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# FLOOD RISK ASSESSMENT OF KARUVANNUR RIVER BASIN IN THRISSUR USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

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**ABSTRACT**

*Around the world, floods are one of the most common disasters. A better understanding of flood hazards and vulnerability areas increases flood prevention and management effectiveness. It is estimated that nearly one fifth of flood-related deaths occur in India, and the recent floods in Kerala emphasize the need for updated risk maps. The purpose of this study is to create a flood risk assessment map for the Karuvannur river basin in Kerala, India by utilising 2018 and 2019 rainfall data to try and replicate the weather condition during floods as well as other available datasets. To create the risk map of the study area, GIS (geographic information system) is used along with AHP (Analytical Hierarchy Process) to combine vulnerability maps and hazard maps. Hazard maps were developed by pairwise comparison in the AHP process based on topographical and hydrological factors such as slope, drainage density, rainfall, etc., while vulnerability maps were generated based on elements such as population density, road network density, and land use. The resultant risk map showed higher risk areas in the central west and south east parts of the basin, and the newspaper reports corresponded to the same area.*

## 1. INTRODUCTION

Flood is one of the most frequent natural disaster that occur around the world. Floods occur when rivers overflows into the surrounding land either due to excessive rainfall or ineffective river management. Flash floods due to heavy rainfall causes widespread destruction to life and property. It also causes damages to environment, spreads diseases and compromises the quality of drinking water.

Kerala witnessed the worst floods of over 100 years in the year 2018 with over 400 people dead and since then there is more frequent floods in the state. Effective flood management and prevention lies with the preparedness of the authorities and people. There are three typical approaches for flood prediction: (i) analyzing the frequency of flooding, through statistical analyses, allows determining the recurrence interval for any year and for a given discharge in the stream (without explicitly characterizing the flood area); (ii) monitoring the progress of storms (e.g., amount of rainfall) can be used to predict short-term flood events; and (iii) the flood hazard maps allow determining the extent of flooded areas based on the estimated discharges for different return periods [1]. But just having hazard maps gives only idea of where the hazard is likely to occur but not how it may affect the lives, for that vulnerability factors like population and infrastructure also need to be incorporated. This can be achieved by creating risk maps of the area.

Risk is formulated by combining hazard and vulnerability and this is done using several methods in the multi criteria analysis or the multi criteria decision making (MCDM). Here in this study the geographical information system (GIS) is used in order to make it more accessible to masses. In MCDM, there are different methods for assessing criterion weights: entropy, ranking, rating, trade-off analysis, and pairwise comparison,

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among others [1]. The Analytic Hierarchy Process (AHP) proposed by Saaty [2] is one of the most common MCDM methods, and it has been widely applied to solve decision-making problems related to water resources [1]. It uses pairwise comparison to determine relative importance of each elements to one other. This method requires only spatial information for the risk map generation and thus is a convenient way of using MCDM approach. In the study AHP criterion was used to first create hazard map layer as well as vulnerability map layer then AHP is again applied giving both hazard and vulnerability equal weightage to develop risk map.

## 2. LITERATURE REVIEW

Flood is seen as the most common natural disaster of all time and various studies were carried out in order to have tools and methods that can predict and project the risks associated with floods. Meyer volker et.al., (2007) discussed about GIS based multicriteria analysis as decision support in flood risk assessment and developed a framework for a GIS-based multicriteria analysis for flood risk assessment and used it for Vereinigte Mulde in the federal state of Saxony, Germany. Vinod P G et.al.,(2013) conducted a flood hazard assessment of the Vamanapuram river basin using remote sensing and GIS techniques making use of the multi criteria evaluation technique of weighted overlay analysis and concluded that using the hazard map flood prone areas can be identified. The analytical hierarchy process in the MCDM was developed by Thomas L Saaty (1970) (2008). Since then several researchers have used AHP along with GIS softwares to develop hazard and risk maps of various areas.

Sani Yahaya et.al., (2010) used both AHP criterion and ranking method to understand flood vulnerable areas in the Hadejia-Jama'are River Basin, Nigeria and suggested that projects including such vulnerability maps should be used for land planning management alternatives. Following the floods in Malaysia in 2006 to 2008, Ranya Fadlalla Abdalla Elsheikh et al. (2015) carried out research to determine potential flood prone areas using spatial multicriteria evaluation, AHP and ranking method. The study reviewed the use of GIS in decision making process. Kamonchat Seejata et al. (2018) assessed flood hazard areas using AHP over the lower Yom basin in sukhothai province. They used six physical parameters to be used in the pair wise comparison matrix and modelled flood hazard in GIS software. In the same year Daniela Rincón et.al., conducted case study of greater Toronto area and stated that the advantages of the approach are its flexibility, ease of handling and low cost as well as the AHP criterion provided not just the best alternative but a tool for effective decision making.

