Ind. J. of Landscape Systems and Ecological Studies **45**(1&2) Jun. & Dec. 2022, 17-38 **ISSN 0971-4170**

Detecting Flood Prone Zones in Lower Keleghai River Basin Using Weighted Overlay Method in GIS

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Abstract : *Flooding is one of the most devastating quasi-natural hazards in South-East Asian monsoon region. The recent study focused on flood risk zones (FRZ) by using multi-criteria evaluation (MCE) method with the help of Geographical Information System (GIS) of lower Keleghai river basin in West Bengal. For this purpose, post monsoon multi-temporal Landsat8 satellite imagery, topographical maps and Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data have been used to identify the severity level of flood risk area. To perform this study, different thematic raster layers of nine flood-conditioning factors integrated to prepare a flood-zoning map using Weighted Overlay Linear Sum Model (WLSM) in GIS environment. The method of training set and validation in different location in the study area of existing flood and prepared flood prone zone was been tested to validate the study. The results depicted that in general very low to severe flood risk zones found in the study area and the proposed multi-criteria approach of spatial layers in GIS environs provides a better assessment of flood risk zone. The outcomes of the study guide in developing comprehensive flood management strategies for efficient management in priority basis of present and future flood hazard in the area.*

Key words: *Flood Risk Zones, Multi-criteria Evaluation, Geographical Information System, Digital Elevation Model, Weighted Overlay Linear Sum Model, Flood Management Strategies.*

Introduction

Flood is considered as quasi-natural hazard and can have monumental impact on human societies all over world. It affects on average, 80 million people per year around the world. In estimation says 17.5 million people across South Asia are affected devastating flood event in 2020 and widespread flooding in India, Bangladesh, Nepal, Bhutan have affected 4 million of children (UNICEF Report, 2020). The major affected regions of India limited to the northern states of Assam, Bihar and West Bengal (Relief Web Report on flood and landslide, 2020). Nearly 46% of India's flood risk prone area lies within eleven states, of which about 35% of area lies within top two states namely Bihar and Uttar Pradesh. Major flood affected districts of the state in

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southern part is Nadia, Howrah, Murshidabad, North 24 Parganas, South 24 Parganas, Hugli, Purba Medinipur and Paschim Medinipur (WBDMD, 2020). Excessive rainfall for geographical location, poor natural drainage system, sedimentation in river bed, landfall of major cyclone associated with heavy downpour is the prime causes for the event in the state every year and resulting severe loss to standing crops, cattle and human properties which occurs in June to September (WBIWD report, 2020; WBDMD, 2020).Several studies have been made using different techniques and approaches to assess flood prone area zonation and delineate them into visualization with the help of maps, e.g., Multiple Criteria Analysis); Cluster Analysis, Frequency Ratio, Principal Component Analysis, 1D Model, 2D Model and other varied statistical models of different parts of the world (Abdullah et al., 2021). Out of these set of methods MCE/MCA is widely been used for flood zonation (Mukhopadhyay, 2016) because MCE method have strong and practical applications to delineate flood zones (Mariappan et al., 2019). Multi-Criteria Evaluation, the best and widely used method, could be used for flood zonation (Rahman and Saha, 2008). In this method several criteria will need to be evaluated and such procedure have been applied widely all over world (Nachappa et al., 2020). Multi-Criteria Evaluation can be achieved by Weighted Overlay (WO)/Weighted Linear Combination (WLC) in GIS environs (Aydi et al., 2013). In recent years, flood susceptibility mapping has been done using remote sensing data and GIS tools by many researchers all over the world and produced considerable good accuracy.

Study Area

The present study is conducted in Lower basin of Keleghai River (**Fig. 1**). The Keleghai river basin lies between 22º05'10"N to 22º21'05"N latitude and 87º05'09"E to 87º51'03" E longitude. The selected basin with an area of 1440 km^2 and located in the northwestern part of Purba Medinipur and Paschim Medinipur districts. This area has a subtropical with monsoon climate having an average annual precipitation 116 mm with the highest intensity of rainfall during June to September. Topography of the area represents elevations ranging from 0m to 41m, and 65% of the total area falls within 1 to 20m altitudes. About 70.21% of the total area falls under moderate to moderately steep slope (5-20$^{æ\%}$), indicating a potential zone for flood. The average monsoonal rainfall is observed 1746.6 mm.

Materials and Methods

The major objective in the present study is to identify the flood zones in terms of spatial dimension in Lower Basin of Keleghai River. Therefore, the major focusses of the present study are - (a) to assess the surface attributes like elevation, slope, drainage density using SRTM DEM, Google Earth and topographical map data set (b) to assess the mean annual rainfall using CHRS data sets (c) to assess water body density and topographic wetness SRTM DEM has been used to map Topographic Wetness Index (TWI) and Stream Power Index (SPI) and LULC from Landsat 8 OLI data set and (e) finally, to integrate the layers by WLC in GIS environment for ultimate flood zonation of the study area with the help of multi-criteria evaluation method using ArcGIS.

