GIS-based Flood Risk Mapping: The Case Study of Kosi River Basin, Bihar, India

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ABSTRACT

Flood risk mapping aims to create an easily read and rapidly accessible map to prioritize the mitigation effects. This study presents an empirical approach to flood risk mapping through the integration of Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) techniques. SRTM 30m DEM is processed using ArcGIS 10.3 software. The study methodology includes the selection of the study area, the identification of the factors responsible for flood and collection of the required data, the generation of the desired thematic layers, and their integration to produce the flood risk map. Geomorphic, hydrologic, and socio-economic analyses are carried out to generate the thematic layers, namely slope, district`s distance to active stream, highest elevation, drainage density, rainfall, population density, and land use-land cover. AHP is used to determine the relative impact weight of the thematic layers. The influence of each thematic layer and the scale values provided based on the weights and score calculated by the AHP are used to integrate the layers in GIS environment to prepare the flood risk map. Consistency ratios are determined from the judgment process to validate the reliability of the proposed approach and results. The study classified the area falling in the basin under different risk zones with Purnia and Madhepura having large areas under high risk. This study may aid decision and policymakers in the evaluation and rapid assessment of flooding phenomena in the region.

Keywords-flood; risk; geomorphic; hydrologic; socio-economic; AHP; SRTM; GIS

I. INTRODUCTION

Floods are one of the most devastating and recurring natural disasters, having huge impact on human lives and property [1, 2]. Floods are caused mainly due to heavy rainfalls, whereas landslides, dam breaches, and earthquakes are some other causes. In addition to these, human activities such as overpopulation, settlement increase in the way of river courses, drainage alterations, deforestation, and climate change are also responsible [3, 4]. Water is the most important factor among the basic needs of life [5]. Rainwater can be captured as a means of preventing flood [6]. Floods are difficult to contain and control, thus effective mitigation/management of flood risk is essential [7, 8]. Flood risk management needs to recognize the interconnections between infrastructures, economic systems and the role of human factors in assessing and managing the risk [8]. Many researchers have used various methodologies to generate flood risk maps [7, 9-19]. Earlier conventional methods were utilized for comparative risk analysis of hazards [9]. To model and predict the magnitude of flood risk areas, integrated Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) analysis techniques are used [10-12]. GIS has been used for the evaluation of satellite-based rainfall estimates [20] and to assess long-term water quality changes [21]. AHP is a theory of relative measurement of intangible criteria [22]. It was proven to be an effective tool for solid waste management in addition to risk analysis [23, 24]. Toposheet maps, satellite photos, Landsat-8, and Digital Elevation Model (DEM) are utilized to create thematic layers in a GIS environment to delineate the flood hazard potential zone in [7]. The integration of GIS and Hierarchical Multi-criteria Analysis (HMA) offer a low-cost methodology to produce vulnerability maps [13]. Landsat images were utilized to identify the land-use for vulnerability analysis in [25]. Flood hazard zone maps are a valuable tool to identify the nature of floods and their effects on human life [14]. A flood hazard zone map can be an effective tool in the planning of the future development of a city [15]. Flood hazard and vulnerability maps are integrated to generate the flood risk map.

The present study aims to map the flood risk of Kosi river basin in Bihar using remote sensing and GIS which can help evaluating the efficiency of drainage network infrastructure and the development efforts needed to reduce flood risk [14].

II. STUDY AREA

In the present study, flood risk mapping of Kosi river basin has been conducted. Kosi river is responsible for many flood incidents in the region during the last 30 years. The river has shifted nearly 150Km westward with extensive flooding in the basin region during the last 200 years [26]. The main reason of this westward movement and frequent flooding in the region is the sedimentation of the basin [27]. The cause of shifting of the river and the sedimentation in the region is the geomorphic and hydrological behavior of the basin [28]. The Kosi river is a major tributary of the Ganga river. The Kosi river originates in the Himalayan region in Nepal. After draining a large area in Tibet and Nepal it enters into Bihar (India) region near Bhimnagar and joins the Ganga river near Kurshela, Katihar district, Bihar. The drainage basin is located between latitudes $25.35^0 – 26.36^0$ N and longitudes $86.53^0 – 87.59^0$ E. The Kosi river basin is surrounded by the Great Himalayas in the north, by Mahananda river basin in the east, by the Burhi Gandak basin in the west, and by the Ganga River in the south. The Kosi river basin (main stem) extends over 10 districts: Araria, Bhagalpur, Khagaria, Katihar, Madhubani, Madhepura, Munger, Purnea, Saharsa, and Supaul of Bihar in the Indian region.