In India Abhishek Ghosh et al. (2018) conducted flood risk assessment of Malda district of west Bengal using AHP criterion and GIS to understand the hazard better along with including socio economic factors. A similar study was conducted at Coochbehar district in West Bengal by Subhankar Chakraborty et al. (2019), they comprehensively assessed hazard vulnerability and flood risk.

## 3. RESEARCH METHODOLOGY

### 3.1. Study Area

The Karuvannur river basin situated in Thrissur district is one among the 44 river basins in Kerala. The river has its origins at Pumalai Hills in Chimmony Wildlife sanctuary of Thrissur District. The river is 48 kilometres in length, drains an area of 1,054 km2 (Water Atlas of Kerala, 1995 & PWD, 1974). Karuvannur river basin extends from 10°19'15" N to 10°36'55"N latitudes and 76°04'55"E to 76°33'45"E longitudes. The average annual rainfall of the river basin is 2922 mm and average stream flow of 1232 $Mm^3$[3]. In 2018, floods destroyed the bund road from Arattupuzha to Karuvannur. The river spread to seven kilometres. Around 200 people from 30-odd families, from PallisseryPanankulam to Arattupuzha bridge, were stranded. Hundreds of houses in Cherpu, Arattupuzha, Ettumuna, Muthulliyal, Chenam, Inchamudi, Pullu, Manakody, Chettupuzha and Panankulam areas were submerged(The Hindu 2018).

### 3.2. Data Collection

The thematic layers like drainage density, slope, and elevation were delineated from SRTM (Shuttle Radar Topography Mission) DEM (digital elevation model). Landuse, microwatershed size and basin shapefile were obtained from the landuse board Thrissur office. Data collected from the 2011 census [4] and open street map were used to create population density and road network density data respectively. Rainfall data of 5 months for the years 2018 and 2019 was also collected from the hydrology department to create rainfall intensity map layers. These thematic maps were used to develop hazard, vulnerability and final risk map.

### 3.3. AHP criterion

The Analytic Hierarchy Process (AHP) was introduced by SAATY (1977) and is highly popular means to calculate the weighting factors by help of a preference matrix where all identified criteria are compared against

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each other. Saaty (1977) and Saaty & Vargas (1991) suggested a scale for comparison consisting of values ranging from 1 to 9 which describe the intensity of importance [5].

| Intensity of importance | Description |
|---|---|
| 1 | Equal importance |
| 3 | Moderate importance of one factor over another |
| 5 | Strong or essential importance |
| 7 | Very strong importance |
| 9 | Extreme importance |
| 2, 4, 6, 8 | Intermediate values |
| Reciprocals | Values for inverse comparison |

**Table 1. Example scale for comparisons (Saaty & Vargas, 1991)**

Saaty (1977) provided the consistency ratio CR which is a single numerical index to check for consistency of the pair-wise comparison matrix. It is defined as the ratio of the consistency index CI to an average consistency index RI, thus

$$CR = \frac{CI}{RI}$$

| n | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| RI | 0.00 | 0.52 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 |

