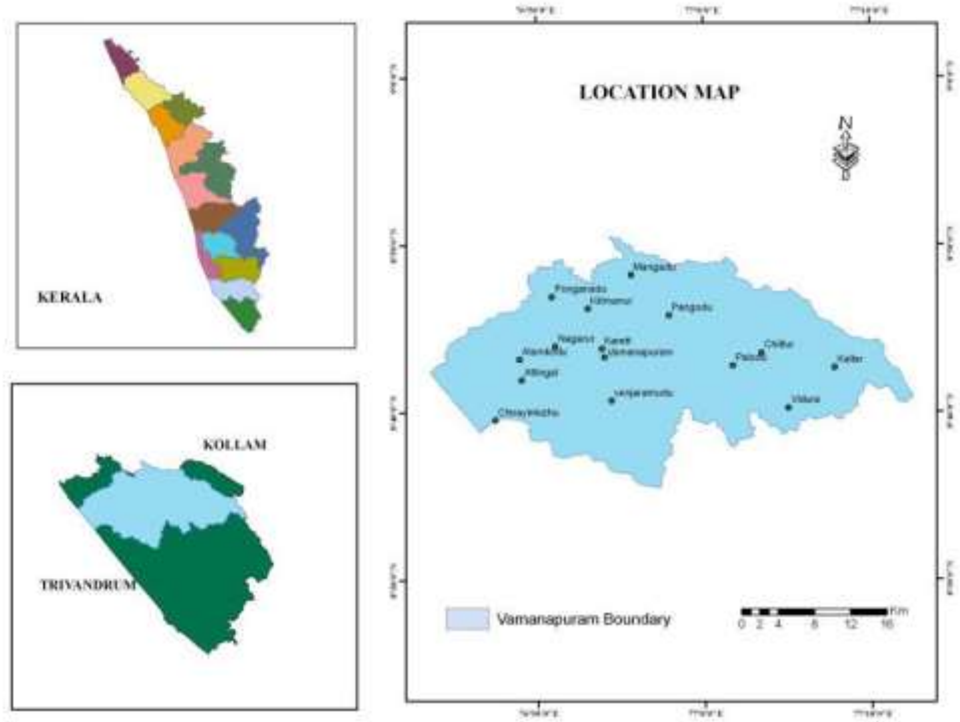

Figure1. Location map of the study area, Vamanapuram River Basin

3. Materials and Methods

The study intends to carry out a flood vulnerability analysis by applying the weighted overlay approach. For the flood-hazard analysis, the main steps were data collection and construction of a spatial

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database from which the relevant factors were extracted, followed by assessment of the flood hazard using the relationship between flood and flood-related factors, and validation of the results (Lee and Pradhan 2006).

Major data's used in the study are Survey of India Topographic maps of scale 1:50000, numbered 58 D/10, 58 D/13, 58 D/14, 58 H/1 and 58 H/2 , ASTER DEM and remotely sensed image dated 11-March-2015. The roads, water body, and drainage were digitized from SOI toposheets. The slope map was prepared using the digital elevation model (DEM) and slope generation tools in ArcGIS software. The Drainage Density map was prepared using Kriging method. The soil map was prepared by digitizing the Kerala State Land use Board (KSLUB) soil map. The rainfall distribution map was prepared from Indian Meteorological Department (IMD) data using IDW method. The land use/land cover map was extracted from (LISS-IV) satellite image and unsupervised classification was done using ERDAS Imagine 9.1 software. Arc Hydro tool was used to process the DEM to delineate watershed, sub-watersheds. The road map was overlaid over micro-watersheds to derive the roads per micro-watershed map.

