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Flood vulnerability analysis of pashchim champaran, india using geographic information system-based overlay and scoring methods

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A B S T R A K

Terletak di Bihar, India, Pashchim Champaran adalah sebuah distrik yang sering mengalami banjir besar akibat kedekatannya dengan sungai-sungai besar dan karakteristik topografi serta hidrologi yang unik. Studi ini bertujuan untuk mengevaluasi kerentanan banjir di Pashchim Champaran dengan menggunakan pendekatan overlay dan penilaian berbasis Sistem Informasi Geografis (SIG). Kerentanan ini sebagian besar disebabkan oleh lokasi geografis distrik yang dekat dengan sungai-sungai besar, ditambah dengan karakteristik topografi dan hidrologi yang unik. Parameter termasuk kemiringan, ketinggian, jenis tanah, curah hujan, tutupan lahan, dan kepadatan sungai digunakan, diberi skor, diberi bobot, dan diintegrasikan menggunakan ArcGIS untuk mengembangkan peta kerentanan banjir. Hasil penelitian menunjukkan bahwa sekitar 63% wilayah berada dalam zona kerentanan tinggi atau sangat tinggi. Hal ini menyoroti kebutuhan akan strategi mitigasi banjir yang terarah dan komprehensif. Pentingnya penelitian ini terletak pada fokus regionalnya yang spesifik dan potensinya dalam persiapan bencana dan pengembangan kebijakan. Penelitian ini menyediakan informasi penting bagi para pembuat kebijakan dan pemangku kepentingan dalam kesiapsiagaan bencana dan alokasi sumber daya untuk pengurangan risiko banjir di Pashchim Champaran.

Keywords:
Flood
Geographic Information System
Pashchim Champaran
Overlay
Scoring

A B S T R A C T

Located in Bihar, India, Pashchim Champaran is a district that frequently experiences substantial flooding due to its proximity to major rivers and distinctive topographical and hydrological characteristics. This study aims to evaluate flood vulnerability within Pashchim Champaran, employing a Geographic Information System-based overlay and scoring approach. This susceptibility is largely attributed to the district's geographical location near major rivers, compounded by its distinctive topographical and hydrological attributes. Parameters including slope, elevation, soil type, rainfall, land cover, and river density are utilized, scored, weighted, and integrated using ArcGIS to develop a flood vulnerability map. The findings suggest that approximately 63% of the area is within high or very high vulnerability zones. This underscores the necessity for targeted and comprehensive flood mitigation strategies. The importance of this research is in its specific regional focus and potential use in disaster readiness and policy development. It offers essential information for policymakers and stakeholders in disaster preparedness and resource allocation for flood risk reduction in Pashchim Champaran.

Introduction

Floods rank among the most prevalent natural disasters, inflicting substantial harm on human lives, infrastructure, agricultural systems, and economic stability (Hanan et al., 2020). India, due to its varied geography and climate, is particularly vulnerable to flooding, especially in low-lying areas near major rivers (Senapati, 2022). Pashchim Champaran, in the northern part of Bihar, is especially flood-prone. Its location on the Gangetic plains and closeness to rivers and the

Nepalese hills contribute to frequent flood events during the monsoon season (Kumar & Jha, 2023).

The region is densely populated and largely dependent on agriculture, which increases its vulnerability. Poor infrastructure, unplanned settlements, and a lack of effective flood management make the situation worse (Ghosh et al., 2022). This study focuses on Pashchim Champaran because most existing flood studies in India are either national-scale or focused on other regions, leaving a gap in detailed, localized flood vulnerability analysis for this district (Das et al., 2022).

This research utilizes GIS overlay and scoring methods to identify flood vulnerability areas in Pashchim Champaran.The primary objectives include, Generating a detailed flood vulnerability map specific to Pashchim Champaran, analyzing the spatial arrangement of areas susceptible to flooding, evaluating the degree of flood vulnerability throughout the region, determining the key elements that intensify flood risk in the region (Ali et al., 2016).

The parameters of this study encompass localized floods, flash floods, and river overflows, but exclude tidal flooding. It integrates terrain, land utilization, precipitation, and hydrological factors. This research employs remote sensing data, historical archives, and on-site surveys to affirm the model and suggest actionable strategies for flood mitigation (Islam et al., 2022).

The outcomes of this investigation provide significant insights for policymakers, disaster management organizations, and local populations. Through the identification of high-risk flood areas and susceptible demographics, this research supports more effective planning by authorities in the realms of land utilization, infrastructure development, and emergency response protocols. This information can help improve how we prepare for disasters and make sure help gets to the right people quickly when floods happen. The study's results can also help get people more involved in reducing flood risks, which is super important for helping communities bounce back and lowering the damage from floods in the future.

Method

Located in the Tirhut Division of Bihar, with Bettiah as its administrative headquarters, Pashchim Champaran is the largest district in the state, spanning 5,228 km². Its geographical positioning on the Gangetic plain, bordering Nepal, renders it susceptible to both seasonal and flash flooding. Pashchim Champaran features mostly flat lands crisscrossed by big rivers like the Gandak. The soil here is alluvial, which is great for farming but also means the area is really easy to flood during monsoon season.

For this study, we utilized both spatial and non-spatial data. Spatial datasets incorporate shapefiles representing administrative demarcations, soil categorization, land cover mapping, watershed delineation, and riverine systems, alongside a digital elevation model. Non-spatial data are composed of precipitation records and historical flood event data. These data are acquired from sources including the India Meteorological Department, the Bihar State Disaster Management Authority, and publicly available GIS repositories. In addition, field investigations and secondary data extracted from academic literature were employed to validate the model.

In spatial analysis, overlaying is the main characteristic. Overlay is one of the methods used in spatial analysis, namely the process of combining a digital map with other digital maps, which will then produce a new digital map based on its attribute data to save layer display during the spatial analysis process.

The method used in the data processing of this research is to use the overlay method, which previously performed scoring in advance of the existing parameters, namely slope (Table 1), land elevation (Table 2), soil type (Table 3), rainfall (Table 4), land cover (Table 5), and river density (Table 6). After all parameters were scored, weights and values were given according to their respective classifications (Table 7). After the two stages passed, it continued by overlaying all parameters using the ArcGIS software.