**Table 2. Values for RI (Saaty & Vargas, 1991; with n = order of matrix)**

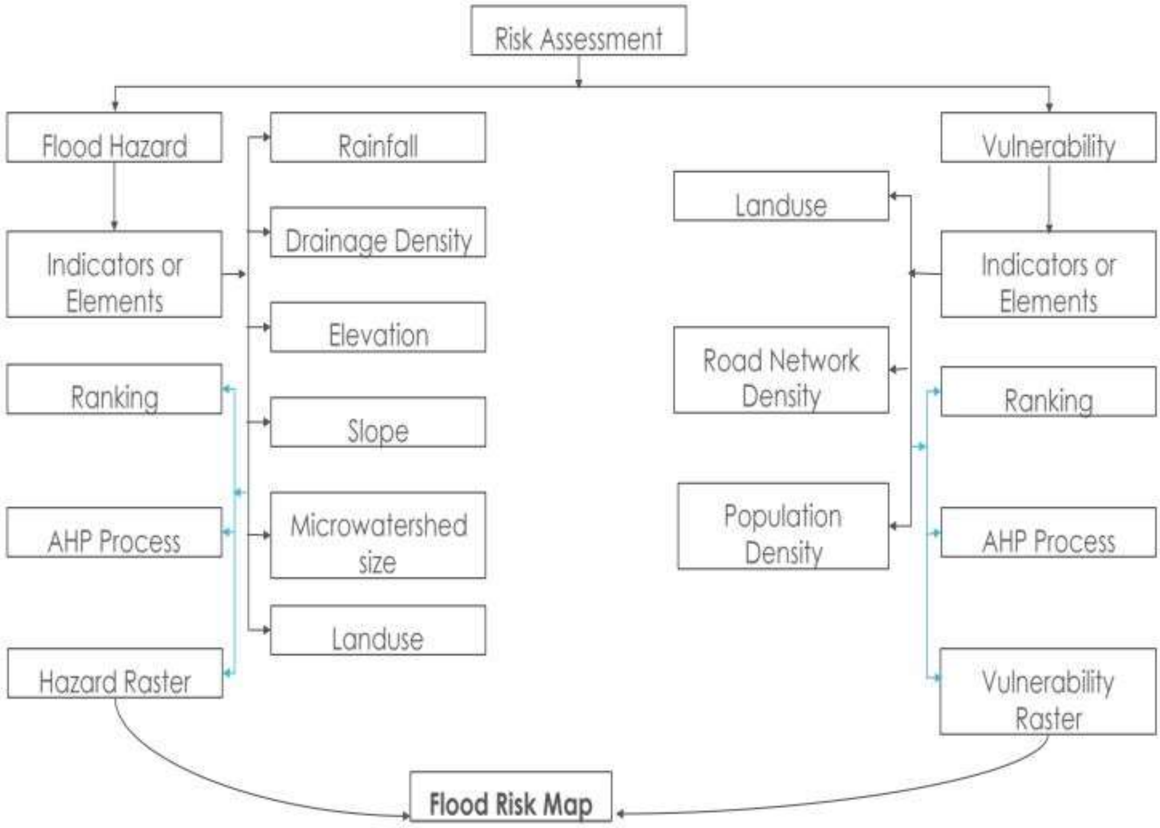
$$CI = \frac{\lambda_{max} - n}{n-1}$$

The consistency index CI can be directly calculated from the preference matrix with
$\lambda_{max}$ =greatest eigenvalue of preference matrix
n= order of matrix
Based on expert knowledge and experience, Saaty & Vargas (1991) recommend a revision of the preference matrix if the consistency ratio CR exceeds a value of 0.1[5].

### 3.4. ExtAhp 20 - ArcGIS extension

To make the process easier an AHP extension was introduced to the ArcGIS software called the extahp20. The provided extension is an update of the old extAHP extension (AHP 1.1) which was available for download from the old Arc Scripts site. This update computes criteria weights according to the Analytic Hierarchy Process (AHP) but integrates a criteria hierarchy. It is a powerful tool for the creation of suitability maps (spatial planning, risk mapping and more). Manual and some example files included. Allows for up to 15 criteria. [5].

### 3.5. AHP criterion methodology and mapping




**Methodology flow chart**

#### 3.5.1. Flood hazard and vulnerability spatial map layers

Each of the maps were delineated or obtained from different sources and was reclassified into 5 categories to be used in the extAhp extension. Rank 5 was given highest importance while 1 was given lowest importance.