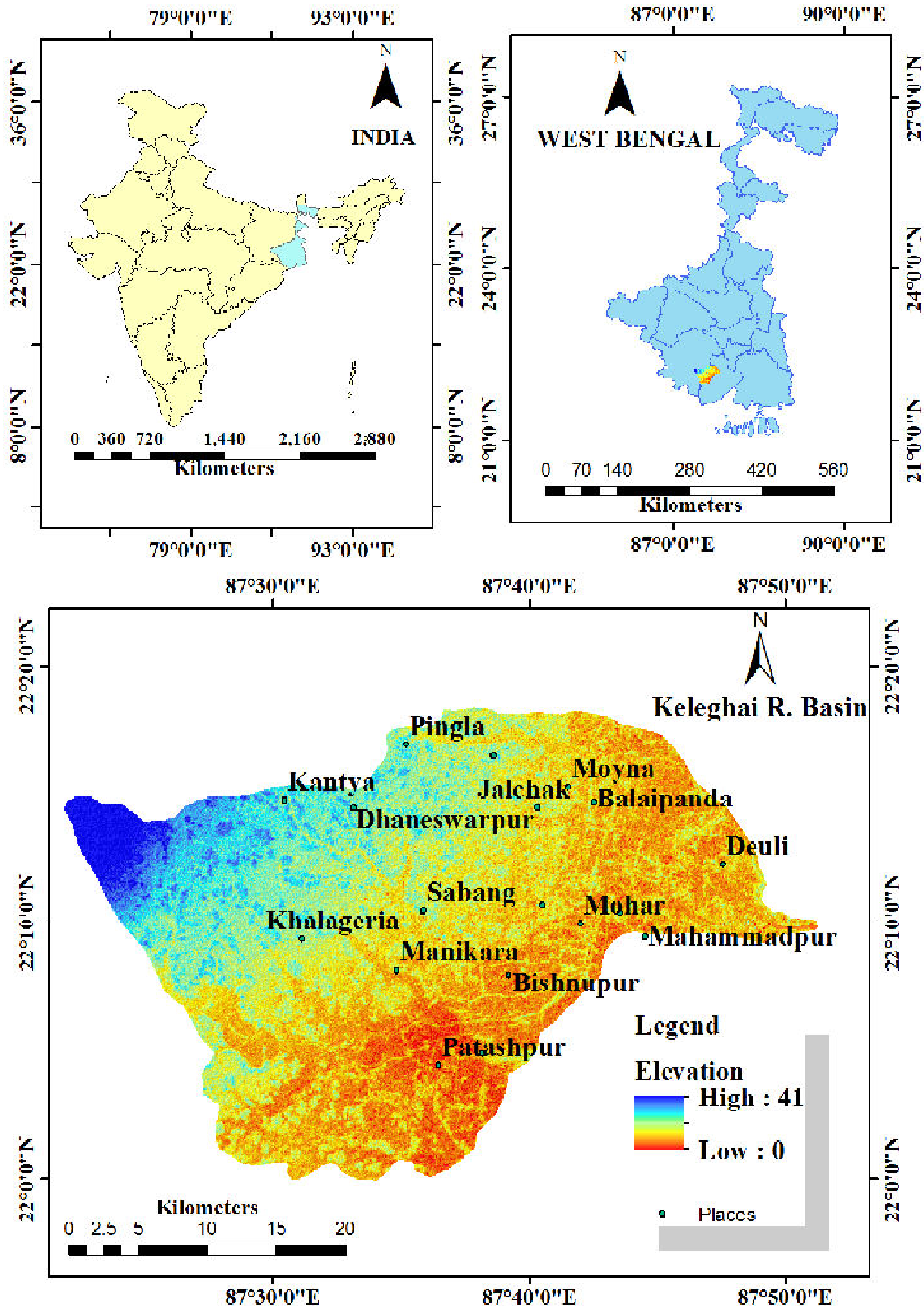

Fig.1: Location of the study area

Materials

To meet the objectives, different spatial data sets (Table 1) have been used viz. SRTM DEM of 30-metre resolution for topographic feature recognition, elevation and surface attributes i.e., slope, drainage density, Topographical Map of 1:250000 scale provided by general library University of Texas and Google Earth Pro version for surface feature, Landsat 8 Operational Land Imager (OLI) data set of 30m resolution for different band combination generated LULC, Geological Survey of India (GSI) provided Geomorphology data set, rainfall data from PERSIANN (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks) Cloud Classification System (PERSIANN-CCS) is a real-time global high resolution (0.04° x 0.04° or 4km x 4km) satellite precipitation product developed by the Centre for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine (UCI) for mean annual rainfall data from 2003 to 2020 delineation as illustrated in Table 1.

Table 1 Details of data used in flood prone zones analysis

Data	Sources (URL)	Type	Time/Period
Digital Elevation Model	https://earthexplorer.usgs.gov/	SRTM 1-arc second global	SRTM V 3.0, 2014
Satellite Images	http://landsat.usgs.gov	Landsat 7 (ETM+), Landsat 8(OLI)	TM, ETM+, 2003-2013, OLI, TIRS 2013-2020
Rainfall data	https://chrsdata.eng.uci.edu/	PERSIANN-CCS Gridded data Set	2003-2020
Geomorphology	http://www.portal.gsi.gov.in	Reference type	Geomorphology 250k Scale
Drainage networks	http://earth.google.com	Google Earth	Google Earth Pro 2020

Methodology

To meet the specific objective integrated remote sensing and GIS technique through MCE methodology have been adopted, which have been widely used for flood zonation mapping all over world. MCE is best and widely used method for flood hazard zonation around the world. The complete methodological overview illustrated in **Fig 2.**

Multi-Criteria Evaluation (MCE)

MCE method is best and widely used procedure to evaluate multiple/numerous criteria (Hazarika et al., 2018). The method is a decision-making tool used in environmental system analysis to evaluate a problem by giving an order of preference for multiple alternatives on the basis multiple criteria that may have different units and weight (Chakraborty and Mukhopadhyay, 2019). The MCE method can be achieved by two procedures as: (i) *Boolean Overlay* and (ii) weighted linear combination (WLC). Of the two WLC have been used in the study to execute the specific objective.

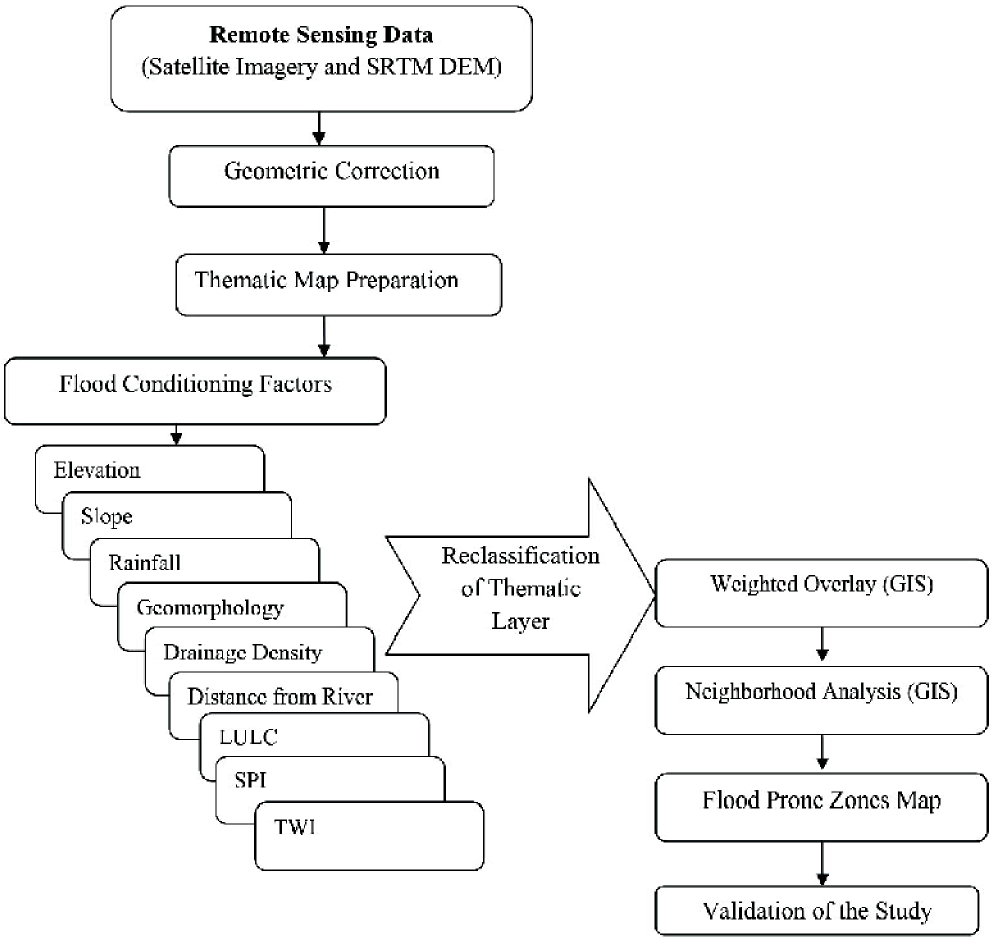

Fig.2: Methodological Overview of the study

Flood Contributing Factors

In our recent study, a composite flood hazard map based on nine flood-conditioning factors was constructed to identify flood prone zones. The flood conditioning factors considered in this study were selected based on literature survey and overall approach to flood hazard. **Figure 2** shows the methodology flowchart that was followed to map flood prone zones.

Elevation (m)

For determination of flood prone zones topography plays an important role in any area around the world. Specifically, areas in low elevations and in flat areas are particularly susceptible to flood hazards. Topographic elevation (**Figure 3a**) is inversely proportional to flood hazard (Kwak and Kondoh, 2008).

