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FLOOD HAZARD MAPPING OF KARUVANNUR RIVER BASIN OF KERALA, INDIA

Management

KEYWORDS: flood hazard map, morphometric analysis, Karuvannur River

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ABSTRACT

Frequent occurrence of floods causes destruction to life and property. Flood hazard maps are created for identifying the flood prone area. Morphometry based flood hazard zone delineation is an indirect method. In this study morphometry based flood hazard zone was identified in Karuvannur river basin of Kerala using geographic Information System (GIS). The riverbasin was divided into five subbasins according to the location of the stream gauge stations. The morphometric parameters are divided into two groups as to how they affect floods. The group I include morphometric parameters like basin area (A), drainage number (Nu), total stream length (Lu), drainage density (Dd), stream frequency (Fs), circulatory ratio (Rc), basin slope (Bh) which are directly proportional to flood. Group II includes elongation ratio (Re), mean bifurcation ratio (Rb), infiltration number (If), and Ruggedness Coefficient (Rn) which are inversely proportional to flood. The summation of the parameters in each group after normalization divides this area into five groups of flood zones; very high risk, high risk, medium risk, low and very low risk area. The study reveals that about 6.75% of area is prone to high flood risk and 57.28% medium flood risk. This study will help in the planning of flood management.

INTRODUCTION

Extreme events like floods are occurring frequently in many parts of India. As per the National Flood Commission (Rashtriya Barh Ayogh-RBA) in 1980 an area of 40 Million hectares are flood prone in India (GIPC, 2011). Heavy rainfall along with the topographic characteristics of the watershed like area, length of stream, slope etc enhances the flood. The morphometric parameters calculated from the watershed characteristics influence the hydrological processes. The effect of morphometric parameters on hydrology was depicted in a study conducted in Western Ghats region of Maharashtra (Samal, 2015). GIS was successfully applied in all the morphometry related studies.

Flood Hazard Mapping is an important component in flood studies which helps in planning necessary flood management measures. It creates easily-read, rapidly-accessible charts and maps which facilitate the identification of areas at risk of flooding and also helps to prioritise mitigation and response efforts (Bapulu & Sinha, 2005). Flood hazard maps are delineated to increase awareness of the likelihood of flooding among the public, local authorities and other organisations. This helps the residents of flood-prone areas to find out more about the local flood risk and to take appropriate action (Environment Agency, 2010).

Flood hazard maps are delineated using satellite images of the time when flood occurred (Ho, 2010). This is a direct approach. On the contrary morphometric parameters can be used for delineating flood prone area which is an indirect method. In a study conducted by Lingadevaru (2015) flood prone zonation has been done using morphometric parameter in Karnataka.

Due to heavy and continuous rainfall riverine flooding is recurring phenomena in Kerala. In this State, flood damages are caused due to reclamation and settlement in floodplain area as per Kerala State Disaster Management Authority. According to National Centre for Earth Science Studies, 2010 about 14.8% of Kerala State is prone to flooding. More than 50% of area in Alappuzha district is flood prone followed by Ernakulam and Thrissur districts. In Thrissur district an area of 688.44 Km2 is identified as flood prone (KSDMP, 2010). Hence Karuvannur river basin that falls in Thrissur district was taken for the present study. The objective of the study is to identify the flood prone area in Karuvannur river basin based on basin morphometry using GIS.

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 kilometers 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 downstream end of the river basin is Kol wet land. The river joins river Conolly Canal which takes branches out and joins Enamakkal Lake in one direction and joins Periyar River in another direction. The average annual rainfall of the river basin is 2922 mm and average stream flow of 1232 Mm^3.