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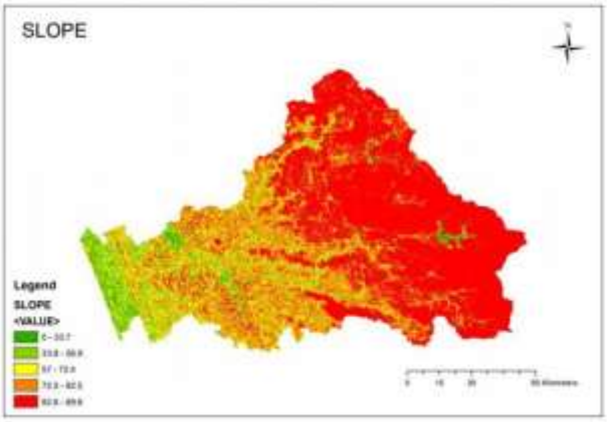
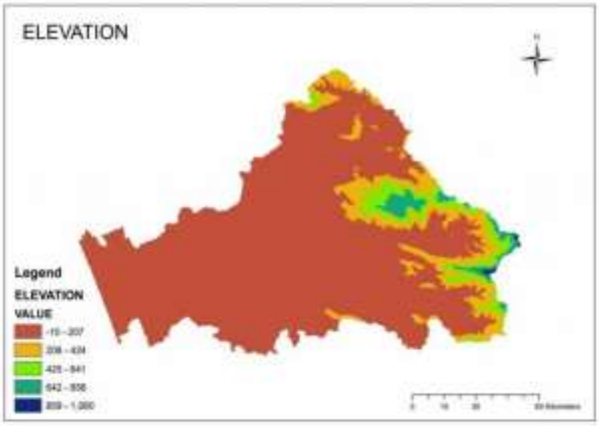
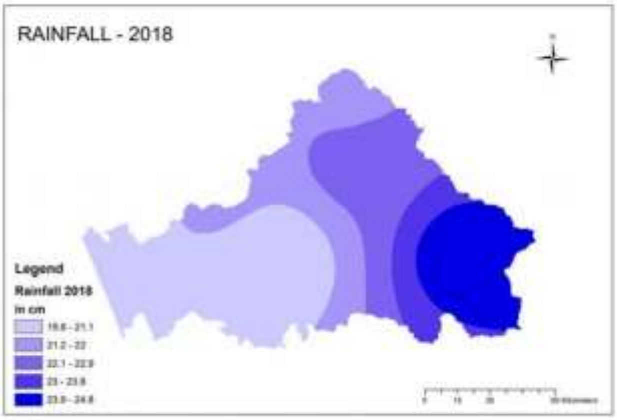
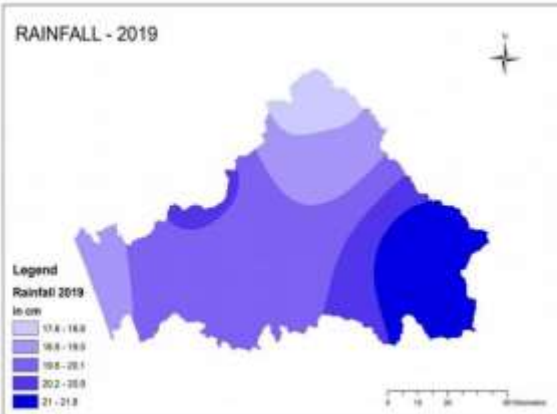



(a) (b)




(c) (d)

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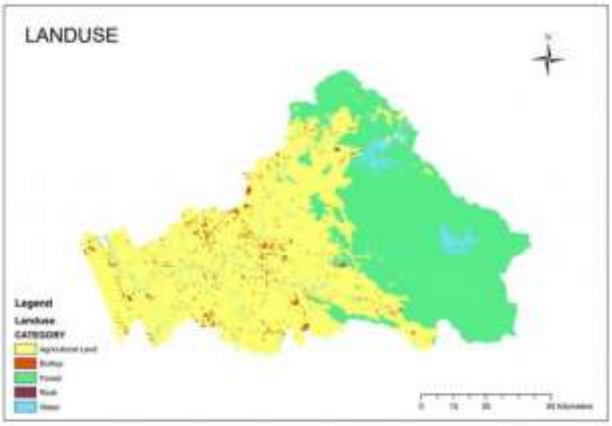
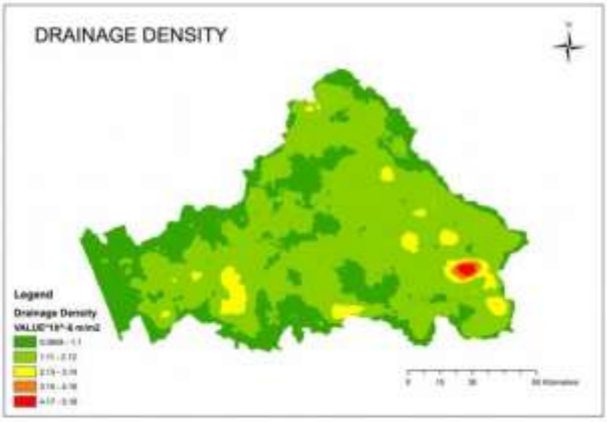
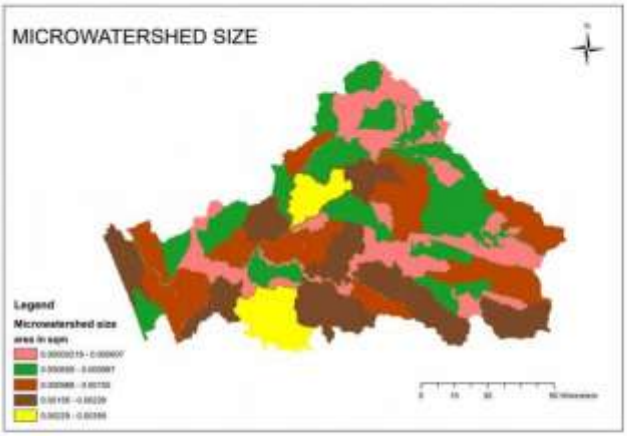



(e) (f)




(g)

Fig 1. Flood hazard elements (a) slope, (b) elevation (both delineated from DEM), (c) rainfall 2018, (d) rainfall 2019 ( 5 month average rainfall maps created using IDW technique), (e) landuse, (f) drainage density (from DEM), (g) microwatershed size.