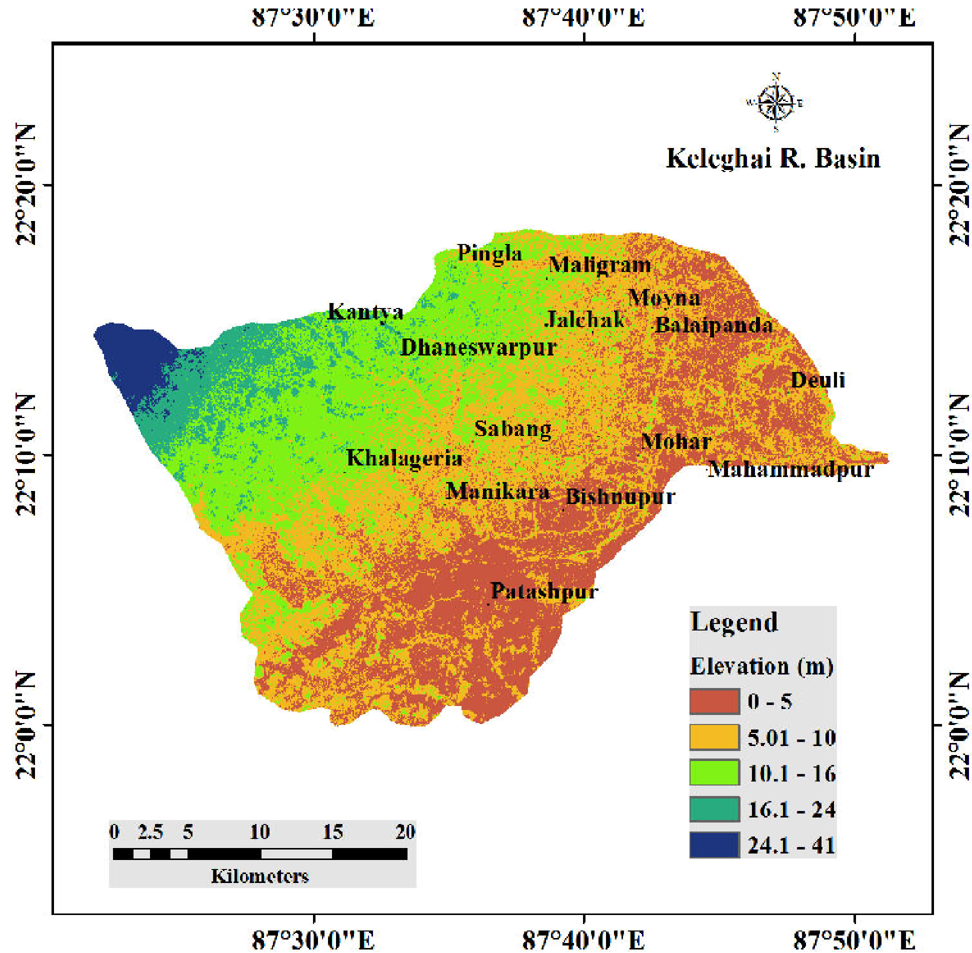

Fig.3a: Flood conditioning factors (a)-Digital Elevation Model

Slope (Degree)

Slope (**Figure 3b**) is one of the important factors that serve as a strong benchmark to indicate flood susceptibility in plain areas and areas with low topographic elevation. The risk of flood increases as the surface slope increases and it decreases as slope decreases in a specific area of study. The magnitude and intensity of water accumulation, water percolation are defined by the slope (Choubin et al., 2019).

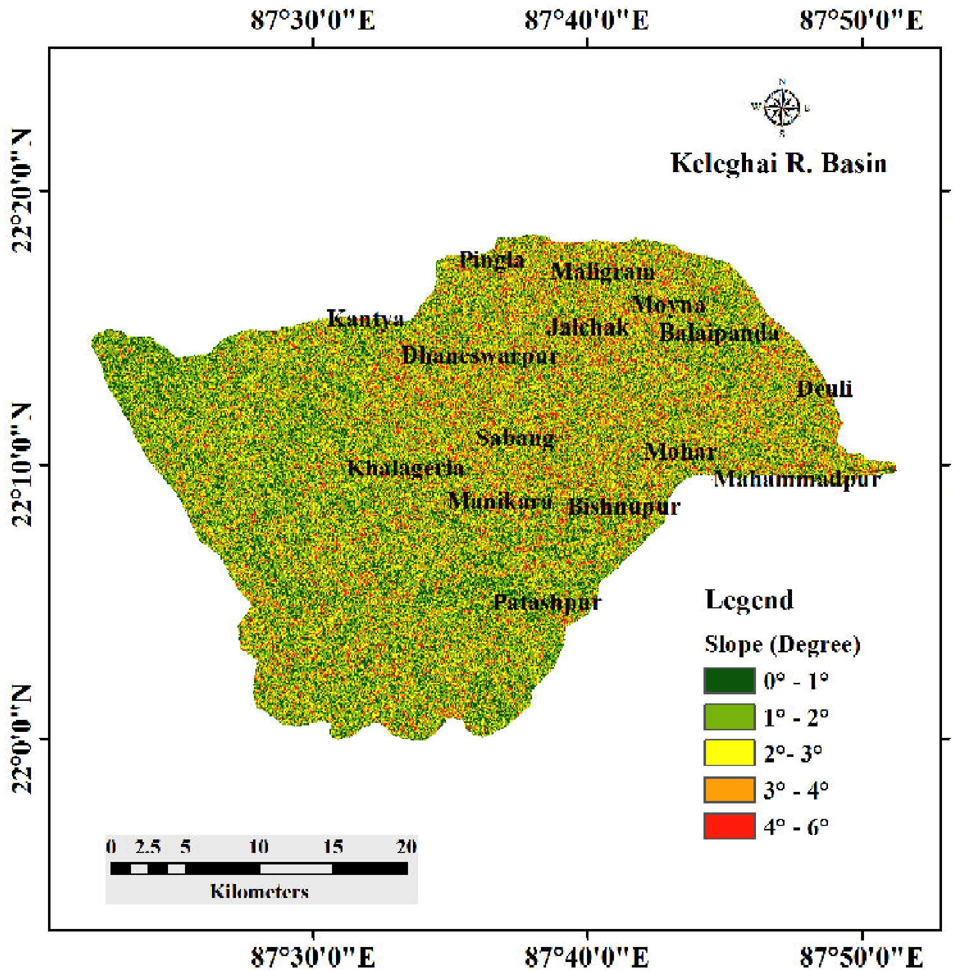

Figure.3b: Flood conditioning factors (b)-Slope

Rainfall (cm)

Rainfall is directly proportional to flood hazard (Tehrany et al. 2017). This factor was included in the study wherein average annual rainfall data (cm.) was obtained for four stations in the study area for the period between 01/01/2003 and 12/31/2020. The rainfall data have been used to create a rainfall map of the study area by the help of Inverse Distance Weightage method in ArcGIS (**Figure 3c**).

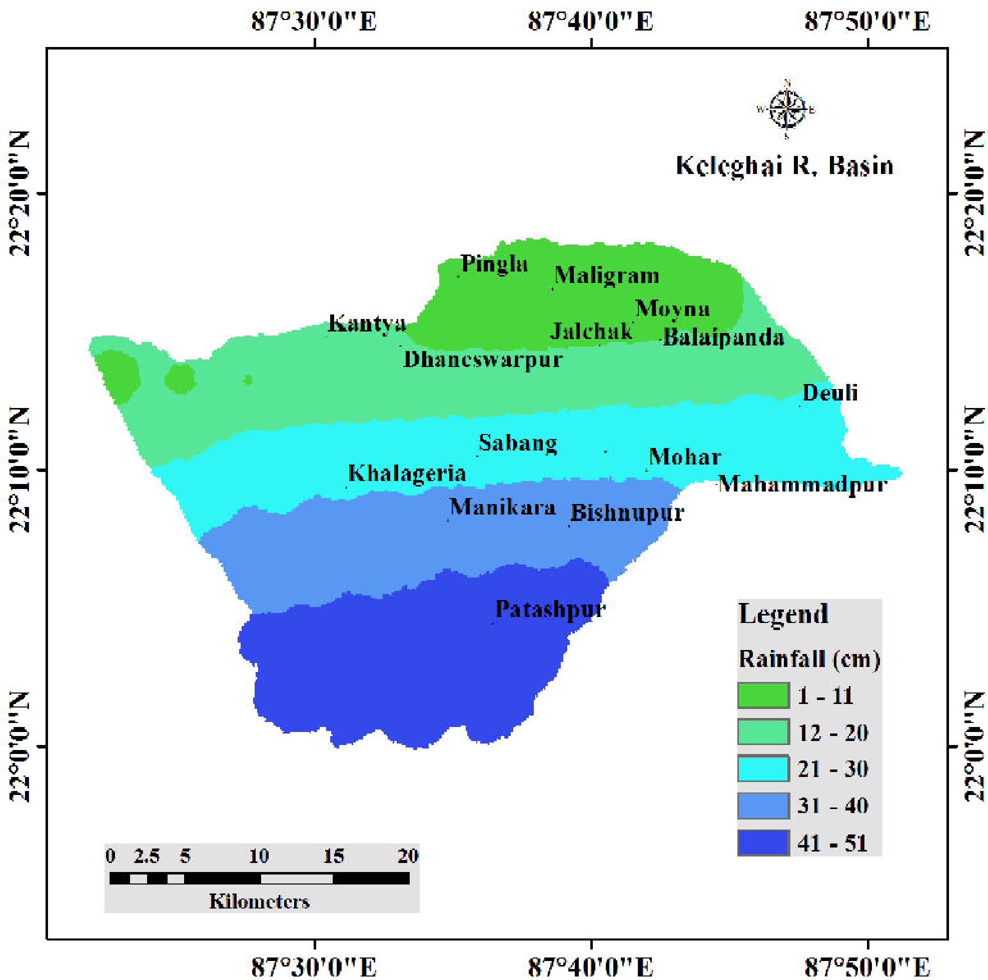

Fig.3c: Flood conditioning factors (c)-Rainfall

Geomorphology

The recent study area underlain by fluvial origin, which is overlain by river valley fill sediments and minor alluvium of recent age along the drainage courses. The study area experiences heavy erosion and erosional matter deposited in river bed resulting increase of river bed.