Weighting is giving weight to digital maps of each parameter that affects flood disasters. Determination of the weight on each thematic map is based on considerations both objectively using statistics and subjectively based on certain considerations based on an understanding of the process, the possibility of flooding is influenced by each geographic parameter that has been determined and will be used in conducting GIS analysis (Darmawan et al., 2017). Scoring is the assignment of a total value to each class for each parameter.

The influence of class on an incident will affect the scoring. In getting a score or total value, it is necessary to first give a value to each class of each parameter, which will then be multiplied by the weight so that the result of the multiplication operation is a total value or commonly known as a score. The value given to each class of each parameter is the same, namely 1-5, while the weighting depends on how influential each parameter is on the level of flood vulnerability (Matondang J.P., 2013 in Darmawan et al., 2017).

Table 1. Slope classification

No.	Slope (%)	Description	Score
1.	0-8	Flat	5
2.	8-15	Sloping	4
3.	15-25	Slightly steep	3
4.	25-45	Steep	2
5.	>45	Very steep	1

Source: Ministry of Forestry (2009) with author's modifications.

Table 2. Elevation classification

No.	Elevation	Score
1.	<10	5
2.	10-50	4
3.	50-100	3
4.	100-200	2
5.	>200	1

Source: Catalog of Geo Hazard Map Preparation Methodology with GIS in (Darmawan et al., 2017).

Table 3. Soil classification

No.	Soil Type	Infiltration	Score
1.	Alluvial, Planosol, Grey Hydromorph, Lateric, Soil Water	Not Sensitive	5
2.	Latosol	Somewhat Sensitive	4
3.	Brown Forest Soil, Mediterranean Soil	Moderate Sensitivity	3
4.	Andosol, Grumusol, Podsolic	Sensitive	2
5.	Regosol, Lithosol, Organosol, Renzina	Very Sensitive	1

Source: Asdak (1995) in (Darmawan et al., 2017) with the author's modification.

Table 4. Rainfall Classification

No.	Description	Mm/years	Score
1.	Very wet	>3000	5
2.	Wet	2501-3000	4
3.	Quite wet	2001-2500	3
4.	Dry	1501-2000	2
5.	Very dry	<15000	1

Source: Puslittanak (2004) in (Hardianto et al., 2020: 23–31) with the author's modification.

Table 5. Land Cover Classification

No.	Land Cover	Score
1.	Rice Fields and Bare Land	5
2.	Dry Land Farming and Settlements	4
3.	Bushes and Weeds	3
4.	Plantation	2
5.	Forest	1

Source: (Akhbar, 2019: 172–180) with the author's modification.

Table 6. River Density Classification

No.	River Density (Km/Km2)	Score
1.	<0,62	5
2.	0,62-1,44	4
3.	1,45-2,27	3
4.	2,28-3,10	2
5.	>3,10	1

Source: Linsey, (1959); Meijerink (1970); and Ortiz in (Darmawan et al., 2017).

Table 7. Weight Classification of Flood Vulnerability of Each Parameter

No.	Parameter	Score
1.	Slope	0.20
2.	Land Elevation	0.10
3.	Soil Type	0.20
4.	Rainfall	0.15
5.	Land Cover	0.15
6.	River Density	0.10

Source: (Primayuda, 2006 in (Darmawan et al., 2017) with the author's modification.

The level of vulnerability is determined by dividing equally the vulnerability values by the number of class intervals determined using the following equation:

$$\boldsymbol{Ki} = \frac{(\boldsymbol{Xt} - \boldsymbol{Xr})}{\boldsymbol{k}}$$

Description:
Ki: Interval
Xt: Highest Data
Xr: Lowest Data
k: Desired Number of Classes

Number of Desired Classes (Kingma, 1991 in Ayyubi et al., 2012)

Geographic Information Systems, a specialized information system, enable the management of spatially referenced attribute data to generate new spatially based information. Spatial analysis using GIS can serve as a foundation for decision-making and policy formation.

Research Data and Equipment

The data and equipment used in this study include:

1. Spatial Data
   a. Shapefile (*.shp) administrative map of Pashchim Champaran
   b. Shapefile (*.shp) soil type map of Pashchim Champaran
   c. Shapefile (*.shp) land cover map of Pashchim Champaran
   d. Shapefile (*.shp) watershed map located in the administrative area of Pashchim Champaran
   e. Shapefile (*.shp) map of rivers passing through watersheds in the administrative area of Pashchim Champaran
   f. National Digital Elevation Model (DEM) of Pashchim Champaran.
2. Non-Spatial Data
   a. Rainfall data of Pashchim Champaran
3. Hardware
   a. 1 laptop unit with specifications: Intel (R) Celeron (R) N4000 CPU @ 1.10GHz (2 CPUs), ~1.1GHz; 4GB memory; HD 931.50GB; Windows 10 64-bit.
4. Software
   a. ArcGIS
   b. Microsoft Office 2020.