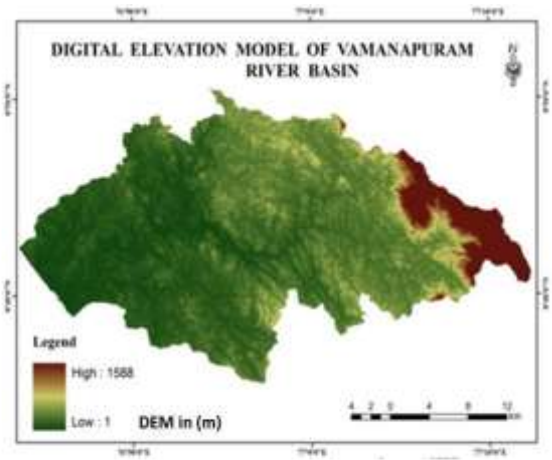

Figure 2: DEM of Vamanapuram basin.

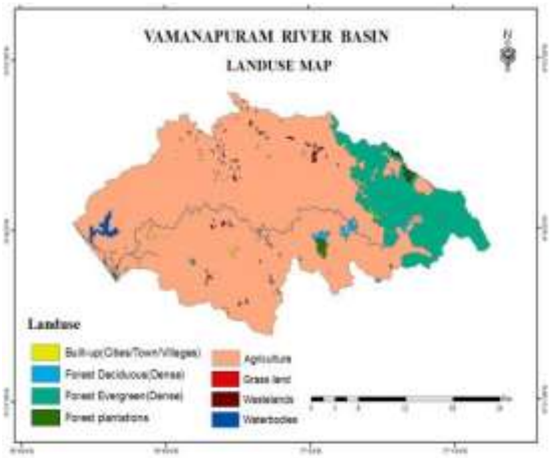

Figure 3: Land-use map of study area.

After the selection of indicators, their standardization, and the definition of indicator weights, an analysis was performed in a raster environment using ArcGIS9.3 software to obtain the final flood risk index map. In the ranking method to generate criterion values for each evaluation unit, each factor was given weightage according to the estimated significance for causing flooding. Inverse ranking was applied to these factors, 1 is the least important and 4 is the most important factor. All weighted maps were overlaid using addition and the flood risk index was then calculated using the Raster Calculator. Adapted criteria and weightage for different thematic layers are shown in Table I.

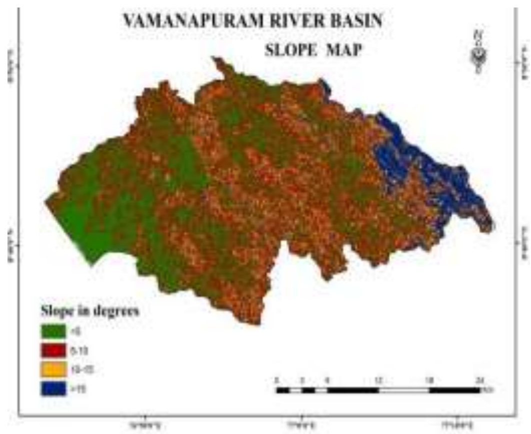

Figure 4: Slope map of the study area.

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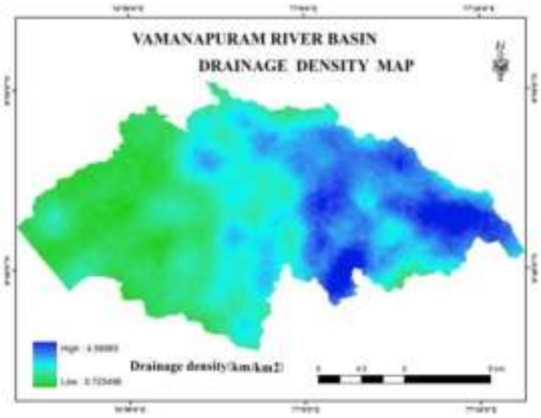


Figure 5: Drainage density map of the study area (km/km^2)

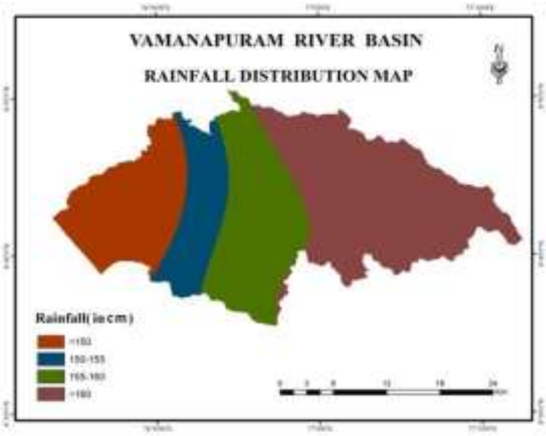


Figure 6: Rainfall distribution map (IDW) (in cm).