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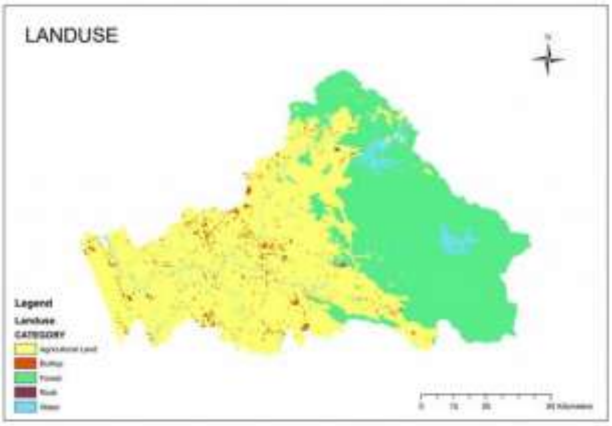
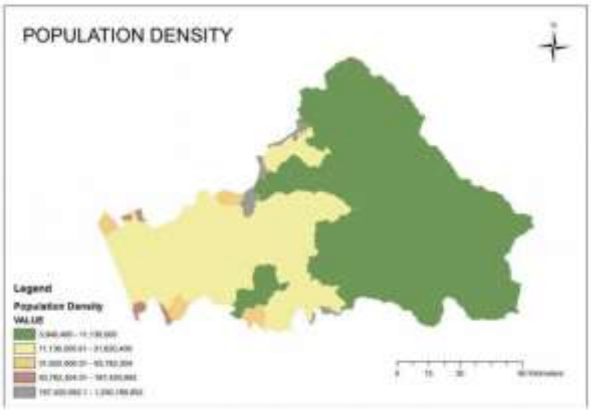
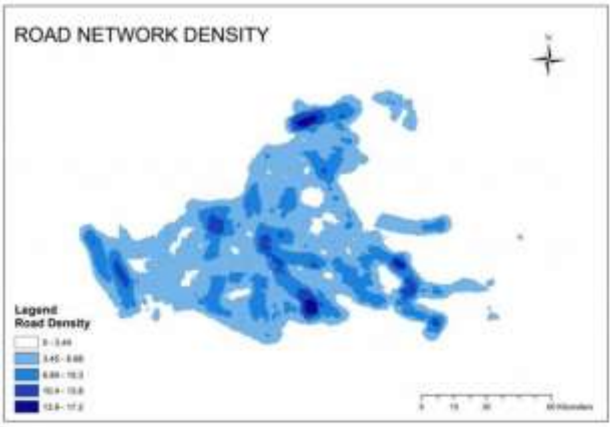



(a) (b)




(c)

Fig 2. Flood vulnerability elements (a) landuse, (b) population density (developed from census data 2011), (c) Road network density (generated from OSM (open street map) file).

### 3.5.2. Pairwise comparison matrix for hazard and vulnerability maps

In the comparison matrix values are given according to the SAATY scale of comparison given in table 1. The comparison matrix given such that the consistency value CR is less than 0.1. This comparison matrix gave weightages to each elements according to which the hazard map and vulnerability maps were generated.

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| | Rain 2018 | Rainfall 2019 | Drainage Density | Elevation | Slope | Microwatershed Size | Landuse |
|---|---|---|---|---|---|---|---|
| Rainfall 2018 | 1 | 1 | 0.5 | 5 | 5 | 3 | 7 |
| Rainfall 2019 | 1 | 1 | 0.5 | 5 | 5 | 3 | 7 |
| Drainage Density | 2 | 2 | 1 | 3 | 3 | 3 | 7 |
| Elevation | 0.2 | 0.2 | 0.333 | 1 | 3 | 0.333 | 5 |
| Slope | 0.2 | 0.2 | 0.333 | 0.333 | 1 | 0.333 | 5 |
| Microwatershed Size | 0.333 | 0.333 | 0.333 | 3 | 3 | 1 | 5 |
| Landuse | 0.143 | 0.143 | 0.143 | 0.2 | 0.2 | 0.2 | 1 |