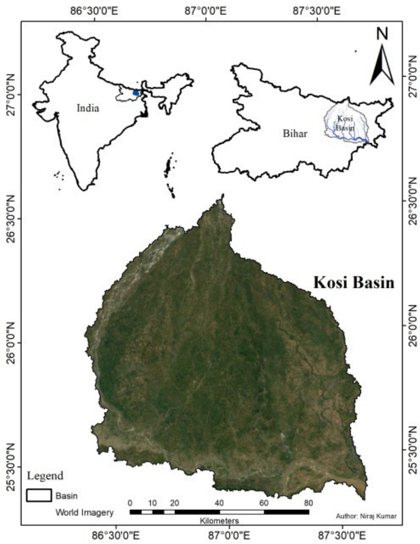


Fig. 1. Kosi river basin (generated by the ArcGIS 10.3).

III. DATA SOURCE

The current study comprises a collection of data to generate the desired thematic layers. Shuttle Radar Topography Mission 1 Arc-Second Global elevation data and Landsat 8 images were extracted from the USGS Earthexplorer platform for geomorphic analysis and socio-economic analysis. Hydrologic analysis was carried out using monthly rainfall data collected from the Indian Meteorological Department, New Delhi. Population data were collected from the Census of India, Ministry of Home affairs, Govt. of India (http://www.censusindia.gov.in/). ArcGIS online services and iBHUGOAL-BiHar infrastrUcture mapping- Geomatics Oriented Application Model Geographical Information System (GIS) (http://gis.bih.nic.in/) were used to create the Indian administrative boundaries and the district maps of Bihar.

IV. METHODOLOGY

The flood risk mapping consisted of several steps which include the selection of the study area, the identification of the factors related to the flood events, the collection of the required data, the generation of the desired thematic layers based on the factors responsible for hazard and vulnerability with the help of the available data, the integration of all the thematic layers to produce flood hazard and vulnerability maps, the generation of the flood risk map, and the validation of the result [7, 9-19]. In this study ArcGIS 10.3 software (ArcMap 10.3) is used. The ArcSWAT tool is used as an add-in in ArcGIS10.3 software to delineate the watershed and to generate stream networks. Spatial Analyst tools and Data Management tools are used in ArcMap 10.3 for generation of the final flood risk map. The various thematic layers based on the data availability are generated. The generation of thematic layers has been divided into three parts, namely geomorphic, hydrologic, and socio-economic.

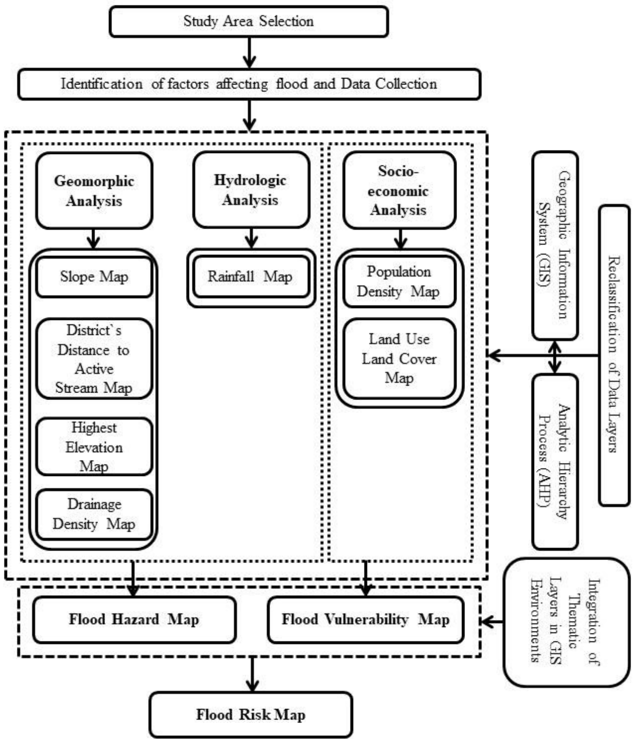


Fig. 2. Methodology.