The landforms have been identified in the study area are fluvial origin active flood plain, older alluvial plain, older flood plain, pediment- pediplain complex and pond and water bodies (**Figure 3d**).

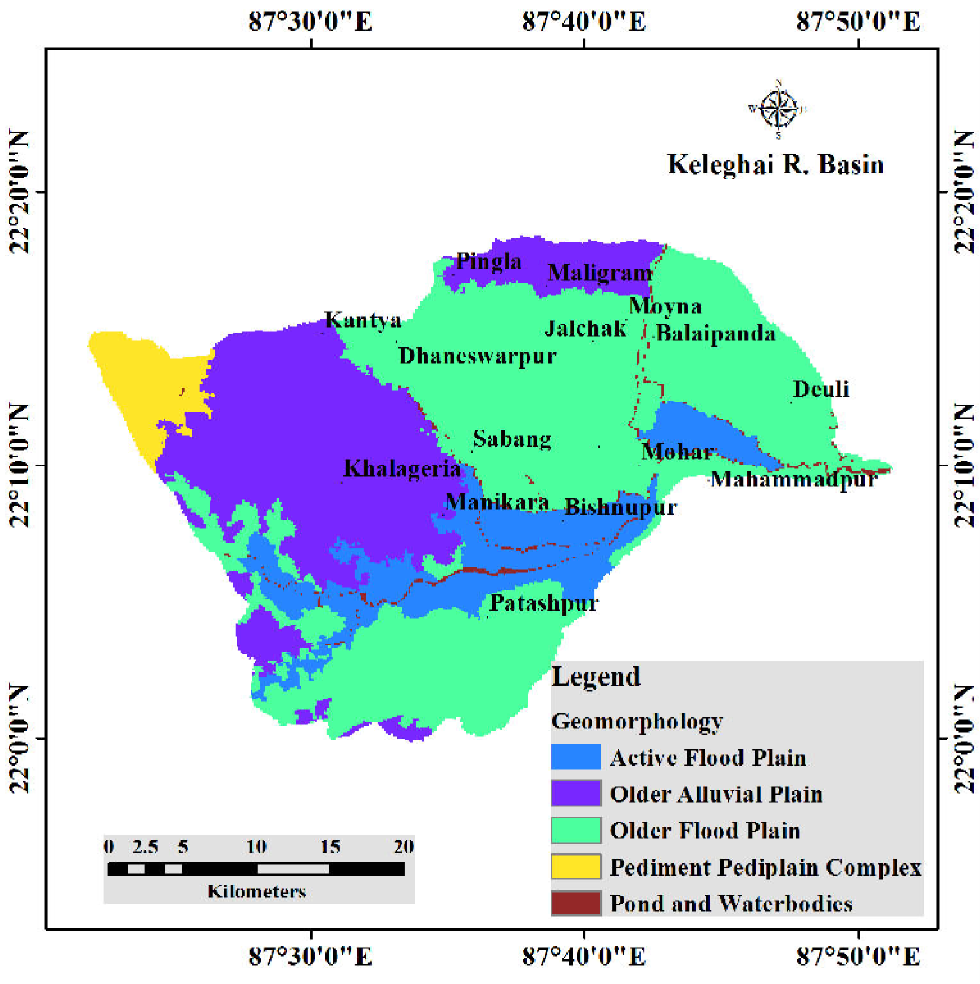

Fig.3d: Flood conditioning factors (d)-Geomorphology

Drainage density (km/km^2)

The drainage density is one of the important determinants of flood hazard and is determined by the drainage length per unit area (Horton, 1932). Therefore, drainage density would be one of the important factors in determining the susceptibility of every region to flood hazard (Shrestha and Lohpaisankrit, 2017). Drainage network was derived from the SRTM DEM and topographical maps published by survey of India (**Figure 3e**).

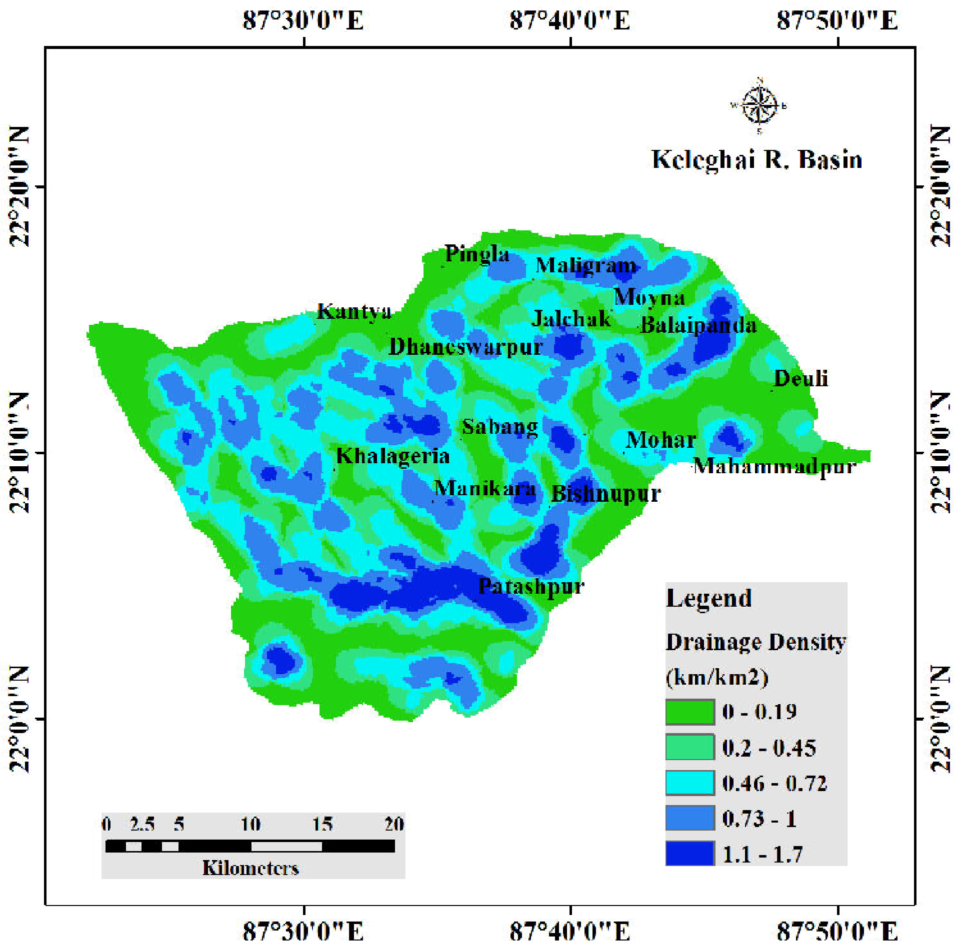

Fig.3e: Flood conditioning factors (e)-Drainage density

Distance from river (m)

As like other parameter distance from river is a significant for assessing flood hazard susceptibility (Choubin et.al., 2019). Heavy and stormy runoff caused Stream flow grows in a drainage system and when as it reaches stream capacity limits it transforms into flood hazard. In the Arc GIS software, the distance from river was prepared from the drainage network derived from topographical maps and SRTM DEM (**Figure 3f**).