The entire process can be seen in outline in Figure 1. Research Flowchart

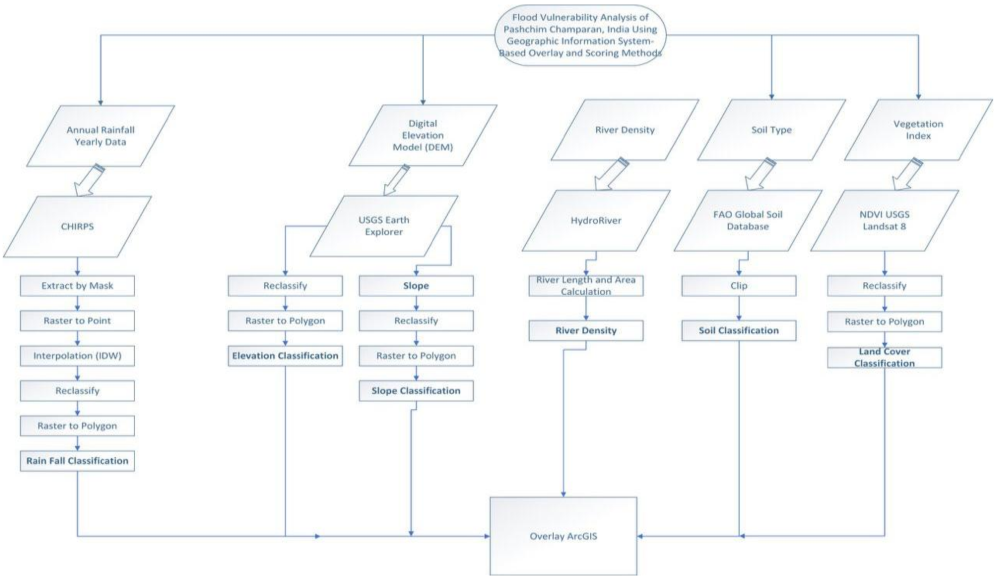

Figure 1. Research Flow Diagram

Results and discussion

Slope gradient classification results for Pashchim Champaran District

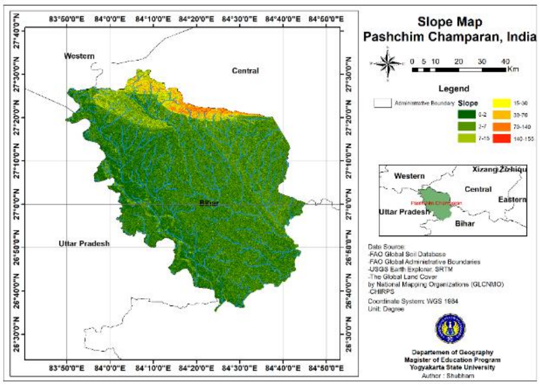

Figure 2. Map of Slope of Pashchim Champaran

The slope is a significant factor that influences surface water flow, as steeper slopes generally result in faster surface runoff. According to the research findings, the watershed area is dominated by a slope range of 0-8%, covering approximately 17,328.93 hectares. This is followed by slopes of 8-15%, covering 4,805.72 hectares, 15-25%, covering 1,417.82 hectares, 25-45%, covering 289.67 hectares, and the smallest area with slopes exceeding 45%, covering 18.37 hectares. Areas with lower slopes tend to have a higher risk of flooding due to slower water runoff and increased water accumulation (Negese et al., 2022).

Table 8. Scoring Slope Gradient Classification

No.	Slope (%)	Description	Score	Weight	Value
1.	0-8	Flat	5	0.20	1.00
2.	8-15	Gently Sloping	4	0.20	0.80
3.	15-25	Moderately Steep	3	0.20	0.60
4.	25-45	Steep	2	0.20	0.40
5.	>45	Very Steep	1	0.20	0.20

Land elevation classification results for Pashchim Champaran District

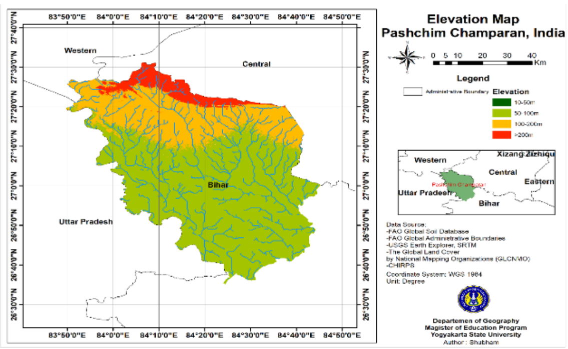

Figure 3. Land Elevation Map of Pashchim Champaran

Morphometric analysis using GIS is crucial for understanding river basin characteristics and flood dynamics. Furthermore, remote sensing and GIS facilitate processing and analyzing morphometric parameters, offering insights into terrain features like hydrology, topography, and geology (Kumar & Jha, 2023). Additionally, GIS tools enable mapping of lineaments, drainage density, and elevation, enhancing flood risk assessment (Mondal, 2012). Moreover, watershed delineation within GIS software helps predict soil erosion and flood-related processes (Achmad et al., 2021). Additionally, watershed management, essential for protecting water resources, relies on morphometric analysis to assess water potential and plan management strategies. Finally, quantitative drainage analysis provides insights into hydrological and geomorphological processes within the watershed. The integration of remote sensing and GIS techniques offers an efficient approach for watershed characterization and management (Jha et al., 2022).

Table 9. Scoring Land Elevation Classification

No	Land Elevation Range	Score	Weight	Value
1.	Less than 10 meters	5	0.10	0.50
2.	10-50 meters	4	0.10	0.40
3.	50-100 meters	3	0.10	0.30
4.	100-200 meters	2	0.10	0.20
5.	Greater than 200 meters	1	0.10	0.10

Soil type classification results for Pashchim Champaran District

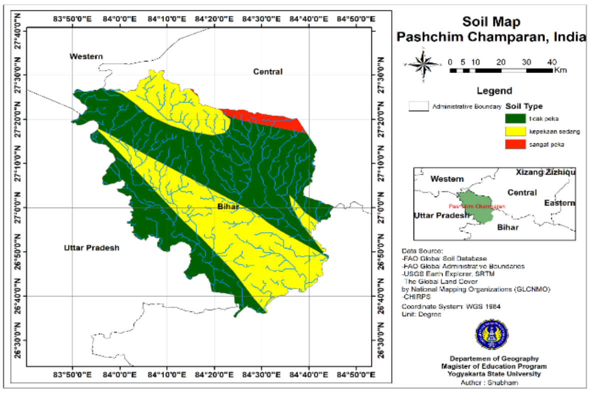

Figure 4. Map of Soil Types Pashchim Champaran

The Pashchim Champaran District exhibits a landscape primarily composed of alluvial plains, which constitute approximately 85.20% of the total area (Kumari, 2014). These plains are bisected by the Burhi Gandak River, creating two distinct tracts with varying characteristics. Notably, north of the river, the soil is predominantly clay-rich "Bangar," covering about two-fifths of the district and supporting extensive paddy cultivation during sufficient rainfall seasons. In contrast, south of the Burhi Gandak, the landscape transitions into a low-lying, flood-prone "khadar" region, characterized by the presence of chaurs, back swamps, and ox-bow lakes. Furthermore, the district is underlain by a piedmont belt, i.e., bhabar of Terai, consisting of a part of the Gandak basin. Importantly, the district lies within the Gandak basin, which is a part of the middle Gangetic plains. Additionally, the district is characterized by young alluvial soil, which is mostly sandy loam to clay loam in texture. These soil categories are crucial as they regulate the volume of water that can penetrate the soil profile, directly influencing the amount of water that turns into outflows (Ofosu et al., 2020).