The geomorphic analysis consists of the generation of the slope map, the district`s distance to the active stream map, the highest elevation map, and the drainage density map. The SRTM 1 Arc-Second Global elevation DEM has been used to extract these maps [29]. The slope map of the study area has been extracted using the Surface tool under Spatial Analyst tool extension in ArcMap 10.3. The drainage density map was generated from the stream network of the basin using the Density tool under the Spatial Analyst tool extension. The district`s highest elevation map and the distance to active streams map were generated using the Zonal tool under the Spatial Analyst tool extension. The final highest elevation and distance to active stream maps were generated using the Interpolation tool under the Spatial Analyst tool extension to create continuous maps within the basin boundary. The Interpolation tool interpolates a raster surface from points using the Inverse Distance Weighted (IDW) technique.

Hydrologic analysis consists of the generation of the rainfall map of the study area. The 10-year mean annual rainfall data collected for the 10 districts of the basin region were imported in ArcGIS. These values are joined in the point feature of each district. Then, the final rainfall map is generated using the Interpolation tool to create a continuous raster rainfall map within in the basin boundary. The socio-economic analysis consists of the generation of the population density map and the Land Use-Land Cover (LULC) map of the study area. The final population density map using the population data for the 10 districts is generated in the similar way as the rainfall map is generated using the IDW tool. The LULC map is generated by processing the Landsat 8 images using the Classification tool extension in ArcMap 10.3. The final generated maps are classified into 5 classes using natural breaks, which are further reclassified using the Reclassify tool under the Spatial Analyst tool extension. The reclassified maps are given values from 1for very low risk to 5 for very high risk. The influence of each thematic layer and the scale values provided based on the weights and score calculated by AHP is used to integrate the layers in GIS environment to prepare the flood hazard and vulnerability maps using the Weighted Overlay tool under the Spatial Analyst tool extension. The fundamental 9-point intensity scale [22] helped in multiple pairwise criteria comparisons in AHP. AHP has been used by various researchers for risk mapping as a vital tool [7, 9-19].

TABLE I. THE FUNDAMENTAL 9-POINT INTENSITY IMPORTANCE SCALE [22]

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another. Its dominance is demonstrated in practice
8	Very very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

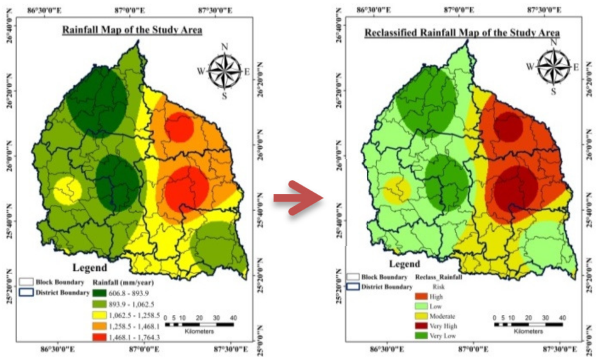
The flood hazard and vulnerability maps are multiplied using the Raster Calculator tool (Map Algebra tool) under the Spatial Analyst tool extension to generate the final flood risk map.

V. RESULTS AND DISCUSSION

A. Thematic Layer Generation

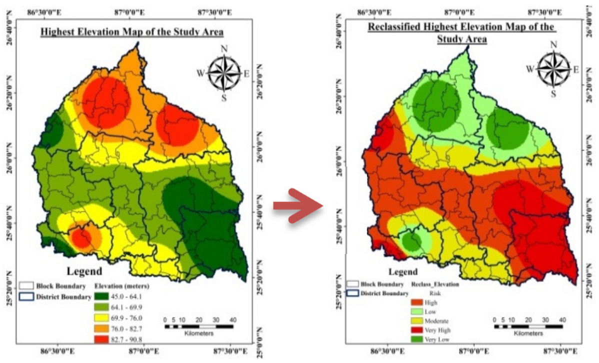
In the present study, 7 thematic layers have been created using the collected data sets. The rainfall map is generated for hydrological analysis. Similarly, slope, district`s distance to active stream, highest elevation, and drainage density maps are generated for geomorphic analysis and population density and LULC maps for socio-economic analysis. These thematic layers are classified into 5 classes using natural breaks, which are further reclassified.

