Original Research Paper

Volume - 12 | Issue - 06 | June - 2022 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Geography

IDENTIFICATION OF FLOOD PRONE ZONES IN LOWER KELEGHAI RIVER BASIN BY USING WEIGHTED OVERLAY METHOD IN GIS

Nityananda Sar School of Human and Environmental Sciences North- Eastern Hill University, Shillong, India.

Dr. P.K Ryngnga* School of Human and Environmental Sciences North- Eastern Hill University, Shillong, India. *Corresponding Author

ABSTRACT The increasing demand of land for human print on earth surface caused large occupation of floodplains, increasing heavy downpour and poor drainage system induced waterlogging problem resulting frequent flood output in sub-tropical South-East Asian Monsoon region. Our recent study done to identify flood prone zones (FPZ) by using multi-criteria evaluation (MCE) method with the help of Geographical Information System (GIS) of lower Keleghai river basin in West Bengal is very helpful to planners and policy makers for executing further decision by initiating remedial measures and prioritizing areas. 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 has been validated by training set and validation set. The results depicted that in general very low to severe flood prone zones found in the study. The study will guide in developing comprehensive flood management strategies for efficient management in priority basis of present and future flood hazard in Keleghai river basin area.

KEYWORDS : Flood Prone Zones, Multi-criteria Evaluation, Geographical Information System, Digital Elevation Model, Weighted Overlay Linear Sum Model, Flood Management Strategies

1.0 Introduction

Flood is considered as quasi-natural hazard and can have monumental impact on human societies all over world. It affect on average, 80 million people per year around the world (Kundzewicz and Schellnhuber 2004). The major affected regions of India limited to the northern states of Assam, Bihar, and West Bengal. Heavy downpour and widespread flooding due to South-West monsoon was most common disaster in eleven states in India in 2020. As per Irrigation and Waterways Department, Government of West Bengal (2020), in West Bengal, major flood events was occurred several flood in the year of 1991, 1993, 1995, 1999 and 2000 during monsoon season. Major flood affected districts of the state in southern part is Nadia, Howrah, Murshidabad, North 24 Parganas, South 24 Parganas, Hoogly, Purba Medinipur and Paschim Medinipur. In East and West Midnapur districts, most of the flood event occurred in the period of June to September and affects entire districts potential impact on corps, animal, human and infrastructure. In recent years, flood susceptibility mapping, vulnerability studies have seen rapid methodological adaptation (Das, 2020). Several studies have been made using different techniques and approaches to assess flood prone area zonation e.g., Multiple Criteria Analysis (Rincon et al., 2018); Cluster Analysis, Frequency Ratio, Principal Component Analysis 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 (Rahman and Saha, 2007). 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 (Mahini and Gholamalifard, 2006).

2.0 Study Area

Our recent study 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 km2 and located in the northwestern part of Purba Medinipur and Paschim Medinipur district.

3.0 MATERIALS AND METHODS

3.1 Materials

For conducting, the study different spatial data sets has used like SRTM DEM from USGS, Landsat 8 OLI from USGS, Toposheets from Survey of India, precipitation data from CHRS of University of California (Table 1). Elevation, Slope, drainage density, topographical wetness index and stream power index has derived from SRTM DEM. Landuse and landcover map has generated from Landsat satellite imagery.

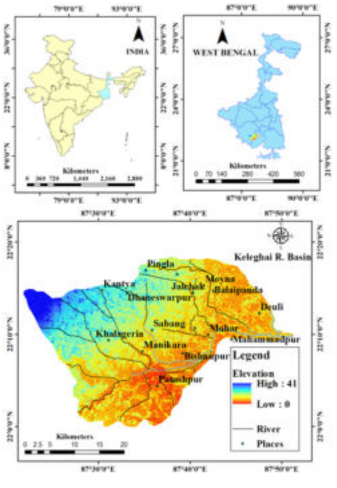

Fig 1 Location of the study area

4.0 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.

4.1 Multi-Criteria Evaluation (MCE)

MCE method is best and widely used procedure to evaluate multiple/numerous criteria (Kumari and Pandey, 2020, 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 major purpose of MCE method is to compare and rank alternative options and to evaluate environmental consequences according to criteria established in the study (Radwan et al., 2019). The MCE method can be achieved by two procedures as: (i) Boolean Overlay and (ii) weighted linear combination (WLC), out of these WLC have been used in the study to execute the specific objective.