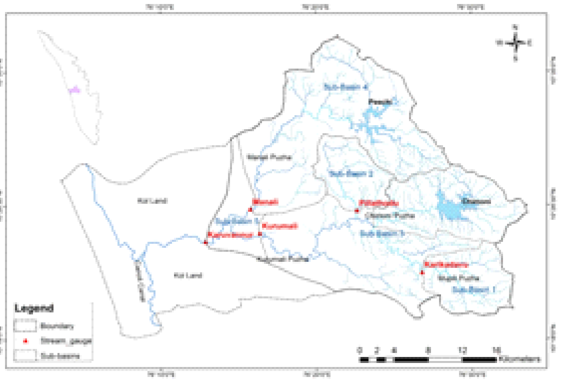

Figure 1: Subbasin map of Karuvannur River basin

MATERIALS AND METHODS

Karuvannur river basin has five stream gauging stations, which are monitored by Water Resource Department, Government of Kerala. The boundary and drainages of river basin were digitalized from topographic maps of survey of India (1: 50000) in ArcGIS. Based on the location of stream gauge station, the river basin was divided into five subbasins. The location of gauging stations and subbasins are given in Fig. 1. The area of subbasins ranges from 67 km2 to 711 km2 and the annual discharge ranges from 195 to 1232 MCM (Table. 2). Since the downstream of the river basin is a low lying area with no defined river stream, this region was not taken for the study. Morphometry based study may not give a proper result for this area.

TABLE – 1 DETAILS OF SUBBASINS

Sl no	Subbasin	Stream gauge station	Catchment area, km^2	Annual Mm^3
1	Subbasin 1	Karikadavu	80.91	255
2	Subbasin 2	Pillathodu	67.50	195
3	Subbasin 3	Kurumali	695.91	880
4	Subbasin 4	Manali	244.34	259
5	Subbasin 5	Karuvannur	725.00	1232

The morphometric parameters like basin area, perimeter andmaximum length of the basin were worked out by direct measurements from ArcGIS, while the other parameters like bifurcation ratio, drainage density, stream length etc have been calculated by the equations given in table 2. The stream ordering was done according to the hierarchical ordering developed by Horton and later modified by Strahler (1945).

TABLE – 2 PARAMETERS AND FORMULAES

Parameter	Formula	Parameter
Linear Aspects		
Stream Order (N_u)	Hierarchical ranking	(Strahler, 1964)
Stream Length (L_u)	Length of the	(Horton, 1945)
Mean stream length (L_{sm})	$Lsm = L_u / N_u$	(Strahler, 1964)
Stream length ratio (R_L)	$R_L = L_{sm}/L_{sm-1}$	(Horton, 1945)
Bifurcation ratio (R_b)	$R_b = N_u/N_{u+1}$	(Schumm, 1956)
Areal Aspect		
Drainage Density (D_d)	$D_d = L_u/A$	(Horton, 1945)
Stream Frequency (F_s)	$F_s = N_u/A$	(Horton, 1945)
Circularity ratio (R_c)	$R_c = 4\pi A/P^2$	(Strahler, 1964)
Elongation ratio (R_e)	$R_e = 2\sqrt{(A/\pi)}/L_b$	Schumm, 1956
Infiltration number (I_f)	$I_f = D_d \times F_s$	(Zavoiance, 1985)
Relief aspect		
Basin relief (B_h)		
Relief ratio (R_h)	$R_h = B_h/L_b$	(Schumm, 1956)
Ruggedness number (R_n)	$R_n = B_h \times D_d$	(Schumm, 1956)

Source: Samal et.al., (2015)

The morphometric parameters are classified into two groups on the basis of morphometric characteristics and their relationships with flood hazard. Group I includes basin area (A), total drainage number (Nd), total stream length (Lu), drainage density (Dd), stream frequency (Fs), circulatory ratio (Rc), basin slope (Bh) and these are directly proportional to flood hazard. Higher the parameter value higher is the parameter risk flood. Group II parameters include elongation ratio (Re), mean bifurcation ratio (Rb), infiltration number (If), and Ruggedness Coefficient (Rn) which are inversely proportional to flood hazard. Higher the parameter value lower is the risk of flood.

The values of these parameters are different in scale and magnitude. So it was necessary to normalize the values to bring them to a common scale (0-1). For group I where the parameters are directly proportional to flood, the parameters are normalized using equation 1. While group II include variables which are inversely proportional to the flood and the same is normalized using the equation 2 (Alrikabi et.al, 2015). The normalized value of all parameters were summed and divided into five categories using equal interval.

$$N_{x(1)} = (x - x_{min})/(x_{max} - x_{min}) \quad \textbf{1}$$
$$N_{x(2)} = 1 - (x - x_{min})/x_{max} - x_{min}) \quad \textbf{2}$$

RESULT AND DISCUSSION

The morphometric parameters were calculated for the five subbasins of Karuvannur River. The result of morphometric analysis was given in table 3. The river basin is a 7^{th} order river and the subbasins are of 5th and 6th order. The stream order increased as the area of the subbasin increased. The values of drainage density indicate that the subbasins fall in low drainage density category. The low drainage density indicated high permeable subsoil under dense vegetative cover (Samal,et. al. 2015). The value of circulatory ratio (Rc) ranges from .38 to .69 which indicates the subbasins are more or less circular in nature. In circular basins runoff is higher than elongated basins (Singh, 2964).