1. Hydrological factors

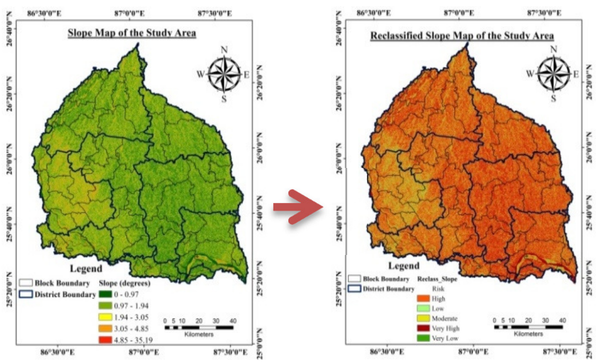


(a) Rainfall map

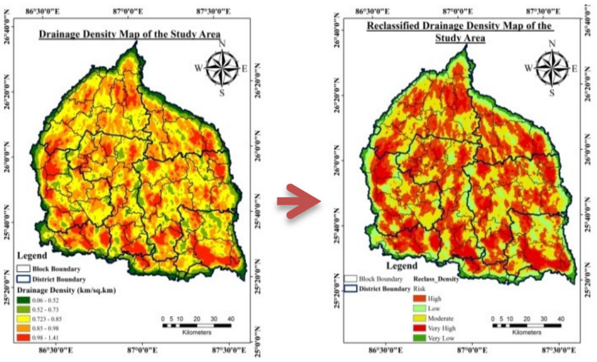
2. Geomorphic factors



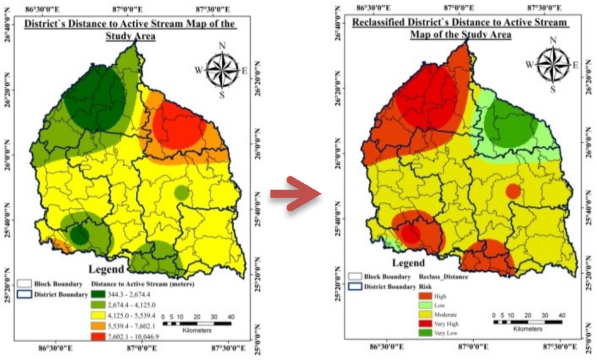
(b) Highest elevation map



(c) Slope map

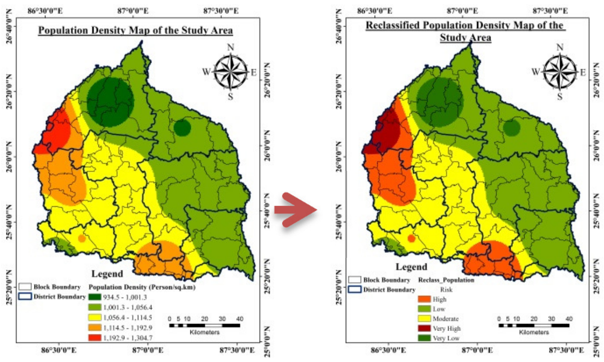


(d) Drainage density map

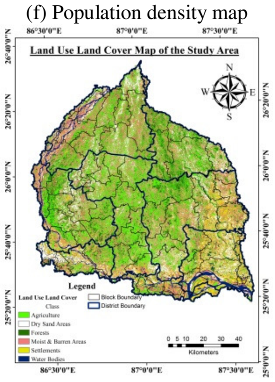


(e) Districts' distance to active stream map

3. Socio-economic factors



(f) Population density map



(g) Land use land cover map

Fig. 3. Thematic layers of the study area.

B. AHP for Flood Risk Assessment

The flood risk assessment is the combination of flood hazard and vulnerability analyses. The analysis of a region using AHP starts with building a hierarchy. The understanding of various factors is used for developing the hierarchy to generate the final flood hazard and vulnerability maps separately. The hierarchy generation comprises of 2 steps, namely the calculation of the reciprocal matrix and the calculation of the normalized matrix. The generated matrices are followed by the generation of matrices of various sub-factors. The calculation of the reciprocal matrix followed by the calculation of the normalized matrix is carried out for each criterion to assign the weight and influence percentage. Further, the score is assigned to different cell attributes of each criterion. After assigning the weight and influence percentage to the criteria and the score to the sub-categories of the criteria the flood hazard and vulnerability maps are generated using the Weighted Overlay tool.