Table 10. Classification of Soil Types

No.	Soil Type	Infiltration	Score	Weight	Value
1.	Sand	Rapid	1	0.25	0.25
2.	Loamy Sand	Moderate-Rapid	2	0.25	0.50
3.	Loam	Moderate	3	0.25	0.75
4.	Silt Loam	Slow-Moderate	4	0.25	1.00
5.	Clay Loam	Slow	5	0.25	1.25
6.	Clay	Very Slow	6	0.25	1.50

Rainfall classification results for Pashchim Champaran District

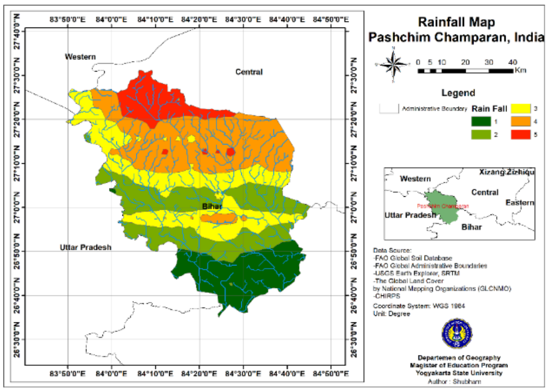

Figure 5. Rainfall Map of Pashchim Champaran

The climate in the region is characterized by hot summers and severe winters, with temperatures reaching up to 43°C in summer and as low as 7°C in winter. Furthermore, the area experiences high annual rainfall, ranging from 1007 to 2086 mm, primarily during the monsoon season from July to September. Flooding is a recurring problem, leading to loss of life, infrastructure damage, and the spread of waterborne diseases. Additionally, rural communities are more vulnerable due to limited access to resources. Flash floods occur frequently, with varying intensity. Consequently, the region's geographical location and hydro-meteorological conditions make it highly susceptible to floods, which significantly impact the agricultural sector and livelihoods of the populace. Therefore, effective flood management strategies are crucial to mitigate the impact on affected communities. In particular, the Terai region receives very heavy rainfall, with the average annual rainfall reported as 1472 mm.

Table 11. Scoring Rainfall Classification

No.	Description	mm/year	Score	Weight	Value
1.	Low Rainfall	0-700	1	0.25	0.25
2.	Moderate Rainfall	700-1400	2	0.25	0.50
3.	High Rainfall	1400-2100	3	0.25	0.75
4.	Very High Rainfall	2100-2800	4	0.25	1.00

Land cover classification results for Pashchim Champaran District

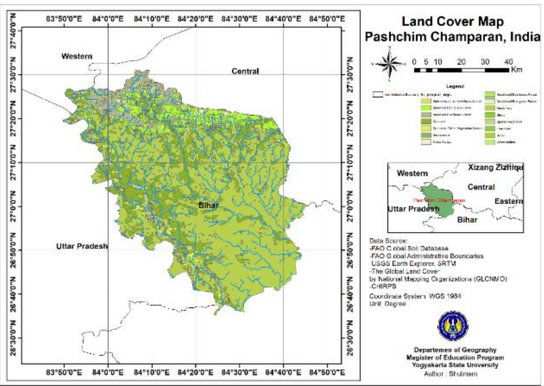

Figure 6. Land Cover Map Pashchim Champaran

The district's Disaster Management Plan emphasizes regular updates and dissemination to stakeholders (District Disaster Management Plan of East Champaran, n.d.). Moreover, floods significantly impact livelihoods, especially agriculture. Additionally, flood-damaged roads and soil erosion exacerbate these issues. Furthermore, Bihar's vulnerable geography and climate make it prone to floods (Pradhan et al., 2021; Singh, 2000). In particular, the northern state region is highly flood-prone, with 73.06% area affected, due to high population, poverty, and agriculture dependence, requiring effective flood management (Senapati, 2022). However, community-based responses utilizing local knowledge can help mitigate flood risks. For instance, in East Champaran of Bihar, heavy rains in Nepal's hilly terrains cause flash floods in northern blocks and floods in central and southern blocks. Additionally, soil erosion is observed in all blocks that face floods, leading to the loss of agricultural land. Given these circumstances, a comprehensive approach to disaster management is essential for building resilience and ensuring sustainable development.

Table 12. Scoring Land Cover Classification

No.	Land Cover	Score	Weight	Value
1.	Built-up Area	6	0.2	1.2
2.	Agriculture Land	1	0.2	0.2
3.	Fallow Land	2	0.2	0.4
4.	Forest area	3	0.2	0.6
5.	Water bodies	5	0.2	1.0

River density classification results for Pashchim Champaran District

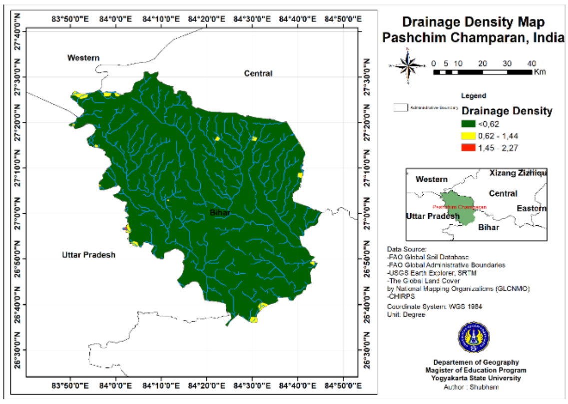

Figure 7. Map of River Density in Pashchim Champaran

The river density values for the Sikrahana and Harha watersheds are 0.77 km/sq km and 0.95 km/sq km, respectively. This indicates a moderate level of stream network development within these watersheds. A higher river density generally implies a greater potential for surface runoff and increased flood risk during periods of heavy rainfall. River density can influence the rate at which water is collected and transported through a watershed, thereby affecting flood dynamics. Therefore, the interaction between the human population, land use, and water bodies within watersheds and river basins underscores the need for comprehensive flood mitigation strategies (Islam et al., 2022).