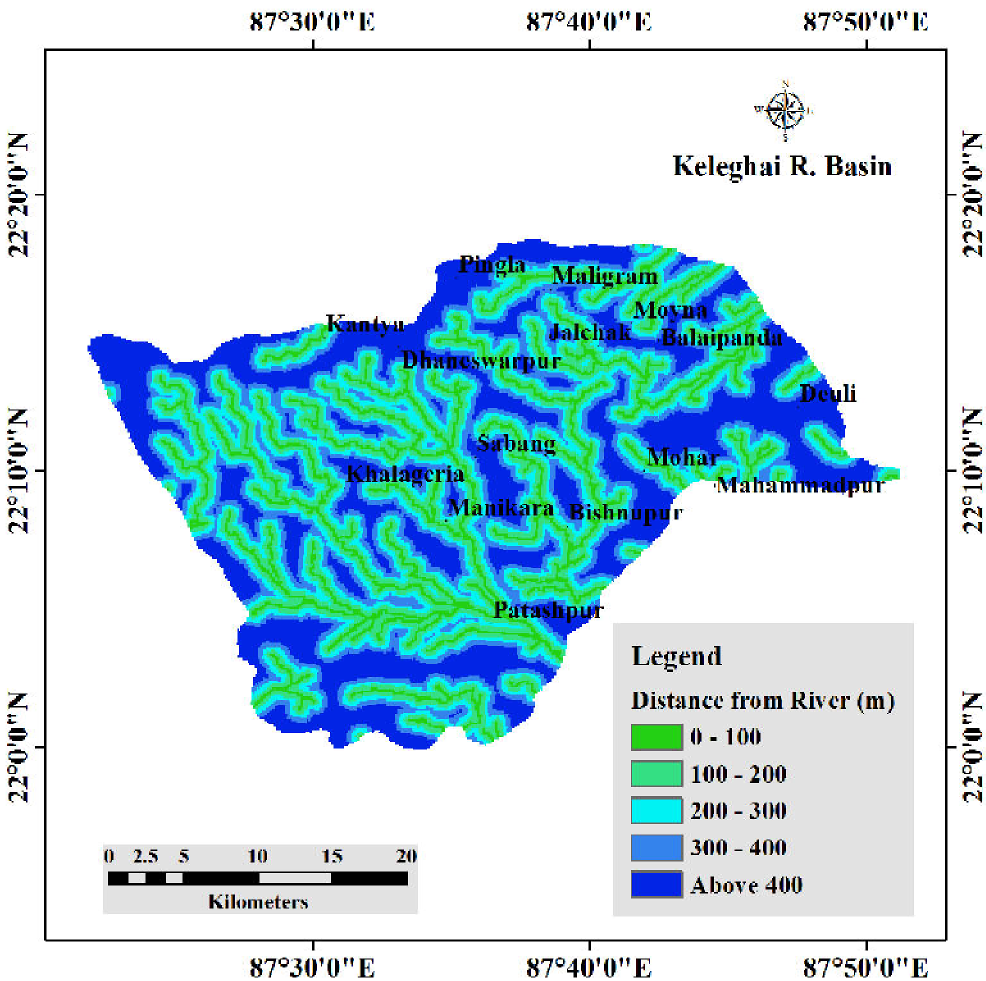

Fig.3f: Flood conditioning factors (f)-Distance from River

Land use and land cover (LULC)

Surface runoff, infiltration, and evapotranspiration process are usually affected by local land use and land cover (LULC) and its amount depends on LULC (Bui et al., 2019). Land use and land cover directly or indirectly affects the vulnerability of a region to flood hazard. In this article, USGS Landsat 8 data collected for prepare land use and land cover. Emphasis was given to five types of land use and land cover such as built up, agriculture, vegetation, fellow land and water body (**Figure 3g**).

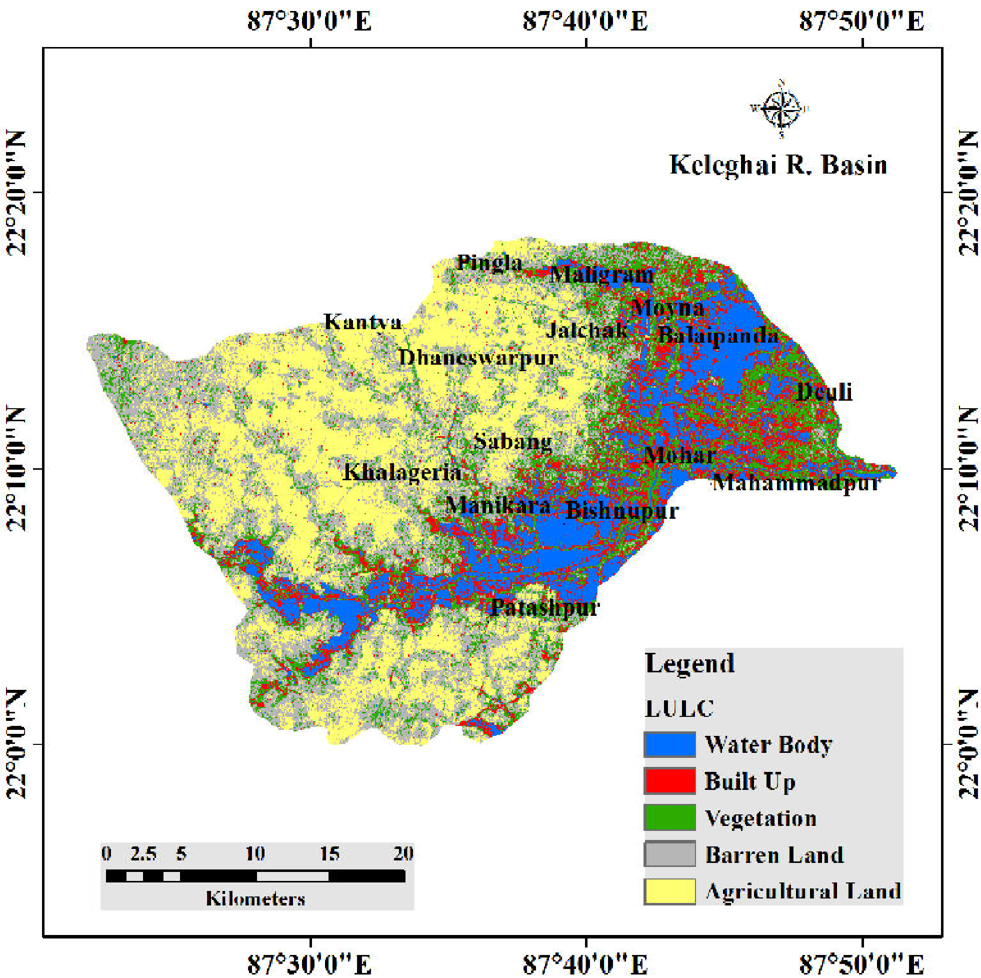

Fig.3g: Flood conditioning factors (g)-Distance from River

Stream Power Index (SPI)

Stream Power Index (SPI) describes the erosive potential and surface runoff rate at certain place (Khosravi et al., 2019). The higher index displays the higher surface runoff capacity and lower index represents the lower surface runoff of a definite region. Throughout stream power index analysis, the following equation 1 (**Figure 3h**) was computed using SRTM DEM in the Arc GIS environment.

$$SPI = A_S \times \tan \beta \qquad \text{(Equation 1)}$$

Where, A_S represent the specific catchment area in square meter and β represent the slope in degree. As per literature several studies have incorporated this index to predict the flood susceptibility of a certain area.