TABLE II. WEIGHTED FLOOD HAZARD RANKING

Criterion	Priority/ weight	Categories (cell attributes)	Re-classed attributes	Score	Scale value
Rainfall (mm/year)	0.435	606.8-893.9	1	Very low	1
		893.9-1062.5	2	Low	1
		1062.5-1258.5	3	Moderate	2
		1258.5-1468.1	4	High	5
		1468.1-1764.3	5	Very high	9
Highest elevetion (m)	0.265	45.0-64.1	5	Very high	9
		64.1-69.9	4	High	5
		69.9-76.0	3	Moderate	2
		76.0-82.7	2	Low	1
		82.7-90.8	1	Very low	1
Slope (deg)	0.154	0-0.97	5	Very high	9
		0.97-1.94	4	High	5
		1.94-3.05	3	Moderate	2
		3.05-4.85	2	Low	1
		4.85-35.19	1	Very low	1
Drainage density (km/km^2)	0.09	0.064-0.524	1	Very low	1
		0.524-0.725	2	Low	1
		0.725-0.852	3	Moderate	2
		0.852-0.979	4	High	5
		0.979-1.413	5	Very high	9
District's distance to active stream (m)	0.055	344.3-2674.4	5	Very high	9
		2674.4-4126.0	4	High	5
		4126.0-5539.4	3	Moderate	2
		5539.4-7602.1	2	Low	1
		7602.1-10046.9	1	Very low	1

1) Flood Hazard Mapping

The 5 thematic layers generated in geomorphic and hydrologic analysis are used to generate the flood hazard map. High rainfall is responsible for frequent flooding in the region and the silting of the river streams, thus it was assigned the higher weight. The next higher weight was assigned to the elevation criterion, followed by criteria like slope, drainage density, and distance to active streams.

2) Flood Vulnerability Mapping

The 2 thematic layers generated in socio-economic analysis are used to generate the flood vulnerability map. The population is much more responsible for the flooding vulnerability of the region than LULC.

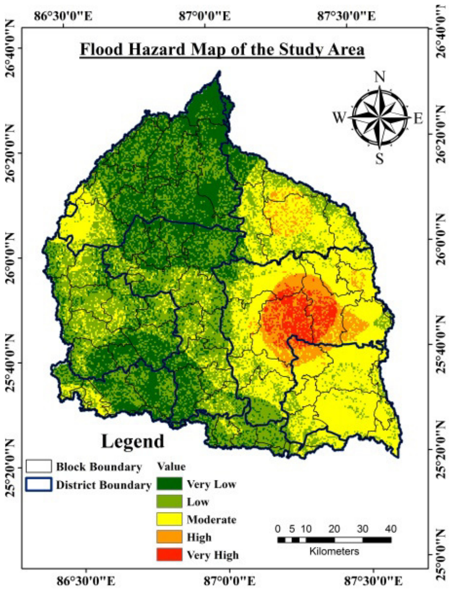


Fig. 4. Flood hazard map.

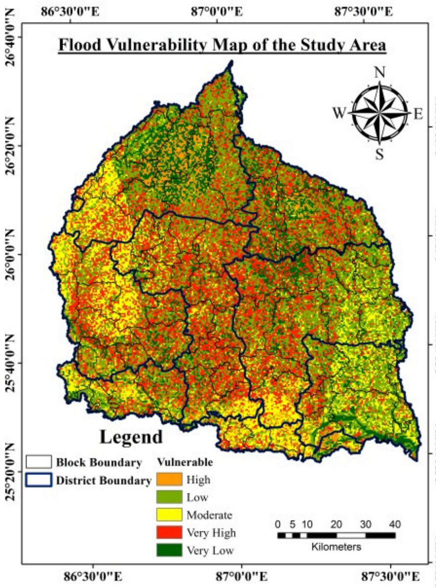


Fig. 5. Flood vulnerabilty map.

TABLE III. WEIGHTED FLOOD VULNERABILITY RANKING

Criterion	Priority/ weight	Categories (cell attributes)	Re-classed attributes	Score	Scale value
Population density (persons/km^2)	0.75	934.5-1001.3	1	0.623	1
		1001.3-1056.5	2	1.213	1
		1056.5-1114.5	3	2.405	2
		1114.5-1192.9	4	4.658	5
		1192.9-1304.7	5	9.000	9
LULC class	0.25	Agriculture		9.000	9
		Settlement		6.193	6
		Dry sand		4.437	4
		Open land		2.750	3
		Water body		1.402	1
		Forest		0.750	1

3) Flood Risk Mapping

In the present study, the final risk map is generated by simply multiplying the classified flood hazard and vulnerability maps using the Raster Calculator tool. The generated map is then classified into 5 main classes, namely Very Low, Low, Moderate, High, and Very High using the Reclassify tool. The tabulate area tool (Zonal tool) is used to calculate the district area and block area under different risk classes.