**Table 3. Pairwise comparison matrix for hazard map**

| | Landuse | Road Network Density | Population Density |
|---|---|---|---|
| Landuse | 1 | 1 | 2 |
| Road Network Density | 1 | 1 | 3 |
| Population Density | 0.5 | 0.333 | 1 |

**Table 4. Pairwise comparison matrix for vulnerability map**

## 4. RESULT AND ANALYSIS

### 4.1. Spatial distribution of hazard

According to the pairwise comparison matrix given, the extension generated weightages for each elements which was developed into the hazard map. And the hazard map of Karuvannur basin was greatly influenced by the rainfall distribution as well as by the other chosen factors. The map showed higher level of hazard in the south eastern part of the basin. The hazard susceptibility was categorised into 5, they are very low, low, medium, high and very high.

| Element | Weightage |
|---|---|
| Rainfall 2018 | 22.967 |
| Rainfall 2019 | 22.967 |
| Drainage Density | 27.37 |
| Elevation | 7.564 |
| Slope | 5.468 |
| Microwatershed Size | 11.345 |
| Landuse | 2.318 |

**Table 5. Weightages generated for hazard map**

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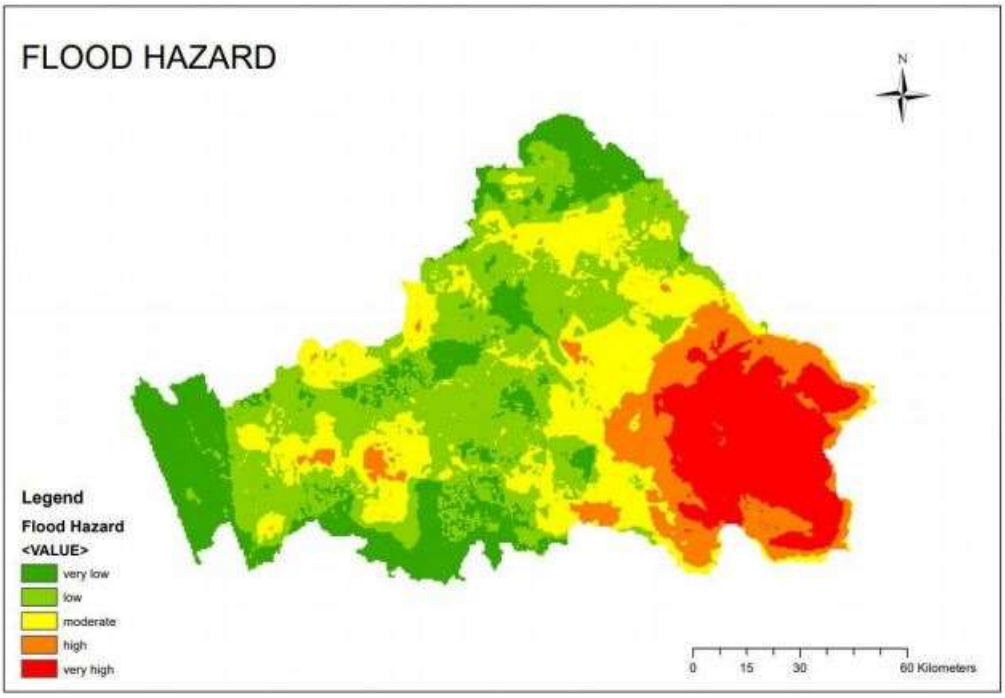


**Fig.3. Flood Hazard Map of Karuvannur river basin**

### 4.2. Spatial distribution of vulnerability

The vulnerability map was created by overlaying the vulnerability elements given in the pairwise comparison matrix and weightages were generated for the same by extahp extension. The resulting map shows that vulnerability was higher at the central area which was identified as areas with higher road network densities and had built up and agricultural land in it. The vulnerability also ranged from very low to very high.

| Element | Weightage |
|---|---|
| Landuse | 38.737 |
| Road Network Density | 44.343 |
| Population Density | 16.92 |