Table 13. River Density Classification

No.	Watershed Name	km/km^2	Score	Weight	Value
1.	Sikrahana	0.77	4	0.25	1
2.	Harha	0.95	4	0.25	1

Overlay analysis of all parameters for Pashchim Champaran District reveals the following flood risk zones

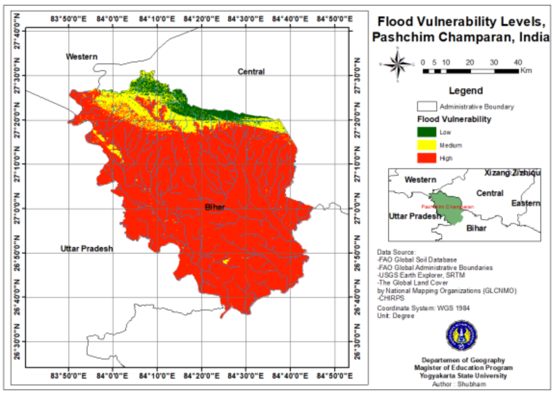

Figure 8. Flood Vulnerability Map in Pashchim Champaran

The Ghaghara, Sarda, and Rapti rivers significantly influence approximately 27,490 localities, emphasizing the importance of implementing effective relief operations to mitigate flood risk (Mohan, 2018). Additionally, floods in the Ganga-Brahmaputra-Meghna basin, spanning across Nepal, India, and Bangladesh, occur regularly, particularly in the middle and lower reaches of the Himalayan drainage systems (Modak & Ghosh, 2021). Furthermore, the monsoon season, from June to September, brings heavy rainfall to the region, leading to widespread inundation of agricultural lands and residential areas. As a result, flooding in the Ganges-Brahmaputra-Meghna basin displaces millions and causes substantial economic losses, impacting agricultural production, infrastructure, and livelihoods (Bernard et al., 2022; Baky et al., 2019). Moreover, climate change studies indicate alterations in precipitation patterns globally and within India, with the frequency and severity of floods increasingly affecting vulnerable populations dependent on agriculture in Central and Northern India. Consequently, the integration of GIS and hydraulic models is crucial for delineating the geometry of the area for one-dimensional steady flow simulation (Pradhan et al., 2022).

Furthermore, the implementation of appropriate flood management strategies is essential to protect lives, infrastructure, and the economy in flood-prone regions like Bihar. Additionally, vulnerability assessments are crucial for understanding the specific challenges faced by communities in flood-affected areas and designing targeted interventions (Senapati, 2022). Moreover, the utilization of GIS and remote sensing technologies aids in identifying areas at high risk of flooding and designing appropriate mitigation measures (Kumar & Jha, 2023). Similarly, river systems such as the Ghaghara, Ganges, and Kosi rivers contribute to flood events in the Indo-Gangetic Plain, causing loss of life and property. Furthermore, the Ganges, Brahmaputra, and Meghna rivers significantly contribute to flooding in the region, impacting agriculture, infrastructure, and livelihoods (Ben-Haim et al., 2019). The Ganges River system supports millions of people, crossing through China, Nepal, India, and Bangladesh (Bhuiyan et al., 2017). In addition, the changing climatic conditions in recent decades have significantly increased the extremity of severe droughts and devastating flooding events in several parts of the country (Swarnkar et al., 2021). The Ganges-Brahmaputra basin, like the broader High Mountain Asia region, is warming at twice the global average, rendering it among the most susceptible basins on Earth (Maina et al., 2024).

Table 14. Flood Vulnerability Interval

No.	Vulnerability	Interval	Flood Risk Zone
1.	Low vulnerability	1.0-2.33	Low Risk
2.	Moderate vulnerability	2.34-3.66	Moderate Risk
3.	High vulnerability	3.67-5.0	High Risk

Flood Susceptibility Interval Analysis for Pashchim Champaran District

The study area, the Ganga River basin, is prone to frequent flooding events, which can have severe consequences for the local communities and their livelihoods (Ghosh et al., 2022). To assess the flood susceptibility in Pashchim Champaran district, an interval-based analysis was conducted using various spatial datasets, including terrain, land cover, and hydrological parameters. The flood susceptibility assessment revealed the following key findings:

a. Approximately 15-25% of the district is classified as having high to very high flood susceptibility, particularly in the low-lying areas near major rivers and their tributaries.
b. These highly susceptible areas are typically characterized by flat terrain, proximity to water

bodies, and the presence of cropland or other agricultural land uses.

c. The northern and eastern parts of the district, which are closer to the Gandak and Burhi Gandak rivers, exhibit a higher concentration of high and very high flood susceptibility zones.
d. The central and southern parts of the district, with slightly higher elevations and a more diverse land cover, tend to have lower flood susceptibility.
e. The flood susceptibility analysis highlights the need for targeted flood mitigation measures, such as the implementation of early warning systems, the development of flood-resilient infrastructure, and the promotion of sustainable land use practices in the high-risk areas.

These findings can inform the development of comprehensive flood management strategies for Pashchim Champaran district, helping to enhance community resilience and minimize the adverse impacts of flooding events on local livelihoods and economic activities. (Moazzam et al., 2020; Mishra & Babu, 2021; Nwilo et al., 2019; Ghosh et al., 2022).

Discussion

The study shows that the northern and eastern areas of Pashchim Champaran are highly susceptible to flooding, particularly in locations characterized by lower elevation, slight topographic slopes, and farmland. This finding aligns with studies in the larger Indo-Gangetic plains, where similar factors increase the risk of flooding (Ghosh et al., 2022; Moazzam et al., 2020).