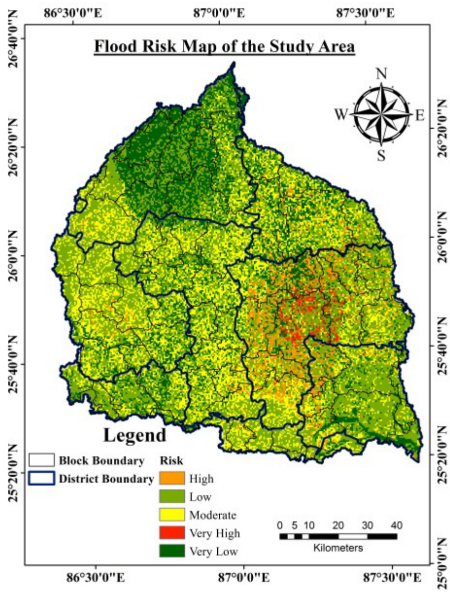


Fig. 6. Flood risk map.

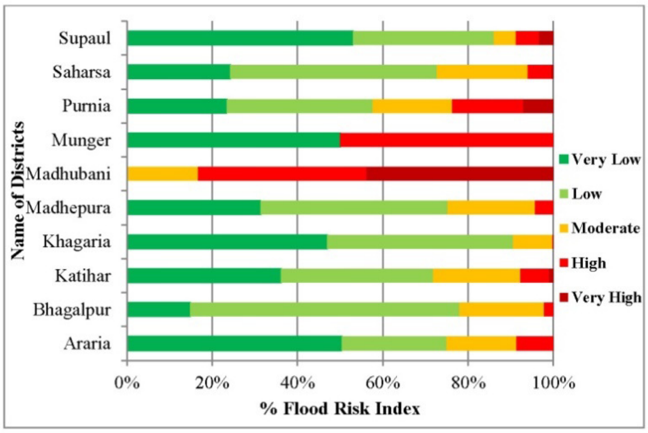


Fig. 7. Bar chart showing the district area percetnage under different risk classes.

The present study shows that all 10 districts of the region have more or less some area under High Risk with Madhubani having the largest percentage of area under Very High Risk and Purnia and Madhepura districts having large areas under High Risk. The regions of Supaul have large areas under Very Low Risk and thus are considered as safer. Araria, Munger and Supaul have large areas under Very Low Risk. Almost all the districts have approximately equal percentage of area under Moderate Risk. Raniganj of Araria district, Krityanand Nagar, Damdaha, Barhara, Bhawanipur and Banmankhi of Purnia district, and Supaul of Supaul district have the largest areas under High Risk.

VI. CONCLUSION

The current study presents an empirical approach for flood risk mapping in the Kosi river basin region through the integration of AHP and GIS techniques. This approach can aid decision and policymakers in the evaluation and assessment of flooding phenomena in the region. It will help evaluating the efficiency of drainage network infrastructure and development efforts needed to reduce flood risk. Consistency ratios are determined from the judgment process to validate the reliability of the proposed approach and results. This approach can be applied to many flood prone regions, where data availability is poor and mapping resources are limited.

The present study classified 10 districts and 76 blocks of the basin region into risk areas. The block level analysis of risk zones will help the decision makers in taking steps at root level. The final flood risk map obtained after combining the different layers in GIS environment has been validated with previous research works. The generation of the maps is not based on some previous inundation data, but on the integrated approach of different factors responsible. Thus, it is not only a hydrological phenomenon, but an integrated response of the river basin. Some of the regions in the map have high hazard risk, even the regions that are not inundated due to the importance of other factors. The use of high resolution images and DEMs increases the mapping efficiency. The results obtained in this study justify the integration of AHP and GIS techniques which gives a powerful tool for decision making procedures in flood risk mapping because these techniques allow a coherent and efficient use of the spatial data.

REFERENCES

[1] S. N. Jonkman, "Global Perspectives on Loss of Human Life Caused by Floods," *Natural Hazards*, vol. 34, no. 2, pp. 151–175, Feb. 2005, https://doi.org/10.1007/s11069-004-8891-3.