Table 1 Details of data used in flood susceptibility 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

4.2 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)

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/km2)	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	
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	

$$FPZ = \sum_{i=1}^{N} (w_i \times r_i) \quad \text{(Equation 1)}$$

Where, denotes flood prone zones, and 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 (2). The flood susceptibility map using weighted overlay linear sum model was constructed using the following equation:

$$FPZ_{WLC} = (El \times w_{WLC}) + (Sl \times w_{WLC}) + (R \times w_{WLC}) + (Geom \times w_{WLC}) + (Dd \times w_{WLC}) + (Dr \times w_{WLC}) + (Lulc \times w_{WLC}) + (SPI \times w_{WLC}) + (TWI \times w_{WLC})$$

(Equation2)

Where, w_{WLC} is the weightage for the each flood contributing factors. The pixel values obtained are then classified into three classes (low, moderate and high) based on natural break to determine the class intervals in the flood prone zones map (Figure 2)

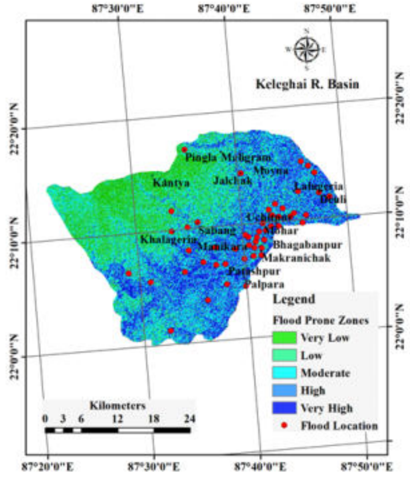

Fig 2 Flood prone zones map of Keleghai River Basin

4.3 Validation of the Study

In this study fifty training samples 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 3).

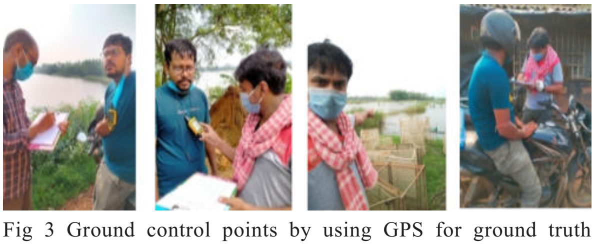

Fig 3 Ground control points by using GPS for ground truth verification/validation of the study

5.0 Results and discussion

5.1 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 2 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.

Table 3 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

5.2 Discussion

As flood hazard is one of major natural threats, which may take life and affect environment abruptly. Increasing population pressure cause human interference on environment and rapid industrialization can affect climate. Climate changes have become more widespread and more severe. Therefore, climate change induced extreme events has been increased recently, specifically flood hazard become more frequent in recent days. Hence, flood prone zones identification studies are very important. For this analysis, Multi Criteria Evaluation (MCE) has been adopted with the help of GIS for identification of flood prone zones by using weighted linear combination method for the Keleghai River basin.

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 forcasts and better management of flood hazard in the study area.

REFERENCES

1. Kundzewicz, Z. W., & Schellnhuber, H. J. (2004). Floods in the IPCC TAR perspective. Natural Hazards, 31(1), 111-128.
2. Das, S. (2020). Flood susceptibility mapping of the Western Ghat coastal belt using multi-source geospatial data and analytical hierarchy process (AHP). Remote Sensing Applications: Society and Environment, 20, 100379.
3. Rincón, D., Khan, U. T., & Armenakis, C. (2018). Flood risk mapping using GIS and multi-criteria analysis: A greater Toronto area case study. Geosciences, 8(8), 275.
4. Abdullah, M. F., Siraj, S., & Hodgett, R. E. (2021). An Overview of Multi-Criteria Decision Analysis (MCDA) Application in Managing Water-Related Disaster Events: Analyzing 20 Years of Literature for Flood and Drought Events. Water, 13(10), 1358.
5. Mukhopadhyay, A., Hazra, S., Mitra, D., Hutton, C., Chanda, A., & 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.
6. Rahman, M. R., & Saha, S. K. (2007). Flood hazard zonation–A GIS aided multi criteria evaluation (MCE) approach with remotely sensed data. Int. J. Geoinf, 3(3), 25-35.
7. Nachappa, T. G., Piralilou, S. T., Gholamnia, K., Ghorbanzadeh, O., Rahmati, O., & Blaschke, T. (2020). Flood susceptibility mapping with machine learning, multi-criteria decision analysis and ensemble using Dempster Shafer Theory. Journal of Hydrology, 125275.
8. Aydi, A., Zairi, M., & 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.
9. Mahini, A. S., & Gholamalifard, M. (2006). Siting MSW landfills with a weighted linear combination methodology in a GIS environment. International Journal of Environmental Science & Technology, 3(4), 435-445.
10. Kumari, B., & Pandey, A. C. (2020). Geo-informatics based multi-criteria decision analysis (MCDA) through analytic hierarchy process (AHP) for forest fire risk mapping in Palamau Tiger Reserve, Jharkhand state, India. Journal of Earth System Science, 129(1), 1-16.
11. Hazarika, N., Barman, D., Das, A. K., Sarma, A. K., & 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.
12. Chakraborty, S., & 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.
13. Radwan, F., Alazba, A. A., & Mossad, A. (2019). Flood risk assessment and mapping using AHP in arid and semiarid regions. Acta Geophysica, 67(1), 215-229.
14. Eastman, J. R. (2001). Guide to GIS and image processing USA: Clark University., p. 144.