Compared with similar studies in Bihar and neighboring regions, the results affirm the effectiveness of GIS-based overlay analysis for identifying vulnerable zones. For instance, (Bahar et al. 2020) also demonstrated the value of integrating slope, land use, and rainfall data to identify high-risk flood zones in Malaysia. The significant susceptibility of farming zones validates research by Singh & Khan (2002), who highlighted the effects of floods on sustainable agriculture in comparable flood-prone areas.

This study contributes to geographical scholarship by offering a data-driven and replicable model for localized flood vulnerability mapping. It further emphasizes the significant role of land use and demographic factors in shaping disaster impacts, thereby underscoring the need for interdisciplinary methodologies in geographical disaster studies.

Implications

The spatial analysis of flood susceptibility in Pashchim Champaran district provides valuable insights for policymakers and land managers to prioritize flood risk reduction efforts. The identification of high-risk areas can guide the implementation of targeted interventions, such as the installation of early warning systems, the construction of flood-resilient infrastructure, and the promotion of sustainable land use practices in the most vulnerable regions.

The Pashchim Champaran District, situated in Bihar, India, has a history of experiencing recurrent flooding

The Pashchim Champaran District in Bihar, India, is historically prone to recurrent flooding due to its geographical characteristics and river systems. In particular, the Kosi River, infamously known as the "Sorrow of Bihar," frequently changes course, causing devastating floods that significantly impact northern Bihar, including districts like Supaul, Madhubani, and Araria. Other rivers such as the Bagmati, Gandak, and Kamla also contribute to the region's flood situation. To mitigate flood risk, proactive measures include constructing flood shelters, planting trees, and promoting homestead gardening. The Kosi River's dynamic behavior affects approximately 2.5 million people in North Bihar annually, leading to inundation, displacement, and loss of livelihoods. Flooding, caused by overflowing water bodies, results from heavy rainfall, melting snow, coastal storms, or dam failures (Syeed et al., 2022). Consequently, floods can cause extensive damage to property and infrastructure, and can even result in loss of life, displacement, and outbreaks of waterborne diseases. Moreover, climate change can affect the intensity and frequency of floods. Given its geography and numerous rivers from the Himalayas, Bihar is one of India's most flood-prone states. As a result, flooding significantly impacts agriculture, livelihoods, and infrastructure (Kumar et al., 2016; Senapati, 2022). Therefore, historical data and analytical methodologies are crucial for developing effective flood mitigation strategies and building community resilience (Khan et al., 2019; Singh, 2000). Additionally, sediment transport within river systems influences floodplain geomorphology and contributes to flood risk. In fact, flood-related disasters between 2005 and 2014 in Asia were the most disaster-prone in the world.

No.	Year	Name of River Affected	Blocks Affected	Number of Population Affected	Estimated Loss
1.	2007	Gandak, Masan, Manor	Bagaha-I, Bagaha-II, Piprasi, Madhubani, Bhitaha, Thakraha, Gaunaha,	11,49,000	4,70,00,000

			Narkatiyaganj, Mainatand, Lauriya, Ramnagar		
2.	2008	Gandak, Masan, Manor	Bagaha-I, Bagaha-II, Piprasi, Madhubani, Bhitaha, Thakraha, Gaunaha, Narkatiyaganj, Mainatand, Lauriya, Ramnagar	10,98,000	3,15,00,000
3.	2017	Gandak, Masan, Manor	Bagaha-I, Bagaha-II, Piprasi, Madhubani, Bhitaha, Thakraha, Gaunaha, Narkatiyaganj, Mainatand, Lauriya, Ramnagar	12,17,000	4,55,00,000

The Ganges and Brahmaputra rivers, originating from the Himalayas, merge before emptying into the Bay of Bengal, playing a crucial role in the region's geopolitics and economy (Maina et al., 2024).

Conclusion

This study provides a GIS-based assessment of flood vulnerability in Paschim Champaran, revealing that approximately 63% of the region falls into high to very high vulnerability categories. These zones are mostly located in low-lying, agriculturally intensive, and densely populated areas near major rivers.

The use of GIS overlay and scoring techniques proves effective for spatial vulnerability assessment and offers a practical tool for planners and policymakers. It enables targeted disaster risk reduction strategies and resource allocation.

The results of this study offer important insights for various stakeholders. Policymakers can use these findings to make better decisions on land use, infrastructure planning, and disaster preparedness. Identifying high-risk areas and vulnerable populations will help in creating effective flood management plans and ensuring timely emergency response. In addition, this research can support awareness campaigns and encourage local community participation in flood mitigation efforts, helping to strengthen resilience and reduce future impacts.

Limitations

This study is significantly dependent on secondary data, which may present inconsistencies across spatial and temporal dimensions. Furthermore, the model does not extensively incorporate socioeconomic data, potentially neglecting the human aspects of vulnerability. The precision of the mapped results may also be affected by limited field validation due to temporal and logistical limitations.

Recommendations for Future Research

Further research endeavors should incorporate real-time flood monitoring data and socioeconomic vulnerability indicators, in addition to evaluating the efficacy of existing disaster policies within the region. Enhanced data reliability and policy relevance could be achieved through collaborative partnerships with local agencies for ground-truthing initiatives.

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References

Achmad, H., Samsuar, Lanuru, M., & Mubarak, H. (2021). Predicting the impact of land-use changes on soil erosion rates in the three small sub-catchments of Larona Catchment. IOP Conference Series Earth and Environmental Science, 807(2), 22074. https://doi.org/10.1088/1755-1315/807/2/022074

Akhbar, R. K. (2019). Analisis spasial rawan banjir terhadap dampak lingkungan Kabupaten Sigi

Provinsi Sulawesi Tengah. *Jurnal Warta Rimba,* *7*(4), 172–180. http://jurnal.untad.ac.id/jurnal/index.php/WartaRimba/article/view/15222

Ali, K., Bajracharya, R. M., & Koirala, H. L. (2016). A review of flood risk assessment. *International Journal of Environment Agriculture and Biotechnology,* *1*(4), 1065. https://doi.org/10.22161/ijeab/1.4.62

Ayyubi, S. Al, Sunaryo, D. K., & Arafah, F. (2012). Kata kunci: banjir, kekeringan, Perka BNPB, Sistem Informasi Geografis. *2012*(2).