**Table 6. Weightages generated for vulnerability map**

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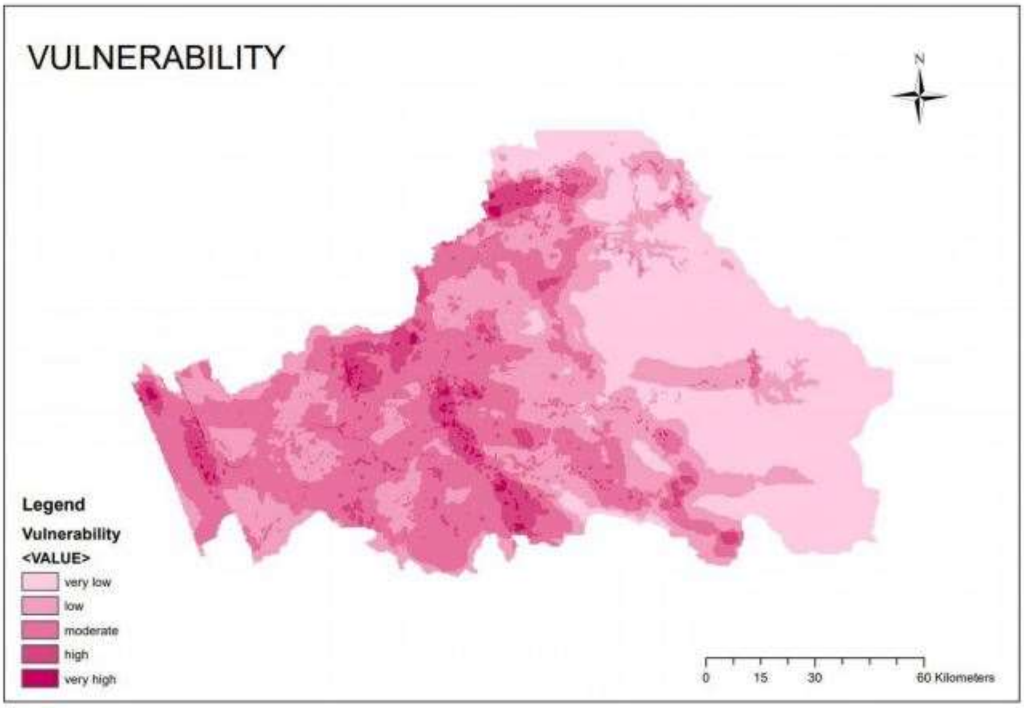


**Fig.4. Flood Vulnerability Map of Karuvannur river basin**

### 4.3. Spatial distribution of risk

The risk map was generated by giving both the hazard map layer and vulnerability map layer an equal importance. So the weightages generated were 50-50 for both hazard and vulnerability. The map resulted gives us an insight on how the risks would be spatially distributed if similar circumstances occur. In the map it shows that according to the criteria used and priorities given higher risks lies in the central and nearby areas of the basin. These areas were identified as places that has settlements and people living nearby with lot of agricultural land area. Here also the risk is categorised into 5 ranging from very low to very high.