In group II, elongation ratio, bifurcation ratio, infiltration factor, ruggedness coefficient and length of overland flow are the parameters taken. The elongation ratios are classified as the value greater than 0.9 indicates circular basin, 0.8-0.9 oval basin, 0.7-0.8 less elongated and less than 0.7 elongated (Gardiner, 1978). Accordingly the elongation ratio (Re) was shown high in subbasin 1, 2, and 4 indicating oval or circular basins. The subbasin 3 and 5 indicate less elongated category. Bifurcation ratio of subbasins ranges from 3-5 which states that geological factor does not alter the drainage pattern (Christopher et. at 2010). In this study all the subbasins were found to have values between 3 and 5. The value of length of overland flow (Lo) ranges from 0.1-0.3 (Gardiner, 1978). Subbasins 1, 2 & 3 were observed to have less length of overland flow indicated more runoff but they have short course of flow.

TABLE – 3 MORPHOMETRY PARAMTERS OF SUBBASINS

Group I					
Parameter	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5
Stream Order	5	5	6	6	7
A(km^2)	67.42	55.91	408.14	255.58	711.91
Nu	323	292	1691	713	2405
Lu	209.59	183.49	1122.02	507.24	1639.97
Dd	3.11	3.28	2.75	1.98	2.30
Fs	4.79	5.22	4.14	2.79	3.38
Rc	0.69	0.61	0.46	0.38	0.54
Rh	0.069	0.052	0.017	0.017	0.014
Group II					
Re	0.92	0.88	0.78	0.81	0.79
Rb	4.02	3.93	4.27	3.64	3.67
If	14.89	17.13	11.39	5.53	7.78
Cr	0.21	0.172	0.047	0.034	0.032
Lo	0.161	0.152	0.182	0.252	0.213

Each parameter was giving some information regarding the runoff. But to make a readable map these parameters were normalized using equation 1 and 2. The normalized values were summed and categorized each subbasin into different zones. The results are shown table 4. Based on the analysis the region has three divisions viz. high flood risk, medium flood risk and low flood risk areas. It was observed that subbasin 5 is under high flood category and subbasins 1, 2 and 3 are in medium flood category. The extreme divisions like very high flood risk area and very low flood risk area are not found in the region. The flood hazard map of Karuvannur river basin is shown in Figure 2.

TABLE – 4 FLOOD HAZARD ZONES

Sl. No	Flood Hazard Risk	Category	Subbasin	Area (km2)
1	> 9.6	Very high flood risk	-	-
2	7.2-9.6	High flood risk	subbasin 5	47.97
3	7.2-4.8	Medium flood risk	subbasin 1, 2 & 3	407.30
4	2.4-4.8	Low flood risk	subbasin 4	255.58
5	< 2.4	Very low flood risk	-	-

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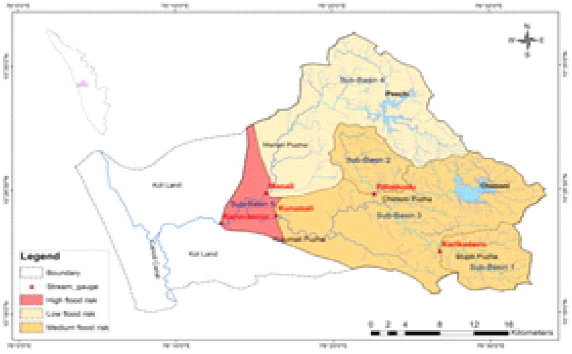

Figure 1: Subbasin map of Karuvannur River basin

CONCLUSIONS

The flood hazard map was derived for the Karuvannur river basin using morphometric parameters in GIS platform. The study reveals that about 6.75% of Karuvannur river basin is prone to high flood risk and 57.28%, medium flood risk. The delineation of flood prone area helps in planning flood management and mitigation measures for future planning.

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