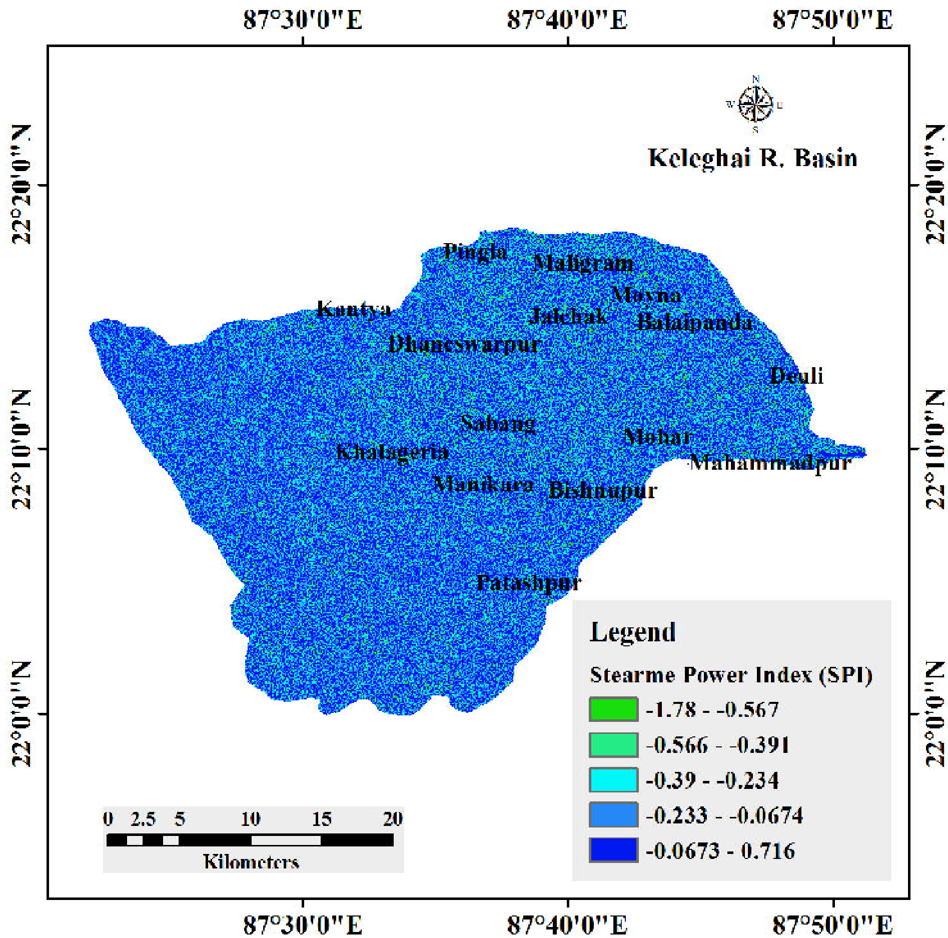

Fig.3h: Flood conditioning factors (h)-Stream Power Index

Topographic Wetness Index (TWI)

Topographic Wetness Index is one of the significant parameters that many scholars used to estimate the susceptibility of a region to flood hazard (Choubin et al., 2019). Spatial spreading and depletion of the surface runoff is regulated by topographic wetness index (Samanta et al., 2018).Topographic wetness index was determined from the DEM in the ArcGIS environment in this research work following the given equation 2 (**Figure 3i**).

$$TWI = \ln\left(\frac{A_S}{\tan(slope)}\right) \qquad \text{(Equation 2)}$$

Where, A_S represents the specific catchment area (m^2 m^{-1}) slope is in degree. Some past studiesshow that *TWI* and flood hazard susceptibility are positively related to each other (Khosravi et al., 2019). Thereby, it isa good indicator to predict the susceptibility of the flood.

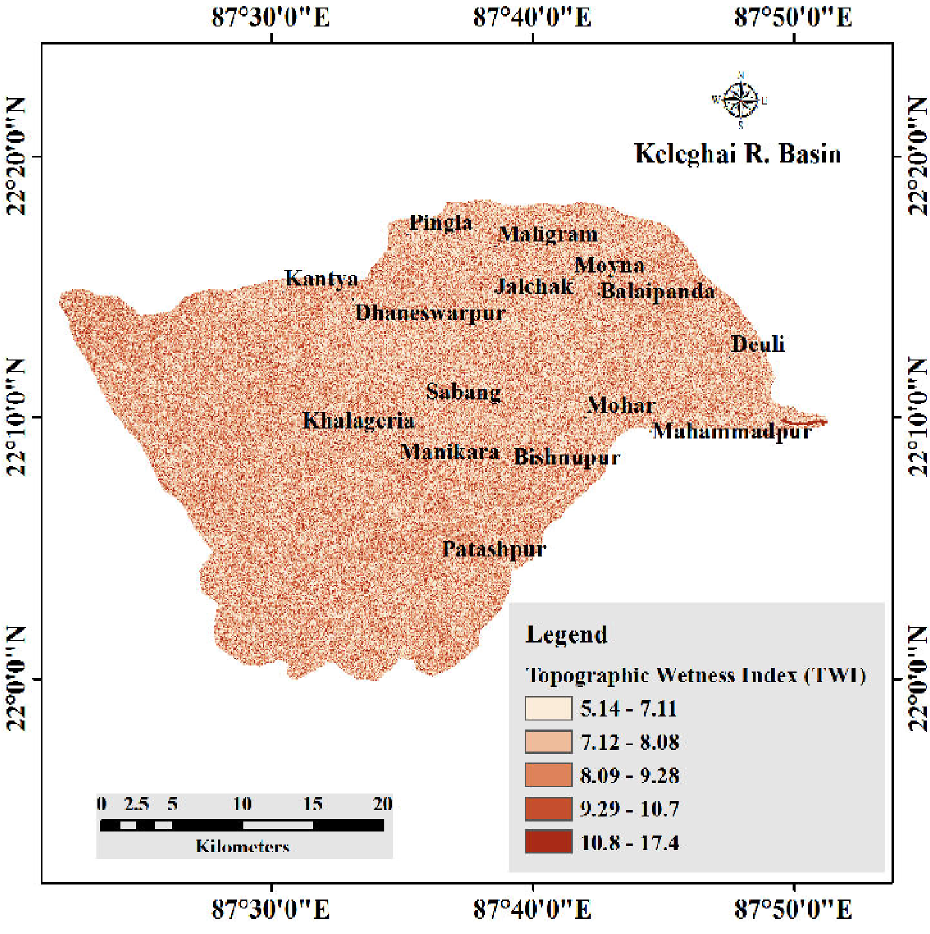

Fig.3i: Flood conditioning factors (i)-Topographic Wetness Index

Weighted Linear Combination (WLC)

Weight linear combination is well known and widely used procedure wherein continuous criteria are standardized to a common numerical range, and then combined them by means of weighted average layer in GIS environment using Multi Criteria Evaluation method. However, for continuous criteria/factor, which can affect flood hazard, a WLC is the most commonly used method, which has been used in several studies. Therefore, the study followed WLC procedure. With a WLC, criteria/factors are combined by applying weight to each followed by a summation of the results to yield a target (flood zonation map), i.e.

$$S = \sum w_i x_i \qquad \text{(Equation 3)}$$

Where, S = Target (flood prone zones map)

w_i = Weight of factor

x_i = Criteria Score of factor

Preparation of flood Prone Zones map using weighted raster-classification

In this study preparation of flood map using weighted raster-classification after computation of weights and ranks through weighted overlay linear sum model for each attribute and sub-attribute, we multiplied all the scores by 100 and integrated them in ArcGIS for the preparation of flood prone zones map using "raster calculator" incorporating the following expression (Eastman 2001):

$$FPZ = \sum_{i=1}^{N} \left(W_i \times r_i \right) \qquad \text{(Equation 4)}$$

Where, FPZ denotes flood prone zones, w_i and r_i indicate weights and ranks of each attribute and sub-attribute, respectively. The above expression can be re-written in a more explained "raster calculator" command form as equation (5). The flood susceptibility map using weighted overlay linear sum model was constructed using the following equation:

$$\begin{aligned} FPZ_{WLC} = {} & \left(El \times w_{WLC} \right) + \left(Sl \times w_{WLC} \right) + \left(R \times w_{WLC} \right) + \left(Geom \times w_{WLC} \right) \\ & + \left(Dd \times w_{WLC} \right) + \left(Dr \times w_{WLC} \right) + \left(Lulc \times w_{WLC} \right) + \left(SPl \times w_{WLC} \right) \\ & + \left(TWI \times w_{WLC} \right) \qquad \text{(Equation 5)} \end{aligned}$$

Where, w_{WLC} is the weightage for each flood contributing actors. The pixel values obtained are then classified into five classes (Very Low, Low, Moderate, High and Very high) based on natural break to determine the class intervals in the flood prone zones map (**Figure 4**).