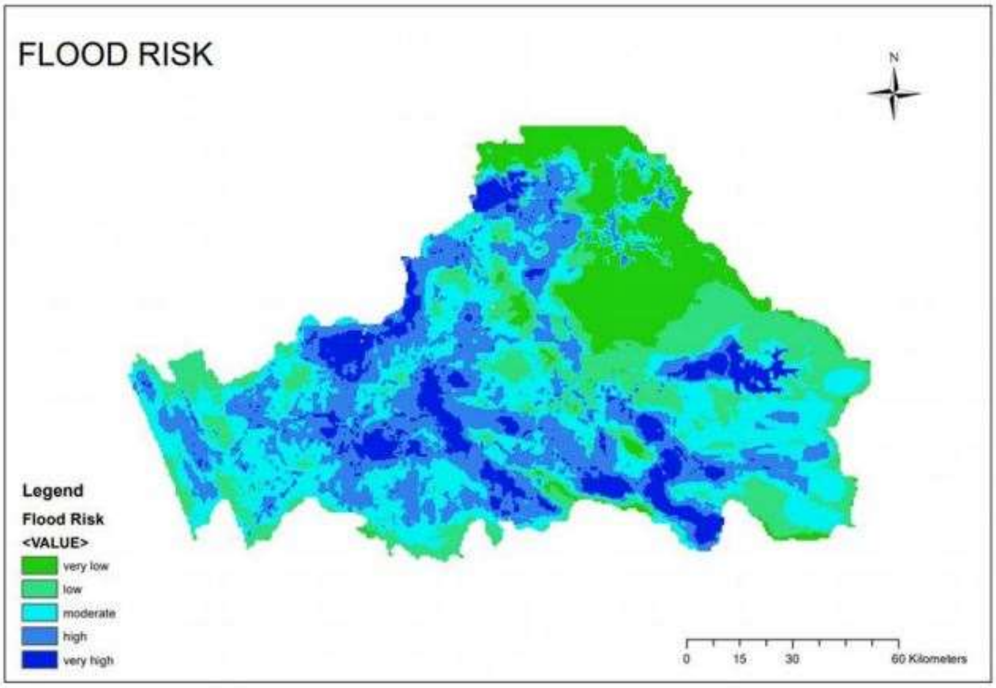


**Fig.5. Flood Risk Map of Karuvannur river basin**

## 5. CONCLUSION

In this study, various factors leading to flood hazard as well was factors that give way for vulnerability was selected and used to develop a risk map for the proposed area. Although a cross check was done with existing paper reports, no scientific validation has been carried out, so the accuracy of this map cannot be guaranteed. However, it can be used to identify the areas of risk, in order to take the best possible mitigation and management measures in the future.

There is need for further detailed study with updated and wider data so that a more accurate risk map can be generated for the area. The multicriteria decision making method adopted in the study was analytical hierarchy process which has its own advantage of being convenient tool for making GIS models using decision making process. The limitation lies with the prioritisation of various elements in the matrix as that is dependent on the skill, topography and causative factors of a flood. So, more integrated researches has to be carried out in order to arrive at more reliable way of prioritising the causative elements.

The results obtained when compared with the news reports indicates the need for further assessment of the basin area and coming to more solid and reliable conclusions which can be used for future planning. Keeping in mind the ever increasing flood situations there is need for government and organisations to invest and conduct detailed studies with presentable GIS models in the river basins like Karuvannur to understand the flood hazard, vulnerability and risk better.

## 6. REFERENCE

1. *Rincon Romero, Daniela & Khan, Usman & Armenakis, Costas. (2018). Flood Risk Mapping Using GIS and Multi-Criteria Analysis: A Greater Toronto Area Case Study. Geosciences. 8. 275. 10.3390/geosciences8080275.*
2. *Saaty, T.L. (2008) 'Decision making with the analytic hierarchy process', Int. J. Services Sciences, Vol. 1, No. 1, pp.83–98.*
3. *Drissia T K, Binny C P, Anitha A B. "Flood Hazard Mapping of Kauvannur River Basin of Kerala India". International Journal of Scientific Research, Volume 5, Issue 12, December-2016*
4. *District Census Handbook Thrissur, Village and Town wise Primary Census Abstract (PCA) series 33, part XII-B, Census of India 2011.*
5. *Oswald Marinoni, (2015), AHP extension extAhp20 pdf document. Intro AHP Extension Satecs.*
6. *Meyer, Volker; Haase, Dagmar; Scheuer, Sebastian (2007): GIS-based multicriteria analysis as decision support in flood risk management, UFZ Discussion Paper, No. 6/2007, Helmholtz-Zentrum für Umweltforschung (UFZ), Leipzig (2007).*
7. *P G, Vinod. (2013). Flood hazard assessment of Vamanapuram River Basin, Kerala, India: An approach using Remote Sensing & GIS techniques. Advances in Applied Science Research. 4. 263-274.*
8. *Yahaya, Sani & Ahmad, Noordin & Abdalla, Ranya. (2010). Multicriteria analysis for flood vulnerable areas in Hadejia-Jama'are River basin, Nigeria. European Journal of Scientific Research ISSN. 42. 1450-216.*
9. *Elsheikh, R.F.A., Ouerghi, S. and Elhag, A.R. (2015) Flood Risk Map Based on GIS, and Multi Criteria Techniques (Case Study Terengganu Malaysia). Journal of Geographic Information System, 7, 348-357.*
10. *Seejata, K., Yodying, A., Wongthadam, T., Mahavik, N., & Tantanee, S. (2018). Assessment of flood hazard areas using Analytical Hierarchy Process over the Lower Yom Basin, Sukhothai Province. In Procedia Engineering (Vol. 212, pp. 340–347). Elsevier Ltd.*
11. *Ghosh, Abhishek & Kar, Shyamal. (2018). Application of analytical hierarchy process (AHP) for flood risk assessment: a case study in Malda district of West Bengal, India. Natural Hazards. 94. 10.1007/s11069-018-3392-y.*
12. *Subhankar Chakraborty & Sutapa Mukhopadhyay, 2019."Assessing flood risk using analytical hierarchy process (AHP) and geographical information system (GIS): application in Coochbehar district of West Bengal, India," Natural Hazards: Journal of the International Society for the Prevention and Mitigation of Natural Hazards, Springer;International Society for the Prevention and Mitigation of Natural Hazards, vol. 99(1), pages 247-274, October.*