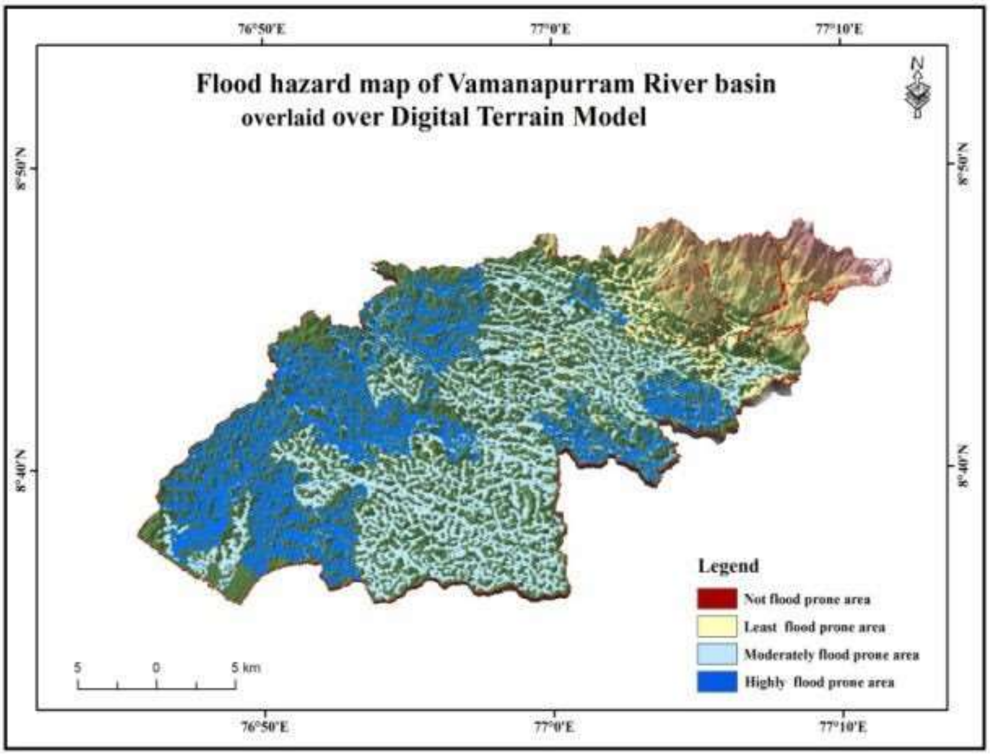
Figure 7: Roads over Micro-watersheds.