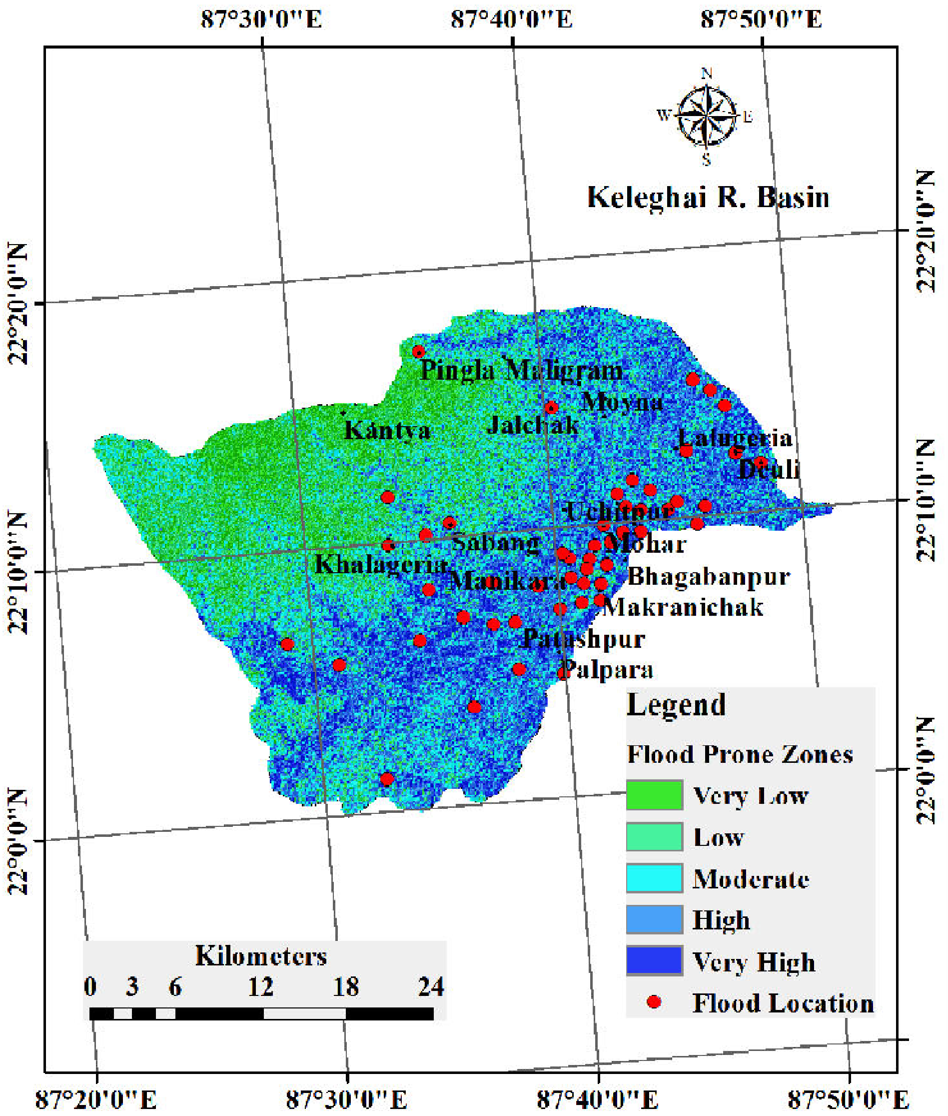

Fig.4: Flood prone zones map of Keleghai River Basin

Validation of The Study

In this study fifty training samples (**Figure 5**) has been marked randomly on the basis of flood location after making final layer of flood prone zones and at last it was validated in field to verify the flood prone zones in the study area as well. For this purpose, same location in map was validated by using GPS device of fifty-point location during rainy season in study area and some picture of the area also collected as a proof (**Figure 6**).

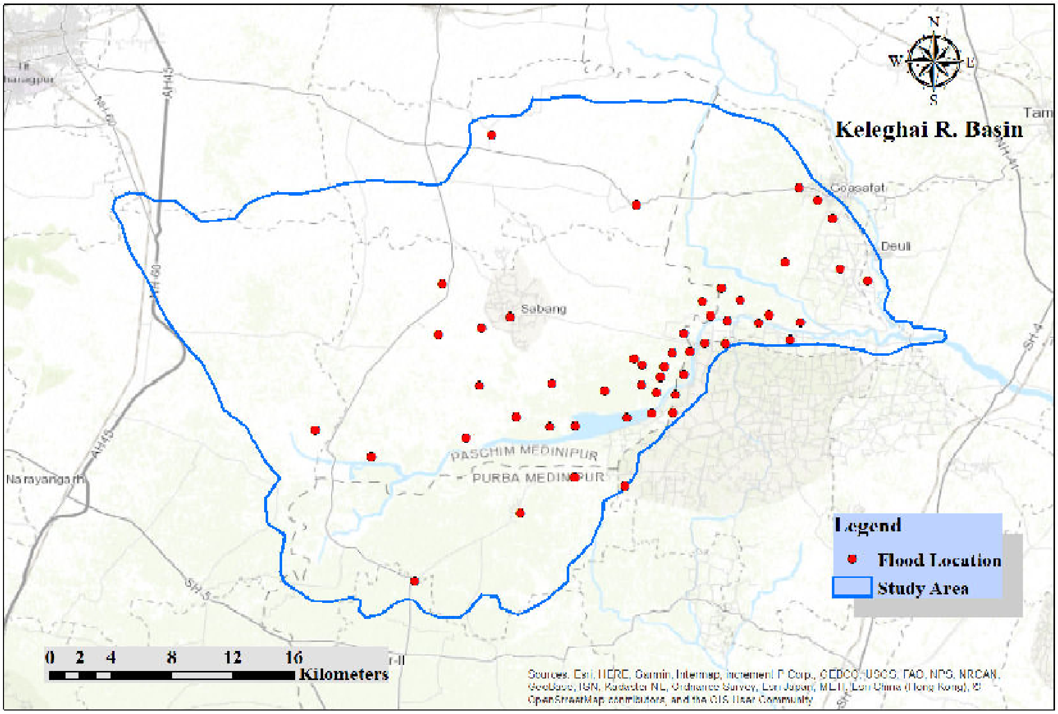

Fig.5 : Training samples

Fig 6 Ground control points by using GPS for ground truth verification/validation of the study

Table 2: Assignment of ranking and weightage values of different thematic map layers

Parameter	Sub-Class	Rank	Weight
Elevation (m)	0-5	5	31
	5-10	4	
	10-16	3	
	16-24	2	
	24-41	1	
Slope (°)	0-1	5	22
	1-2	4	
	2-3	3	
	3-4	2	
	4-6	1	
Rainfall (cm)	1.01-11.4	5	15
	11.5-20.2	4	
	20.3-29.8	3	
	29.9-39.8	2	
	39.9-51	1	
Geomorphology	Older Alluvial Plain	5	11
	Pediment Pediplain Complex	4	
	Older Flood Plain	3	
	Active Flood Plain	2	
	Pond and Water body	1	
Drainage Density (km/km^2)	0-0.188	5	7
	0.189-0.449	4	
	0.45-0.718	3	
	0.719-1.05	2	
	1.06-1.71	1	
Distance from River (m)	0-100	5	5
	100-200	4	
	200-300	3	
	300-400	2	
	400-600	1	

Table 2: contd..

LULC	Agricultural Land	5	4
	Barren Land	4	
	Water body	3	
	Vegetation	2	
	Built Up	1	
SPI	-1.78- -0.557	5	3
	-0.557- -0.371	4	
	-0.37- -0.234	3	
	-0.233- -0.077	2	
	-0.077- -0.716	1	
TWI	5.14-7.16	5	2
	7.17-8.08	4	
	8.09-9.23	3	
	9.24-10.7	2	
	10.8-17.4	1	

Results and Discussion

Weighted Overlay based flood prone zones mapping

Application of weighted overlay has been performed for the Keleghai River in flood prone zones. The lower portion of the river basin being low laying region has been found to be highly prone zone to flood. While the upper part of the basin shows very low to moderate to low prone to flooding. The region prone to flooding has been categorized into five groups - such as very low (<0.15), low (0.15-0.20), moderate (0.20 – 0.27), high (0.27 – 0.32) and very high flood susceptible zone (>0.32), depending on the classification system of natural breakage in ArcGIS framework. Spatial coverage of and percentage of the region prone to flood was presented in **Table 3**. **Table 3** and **Figure 4** reveal that large portions of the drainage basin are below the very high flood prone area (13.07%). While the basin's region of 11.71%, 21.75%, 25.98%, and 27.47%, were very low, low, moderate, high flood prone areas. Flood locations of Keleghai River basin was validated by GPS location with the help of ground control points. The very high and high flood prone zones are connected with the low flat alluvial plain at an altitude of between 0 and 5 m.