[2] S. I. Khan *et al.*, "Satellite Remote Sensing and Hydrologic Modeling for Flood Inundation Mapping in Lake Victoria Basin: Implications for Hydrologic Prediction in Ungauged Basins," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 49, no. 1, pp. 85–95, Jan. 2011, https://doi.org/10.1109/TGRS.2010.2057513.

[3] C. Clark, "Deforestation and Floods," *Environmental Conservation*, vol. 14, no. 1, pp. 67–69, 1987.

[4] Z. W. Kundzewicz *et al.*, "Flood risk and climate change: global and regional perspectives," *Hydrological Sciences Journal*, vol. 59, no. 1, pp. 1–28, Jan. 2014, https://doi.org/10.1080/02626667.2013.857411.

[5] L. Kumar *et al.*, "Analysis of Groundwater Quality Parameter of Hand-Dug Well and Their Health Risk Assessment of Study Area Tharpakar," *International Journal of Modern Research in Engineering & Management*, vol. 2, no. 5, pp. 41–48, May 2019.

[6] V. Kumar *et al.*, "GIS-Based Analysis of a Rainwater Harvesting System in the Multipurpose Hall of Quaid-e-Awam University of Engineering, Science, and Technology," *Engineering, Technology & Applied Science Research*, vol. 12, no. 4, pp. 8837–8842, Aug. 2022, https://doi.org/ 10.48084/etasr.4995.

[7] Malsawmtluanga and C. Vabeihmo, "Assessment of Flood Hazard Zonation Using Geographic Information System and Analytical Hierarchy Process: A Case Study of Tlawng River Watershed in Sairang, Mizoram, India," *Nature Environment and Pollution Technology*, vol. 21, no. 1, pp. 101–109, Mar. 2022, https://doi. org/10.46488/NEPT.2022.v21i01.011.

[8] S. Jonkman and R. Dawson, "Issues and Challenges in Flood Risk Management—Editorial for the Special Issue on Flood Risk Management," *Water*, vol. 4, no. 4, pp. 785–792, Oct. 2012, https://doi.org/10.3390/w4040785.

[9] R. W. Kates and J. X. Kasperson, "Comparative risk analysis of technological hazards (a review).," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 80, no. 22, pp. 7027–7038, Nov. 1983.

[10] Y. O. Ouma and R. Tateishi, "Urban Flood Vulnerability and Risk Mapping Using Integrated Multi-Parametric AHP and GIS: Methodological Overview and Case Study Assessment," *Water*, vol. 6, no. 6, pp. 1515–1545, Jun. 2014, https://doi.org/10.3390/w6061515.

[11] A. Ghosh and S. Kar, "Application of analytical hierarchy process (AHP) for flood risk assessment: a case study in Malda district of West Bengal, India," *Natural Hazards*, vol. 94, pp. 349–368, Oct. 2018, https://doi.org/10.1007/s11069-018-3392-y.

[12] N. Kazakis, I. Kougias, and T. Patsialis, "Assessment of flood hazard areas at a regional scale using an index-based approach and Analytical Hierarchy Process: Application in Rhodope–Evros region, Greece," *Science of The Total Environment*, vol. 538, pp. 555–563, Dec. 2015, https://doi.org/10.1016/j.scitotenv.2015.08.055.

[13] K. Loumi and A. Redjem, "Integration of GIS and Hierarchical Multi-Criteria Analysis for Mapping Flood Vulnerability: The Case Study of M'sila, Algeria," *Engineering, Technology & Applied Science Research*, vol. 11, no. 4, pp. 7381–7385, Aug. 2021, https://doi.org/10.48084/ etasr.4266.

[14] A. A. Ghezelsofloo and M. Hajibigloo, "Application of Flood Hazard Potential Zoning by using AHP Algorithm," *Civil Engineering Research Journal*, vol. 9, no. 5, pp. 150–159, Feb. 2020, https://doi.org/10.19080/ CERJ.2019.09.555775.

[15] B. Büchele *et al.*, "Flood-risk mapping: contributions towards an enhanced assessment of extreme events and associated risks," *Natural Hazards and Earth System Sciences*, vol. 6, no. 4, pp. 485–503, Jun. 2006, https://doi.org/10.5194/nhess-6-485-2006.

[16] B. Das, S. C. Pal, and S. Malik, "Assessment of flood hazard in a riverine tract between Damodar and Dwarkeswar River, Hugli District, West Bengal, India," *Spatial Information Research*, vol. 26, no. 1, pp. 91–101, 2018, https://doi.org/10.1007/s41324-017-0157-8.