Bahar, A. M. A., Muhammad, M., Khan, M. M. A., & Jemali, N. J. N. (2020). Statistical and spatial analyses of the Kelantan Big Yellow Flood 2014. In *IOP Conference Series: Earth and Environmental Science* (Vol. 549, Issue 1, p. 012014). IOP Publishing. https://doi.org/10.1088/1755-1315/549/1/012014

Baky, M. A. A., Islam, M., & Paul, S. (2019). Flood hazard, vulnerability and risk assessment for different land use classes using a flow model. *Earth Systems and Environment,* *4*(1), 225. https://doi.org/10.1007/s41748-019-00141-w

Ben-Haim, Z., Анисимов, В. И., Yonas, A., Gulshan, V., Shafi, Y., Hoyer, S., & Nevo, S. (2019). Inundation Modeling in Data Scarce Regions. arXiv (Cornell University). https://doi.org/10.48550/arxiv.1910.05006

Bernard, A., Long, N., Becker, M., Khan, M. J. U., & Fanchette, S. (2022). Bangladesh's vulnerability to cyclonic coastal flooding. Natural Hazards and Earth System Sciences, 22(3), 729. https://doi.org/10.5194/nhess-22-729-2022

Bhatt, C. M., Gupta, A., Roy, A., Dalal, P., & Chauhan, P. (2020). Geospatial analysis of September, 2019 floods in the lower gangetic plains of Bihar using multi-temporal satellites and river gauge data. Geomatics Natural Hazards and Risk, 12(1), 84. https://doi.org/10.1080/19475705.2020.1861113

Bhuiyan, M. A. H., Islam, S. M. D.-U., & Azam, G. (2017). Exploring impacts and livelihood vulnerability of riverbank erosion hazard among rural household along the river Padma of Bangladesh. ENVIRONMENTAL SYSTEMS RESEARCH, 6(1). https://doi.org/10.1186/s40068-017-0102-9

Brouwer, R., Akter, S., Brander, L., & Haque, E. (2007). Socioeconomic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh. *Risk Analysis,* *27*(2), 313. https://doi.org/10.1111/j.1539-6924.2007.00884.x

Darmawan, K., Hani'ah, & Suprayogi, A. (2017). Analysis of flood hazard levels in Sampang District using overlay method with scoring based on geographic information systems. *Jurnal Geodesi Undip, 6*(1), 31–40.

Das, B. K., Sahu, S. K., & Parida, P. K. (2022). Inland water bodies of Bihar.

District Disaster Management Plan of East Champaran. (n.d.).

Ghosh, S., Hoque, M. M., Islam, A., Barman, S. D., Mahammad, S., Rahman, A., & Maji, N. K. (2022). Characterizing floods and reviewing flood management strategies for better community resilience in a tropical river basin, India. *Natural Hazards,* *115*(2), 1799. https://doi.org/10.1007/s11069-022-05618-y

Hanan, N. A. M., Abas, M. A., Nor, A. N. M., Amin, M. F. M., Hassin, N. H., Yusoff, A. H., Awang, N. R., Mohamed, S., & Wee, S. T. (2020). A GIS-based flood vulnerability assessment in Pasir Mas, Kelantan. In *IOP Conference Series: Earth and Environmental Science* (Vol. 549, Issue 1, p. 012004). IOP Publishing. https://doi.org/10.1088/1755-1315/549/1/012004

Hardianto, A., Winardi, D., Rusdiana, D. D., Putri, A. C. E., Ananda, F., Devitasari, Djarwoatmodjo, F. S., Yustika, F., & Gustav, F. (2020). Pemanfaatan informasi spasial berbasis SIG untuk pemetaan tingkat kerawanan longsor di Kabupaten Bandung Barat, Jawa Barat. *Jurnal Geosains Dan Remote Sensing,* *1*(1), 23–31. https://doi.org/10.23960/jgrs.2020.v1i1.16

Islam, M. N. (2017). Community-based responses to flood and river erosion hazards in the active

Ganges floodplain of Bangladesh. In Elsevier eBooks (p. 301). Elsevier BV. https://doi.org/10.1016/b978-0-12-812711-7.00018-3

Islam, S., Tahir, M., & Parveen, S. (2022). GIS-based flood susceptibility mapping of the lower Bagmati basin in Bihar, using Shannon's entropy model.

Jamshed, A., Birkmann, J., McMillan, J. M., Rana, I. A., Feldmeyer, D., & Sauter, H. (2020). How do rural-urban linkages change after an extreme flood event? Empirical evidence from rural communities in Pakistan. *Science of The Total Environment, 750*, 141462. https://doi.org/10.1016/j.scitotenv.2020.141462

Jha, A., Gupta, N. C., & Dey, B. (2022). Morphometric Analysis of Gandak River Drainage Basin Using Geographic Information System (GIS) And SRTM-DEM. Salud Ciencia y Tecnología, 2, 189. https://doi.org/10.56294/saludcyt2022189

Khan, A., Bhuyan, M. J., & Borah, D. (2019). Assessment of Flood Hazard and its Effects in Dolokhat village of Lakhimpur District, Assam. International Journal of Innovative Technology and Exploring Engineering, 8(12), 5365. https://doi.org/10.35940/ijitee.l3774.1081219

Kumar, N., & Jha, R. (2023). GIS-based Flood Risk Mapping: The Case Study of Kosi River Basin, Bihar, India. Engineering Technology & Applied Science Research, 13(1), 9830. https://doi.org/10.48084/etasr.5377

Kumar, V., Cheng, S. Y. C., & Singh, A. K. (2016). Impact of flood on rural population and strategies for mitigation: A case study of Darbhanga district, Bihar state, India. *Contemporary Rural Social Work Journal, 8*(1). https://doi.org/10.61611/2165-4611.1109

Kumari, V. (2014). Land Resource its appraisal, Management and Planning: A case study of East Champaran District.