Hydrologically, the area belongs to the lower Keleghai-Bagai-Kapaleswari basin; it is an extensive floodplain consisting of a number of flood basins like Brachokha, Dubda, Moyna and

Table3: Spatial coverage of and percentage of the region prone to flood.

Flood Prone Zones	Value	Number of Pixel	Area (in %)	Location
Very Low Prone Zones	<0.15	6711	11.71	Kantya, Khakurda
Low Flood Prone Zones	0.15-0.20	12468	21.75	Pingla, Maligram
Moderate Flood Prone Zones	0.20 – 0.27	14891	25.98	Jalchak, Moyna
High Flood Prone Zones	0.27 – 0.32	15745	27.47	Bhagabanpur, Mohar
Very High Flood Prone Zones	>0.32	7494	13.07	Sabang, Pataspur

Bhagabanpur Basins. It is found that elevation, slope, LULC, geomorphology, rainfall, drainage density, distance from river, SPI, TWI, recent alluvium and older alluvium (Panskura formation) of the study area have become very influential in flood prone zones mapping. Result shows that Kantya and Khakurda falls in very low flood prone zone (11.71%), Pingla and Maligram falls in low flood prone zone (21.75%), Jalchak and Moyna falls in moderate flood prone zone (25.98%), Bhagabanpur and Mohar falls in high flood prone zone (27.47%), Sabang and Pataspur falls in very high flood prone zone (13.07%). Area lies in high flood prone zone have very high intensity of rainfall, very low elevation, very high drainage density, and less distance from river, causes are responsible flood susceptibility.

Conclusion

Flood hazard is a disastrous natural event causing loss of life and properties every year. The disastrous natural event can occur in any geographic location around the world. Losses of life and properties, due to flooding events have increased exponentially in recent years. Therefore, the study is more significant. In this study, useful and widely used strategy for flood hazard prone zone has been adopted. Such strategies include design of early warning systems, strategies for flood management, integrating GIS and remote sensing techniques, delineating areas prone to flood hazard. Such strategies can serve as a valuable tool for planners, policy makers, government, emergency service providers and people of the area. The study will also help early forecasts and better management of flood hazard in the study area.

References

Abdullah, M. F., Siraj, S. and Hodgett, R. E. (2021). An Overview of Multi-Criteria Decision Analysis (MCDA) Application in Managing Water-Related Disaster Events: Analysing 20 Years of Literature for Flood and Drought Events. *Water*, *13*(10), 1358.

Aydi, A., Zairi, M., and Dhia, H. B. (2013). Minimization of environmental risk of landfill site using fuzzy logic, analytical hierarchy process and weighted linear combination methodology in a geographic information system environment. *Environmental Earth Sciences*, *68* (5), 1375-1389.

Bengal Disaster Management and Civil Defence Department, Government of West Bengal, India. East and West Midnapore District Disaster Management Plan, 2018-2020. Available online: http://wbdmd.gov.in/Pages/district_dm_plan.aspx (accessed on July 2020).

Bui, D. T., Tsangaratos, P., Ngo, P. T. T., Pham, T. D., & Pham, B. T. (2019). Flash flood susceptibility modeling using an optimized fuzzy rule-based feature selection technique and tree-based ensemble methods. *Science of the total environment*, *668*, 1038-1054.

Chakraborty, S., and Mukhopadhyay, S. (2019). Assessing flood risk using analytical hierarchy process (AHP) and geographical information system (GIS): application in Coochbehar district of West Bengal, India. *Natural Hazards*, *99*(1), 247-274.

Choubin, B., Moradi, E., Golshan, M., Adamowski, J., Sajedi-Hosseini, F., and Mosavi, A. (2019). An ensemble prediction of flood susceptibility using multivariate discriminant analysis, classification and regression trees, and support vector machines. *Science of the Total Environment*, *651*, 2087-2096.

Eastman, J. R. (2001). Guide to GIS and image processing USA: Clark University., p. 144.

Hazarika, N., Barman, D., Das, A. K., Sarma, A. K., and Borah, S. B. (2018). Assessing and mapping flood hazard, vulnerability and risk in the Upper Brahmaputra River valley using stakeholders' knowledge and multicriteria evaluation (MCE). *Journal of Flood Risk Management*, *11*, S700-S716.

Horton, R. E. (1932). Drainage basin characteristics. *Eos, transactions American geophysical union*, *13*(1), 350-361.

Irrigation and Waterways Department, Government of West Bengal, India, Annual Flood Report, 2008. Available Online: https://wbiwd.gov.in/index.php/applications/anual_flood_report (accessed on July 2020).

Kwak, Y., and Kondoh, A. (2008). A study on the extraction of multi-factor influencing floods from RS image and GIS data; a case study in Nackdong Basin, S. Korea. In *The International Archives of The Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS Congress Beijing* (Vol. 37, pp. 421-426).

Khosravi, K., Shahabi, H., Pham, B. T., Adamowski, J., Shirzadi, A., Pradhan, B., and Prakash, I. (2019). A comparative assessment of flood susceptibility modeling using multi-criteria decision-making analysis and machine learning methods. *Journal of Hydrology*, *573*, 311-323.

Mariappan, S., Roslee, R., and Sharir, K. (2019, November). Flood Susceptibility Analysis (FSAn) Using Multi-Criteria Evaluation (MCE) Technique for Land use Planning: A Case from Penampang, Sabah, Malaysia. In *Journal of Physics: Conference Series* (Vol. 1358, No. 1, p. 012067). IOP Publishing.

Mukhopadhyay, A., Hazra, S., Mitra, D., Hutton, C., Chanda, A., and Mukherjee, S. (2016). Characterizing the multi-risk with respect to plausible natural hazards in the Balasore coast, Odisha, India: a multi-criteria analysis (MCA) appraisal. *Natural Hazards*, *80* (3), 1495-1513.

Nachappa, T. G., Piralilou, S. T., Gholamnia, K., Ghorbanzadeh, O., Rahmati, O., and Blaschke, T. (2020). Flood susceptibility mapping with machine learning, multi-criteria decision analysis and ensemble using Dempster Shafer Theory. *Journal of Hydrology*, 125275.

Rahman, R., and Saha, S. K. (2008). Remote sensing, spatial multi criteria evaluation (SMCE) and analytical hierarchy process (AHP) in optimal cropping pattern planning for a flood prone area. *Journal of Spatial Science*, *53*(2), 161-177.

Relief Web Report. 17.5 million Affected by floods and threatened by disease in South Asia—August 2020. Available online: https://reliefweb.int/disaster/fl-2020-000164-ind (accessed on 6th August 2020).

Relief Web. India: Floods and Landslides—July 2020. Available online: https://reliefweb.int/disaster/fl-2020-000164-ind (accessed on 15 August 2020).

Shafapour Tehrany, M., Shabani, F., Neamah Jebur, M., Hong, H., Chen, W., and Xie, X. (2017). GIS-based spatial prediction of flood prone areas using standalone frequency ratio, logistic regression, weight of evidence and their ensemble techniques. *Geomatics, Natural Hazards and Risk*, *8*(2), 1538-1561.

Shrestha, S., and Lohpaisankrit, W. (2017). Flood hazard assessment under climate change scenarios in the Yang River Basin, Thailand. *International Journal of Sustainable Built Environment*, *6*(2), 285-298.

UNICEF Report. Millions of children affected by devastating flooding in South Asia. Available online: https:/ /www.unicef.org/press-releases/millions-children-affected-devastating-flooding-south-asia-many-more-risk-covid-19 (accessed on 23rd July 2020).

West Bengal Disaster Management and Civil Defence Department, Government of West Bengal, India. Report on Natural Disaster: Flood. Available Online: http://wbdmd.gov.in/pages/flood2.aspx (accessed on July 2020).