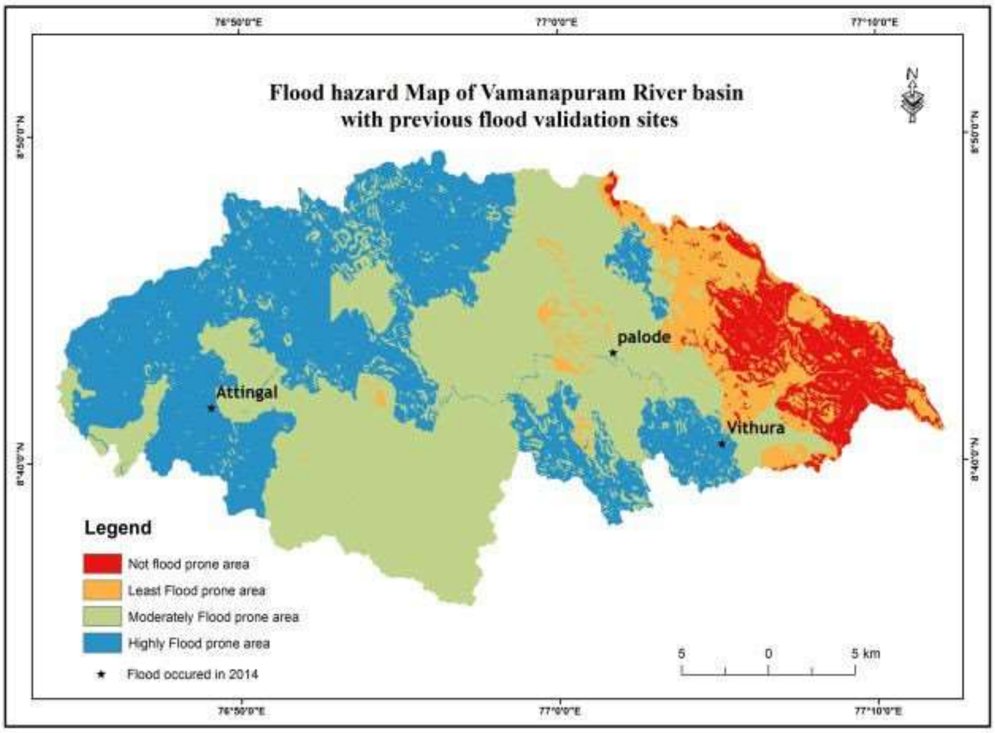
Table I: Adapted criteria and weightages for different thematic layers.

SL NO.	PARAMETER	CLASS	RANK	WEIGHTAGE	INDEX
1.	Drainage density	<1	4		60
		1-2	3		45
		2-3	2	15	30
		>3	1		15
2	Rainfall	<150	1		20
		150-155	2		40
		155-160	3		60
		>160	4	20	80
3.	Slope	<5	4		120
		5-10	3		90
		10-15	2	30	60
		>25	1		30
4.	Soil type	Gravelly loam	1		10
		Loam	2		20
		Gravelly clay	3		30
		Clay	4	10	40
		Water body	4		40
5.	Land use	Agriculture	3		45
		Built up	3		45
		Forest deciduous	2		30
		Forest evergreen	1	15	15
		Forest plantations	1		15
		Grasslands	1		15
		Wastelands	3		45
		Water bodies	4		60
7.	Road per micro watershed	<10	1		10
		10-18	2		20
		18-25	3	10	30
		>25	4		40

4. Results and Conclusions

The aim of this study was to create an accurate flood hazard susceptibility map along the Vamanapuram River basin. The different thematic layers corresponding to the causative factors that influence the occurrences of floods in this region were prepared using remote sensing and topographic information. All the created thematic layers were reclassified in ArcGIS software by assigning the weightages to the each class of the thematic layer from 0 to 4 on the scale in which 4 denotes highest contributor towards the flood and 1 denotes the least contributor. To obtain a flood risk rating map, it was necessary to divide the flood risk index map into different ca susceptibility were distinguished: not flood prone, low, moderate and highly flood prone areas (Figure 8).





Flood Hazard Zonation....

Figure 9: Validated Flood hazard map.

As shown in Fig. 8, 8% of the study area was found to be not flood prone. Least and moderate zones made up 9%, 47% respectively. The very high risk area constituted 36% of the total study area. The hazard map was validated with previous flood occurrence's reports .Kilimanoor, Vamanapuram, Ottoor ,Manampoor are the panchayats falling under highly flood prone, while Pothancode, Pangodu, Vithura and Vembayam are moderately flood prone. In long term high risk locations can be identified using Flood hazard maps thus help keep future flood risk down. Flood hazard maps can be used effectively as an evacuation manual during a flood occurrence and offers local residents with information on the flood danger levels of their properties(usually shown as inundation depth). Structural and non-structural measures can be implemented to reduce flood risk, like measures to increase the infiltration, reduce the runoff rate in upper catchment areas, structures to keep the floodwaters away from the people and property such as dam, levees, dikes, embankments and raise awareness about emergency flood procedures.

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