[17] P. Dash and J. Sar, "Identification and validation of potential flood hazard area using GIS-based multi-criteria analysis and satellite data-derived water index," *Journal of Flood Risk Management*, vol. 13, no. 3, 2020, Art. no. e12620, https://doi.org/10.1111/jfr3.12620.

[18] R. S. Ajin, R. R. Krishnamurthy, M. Jayaprakash, and P. G. Vinod, "Flood hazard assessment of Vamanapuram River Basin, Kerala, India: An approach using Remote Sensing & GIS techniques," *Advances in Applied Science Research*, vol. 4, no. 3, pp. 263–274, May 2013.

[19] K. S. Vignesh, I. Anandakumar, R. Ranjan, and D. Borah, "Flood vulnerability assessment using an integrated approach of multi-criteria decision-making model and geospatial techniques," *Modeling Earth Systems and Environment*, vol. 7, no. 2, pp. 767–781, Jun. 2021, https://doi.org/10.1007/s40808-020-00997-2.

[20] T. G. Gebremicael *et al.*, "Satellite-based rainfall estimates evaluation using a parsimonious hydrological model in the complex climate and topography of the Nile River Catchments," *Atmospheric Research*, vol. 266, Mar. 2022, Art. no. 105939, https://doi.org/10.1016/j.atmosres. 2021.105939.

[21] L. Kumar *et al.*, "Assessment of physicochemical parameters in groundwater quality of desert area (Tharparkar) of Pakistan," *Case Studies in Chemical and Environmental Engineering*, vol. 6, Dec. 2022, Art. no. 100232, https://doi.org/10.1016/j.cscee.2022.100232.

[22] T. L. Saaty, *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*. New York, NY, USA: McGraw-Hill, 1980.

[23] S. Joel, M. L. Ernest, and A. Ajapnwa, "Application of Analytic Hierarchy Process Decision Model for Solid Waste Management Strategy in Yaoundé, Cameroon," *The Journal of Solid Waste Technology and Management*, vol. 45, no. 4, pp. 502–517, Nov. 2019, https://doi.org/10.5276/JSWTM/2019.502.

[24] T. Hazra, B. Maitra, and S. Goel, "Development and Application of a Multi-Criteria Decision Making (MCDM) Tool for Solid Waste Management: Kolkata as a Case Study," in *Advances in Solid and Hazardous Waste Management*, S. Goel, Ed. Cham: Springer International Publishing, 2017, pp. 275–299, https://doi.org/10.1007/978-3-319-57076-1_14.

[25] T. L. Dammalage and N. T. Jayasinghe, "Land-Use Change and Its Impact on Urban Flooding: A Case Study on Colombo District Flood on May 2016," *Engineering, Technology & Applied Science Research*, vol. 9, no. 2, pp. 3887–3891, Apr. 2019, https://doi.org/10.48084/etasr.2578.

[26] C. V. Gole and S. V. Chitale, "Inland Delta Building Activity of Kosi River," *Journal of the Hydraulics Division*, vol. 92, no. 2, pp. 111–126, Mar. 1966, https://doi.org/10.1061/JYCEAJ.0001406.

[27] N. A. Wells and J. A. Dorr Jr., "Shifting of the Kosi River, northern India," *Geology*, vol. 15, no. 3, pp. 204–207, Mar. 1987, https://doi.org/10.1130/0091-7613(1987)15<204:SOTKRN>2.0.CO;2.

[28] T. Chakraborty, R. Kar, P. Ghosh, and S. Basu, "Kosi megafan: Historical records, geomorphology and the recent avulsion of the Kosi River," *Quaternary International*, vol. 227, no. 2, pp. 143–160, Nov. 2010, https://doi.org/10.1016/j.quaint.2009.12.002.

[29] N. Kumar and R. Jha, "Morphometric Analysis of Kosi River Basin, Bihar, India Using Remote Sensing and GIS Techniques," in *Climate Change Impacts on Water Resources: Hydraulics, Water Resources and Coastal Engineering*, R. Jha, V. P. Singh, V. Singh, L. B. Roy, and R. Thendiyath, Eds. Cham: Springer International Publishing, 2021, pp. 469–481, https://doi.org/10.1007/978-3-030-64202-0_40.