Maina, F. Z., Getirana, A., Kumar, S. V., Saharia, M., Biswas, N. K., McLarty, S., & Appana, R. (2024). Irrigation-driven groundwater depletion in the Ganges-Brahmaputra basin decreases the streamflow in the Bay of Bengal. Communications Earth & Environment, 5(1). https://doi.org/10.1038/s43247-024-01348-0

Matheswaran, K., Alahacoon, N., Pandey, R. K., & Amarnath, G. (2018). Flood risk assessment in South Asia to prioritize flood index insurance applications in Bihar, India. Geomatics Natural Hazards and Risk, 10(1), 26. https://doi.org/10.1080/19475705.2018.1500495

Mishra, P., & Babu, R. (2021). GIS based land capability classification of a watershed for land and water resource management. *International Journal of Current Microbiology and Applied Sciences, 10*(1), 1268. https://doi.org/10.20546/ijcmas.2021.1001.150

Moazzam, M. F. U., Lee, B. G., Rahman, A., Farid, N., & Rahman, G. (2020). Spatio-statistical analysis of flood susceptibility assessment using bivariate model in the floodplain of River Swat, District Charsadda, Pakistan. *Journal of Geoscience and Environment Protection, 8*(5), 159. https://doi.org/10.4236/gep.2020.85010

Modak, S., & Ghosh, S. (2021). Floods as agents of vitality: Reaffirming human-nature synergies. https://doi.org/10.53014/rehq6535

Mohan, R. (2018). Ghaghara River System—Its Current Status and Value to Society. In Springer hydrogeology (p. 151). Springer Nature. https://doi.org/10.1007/978-981-10-2984-4_12

Mondal, S. (2012). Remote Sensing and GIS Based Ground Water Potential Mapping of Kangshabati Irrigation Command Area, West Bengal. Journal of Geography & Natural Disasters, 1(1). https://doi.org/10.4172/2167-0587.1000104

Negese, A., Worku, D., Shitaye, A., & Getnet, H. (2022). Potential flood-prone area identification and mapping using GIS-based multi-criteria decision-making and analytical hierarchy process in Dega Damot district, northwestern Ethiopia. Applied Water Science, 12(12). https://doi.org/10.1007/s13201-022-01772-7

Nwilo, P. C., Olayinka, D. N., & Adzandeh, A. E. (2019). Analysis of impact of exposures and hydrological modelling of flood peak zones in Adamawa catchment, Nigeria. *Deleted Journal, 3*(2), 256. https://doi.org/10.36263/nijest.2019.02.0148

Ofosu, S. A., Adjei, K. A., & Odai, S. N. (2020). Ecological vulnerability of the Densu river Basin due to land use change and climate variability. Cogent Engineering, 7(1), 1735714. https://doi.org/10.1080/23311916.2020.1735714

Pal, S. C., Ghosh, C., & Chowdhuri, I. (2020). Assessment of groundwater potentiality using geospatial techniques in Purba Bardhaman district, West Bengal. *Applied Water Science, 10*(10). https://doi.org/10.1007/s13201-020-01302-3

Pradhan, N. S., Das, P. J., Gupta, N., & Shrestha, A. B. (2021). Sustainable Management Options for Healthy Rivers in South Asia: The Case of Brahmaputra. Sustainability, 13(3), 1087. https://doi.org/10.3390/su13031087

Prasad, D., Swaroop, N., Thomas, T., David, A. A., & Rao, P. (2017). Assessment and characterization of soil of Pandariya Block in Kabeerdham District, Chhattisgarh, India. *International Journal of Current Microbiology and Applied Sciences, 6*(6), 1378. https://doi.org/10.20546/ijcmas.2017.606.162

Senapati, S. (2022). Vulnerability and risk in the context of flood-related disasters: A district-level study of Bihar, India. International Journal of Disaster Risk Reduction, 82, 103368. https://doi.org/10.1016/j.ijdrr.2022.103368

Shrestha, R., Ahlers, R., Bakker, M. H. N., & Gupta, J. (2010). Institutional dysfunction and challenges in flood control: A case study of the Kosi Flood 2008. Economic and Political Weekly/Economic & Political Weekly, 45(2), 45. https://research.vu.nl/en/publications/institutional-dysfunction-and-challenges-in-flood-control-a-case-

Singh, K. M. (2000). A Review of Flood Control Policy in Bihar (India) [Review of A Review of Flood Control Policy in Bihar (India)]. SSRN Electronic Journal. RELX Group (Netherlands). https://doi.org/10.2139/ssrn.2254498

Singh, S. S., & Khan, A. R. (2002). Strategy for managing natural resources in flood-prone eco-systems for sustainable agricultural production. *Acta Agronomica Hungarica, 50*(1), 107. https://doi.org/10.1556/aagr.50.2002.1.13

Swarnkar, S., Mujumdar, P. P., & Sinha, R. (2021). Modified hydrologic regime of upper Ganga basin induced by natural and anthropogenic stressors. Scientific Reports, 11(1). https://doi.org/10.1038/s41598-021-98827-7

Syeed, M. M. A., Farzana, M. H., Namir, I., Ishrar, I., Nushra, M. H., & Rahman, T. (2022). Flood Prediction Using Machine Learning Models. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2208.01234

Thapa, S., Shrestha, A., Lamichhane, S., Adhikari, R., & Gautam, D. (2020). Catchment-scale flood hazard mapping and flood vulnerability analysis of residential buildings: The case of Khando River in eastern Nepal. *Journal of Hydrology Regional Studies, 30*, 100704. https://doi.org/10.1016/j.ejrh.2020.100704

Tiwari, K. R., & Rayamajhi, S. (2018). Devastating Monsoon: Water Induced Disaster Management Practices in Nepal. Forestry Journal of Institute of Forestry Nepal, 15, 57. https://doi.org/10.3126/forestry.v15i0.24921

Windupranata, W., Aziz, A. A., Suwardhi, D., & Nusantara, C. A. D. S. (2019). The integration of bathymetric and UAV photogrammetry for Pangandaran digital elevation model. In *Proceedings of IEEE AGERS* (p. 72). https://doi.org/10.1109/agers48446.2019.9034274