

QSPM Model-Based Socio-Economic Vulnerability Assessment of Farmers in the Riverine Tract of Atrayee and Punarbhaba

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Abstract

Flood stands as recurring and devastating natural hazards in the northwest part of Bangladesh and adjacent areas of West Bengal, India, mainly in regions affected by the Atrayee and Punarbhaba rivers. These two rivers, arising from the hilly grounds of India, flow through heavily populated floodplains and pose a twin challenge. They help agriculture and livelihoods with their seasonal flows while at the same time cause havoc through floods and riverbank erosion due to their geomorphological and hydrological characteristics. When a moderate amount of rainfall occurs, embankments start getting overtopped or breached, particularly in areas like Kushmandi, Gangarampur, and Balurghat in India, along with Biral and Dinajpur Sadar in Bangladesh. Such regions become flood-prone areas because of not just the natural causes but also poor water governance and inadequate maintenance of embankments. The present study deals with the socio-economic vulnerability assessment of the farming community in the riverine tract of Atrayee and Punarbhaba with the help of computation of strengths, weaknesses, opportunities and threats (SWOT), livelihood vulnerability index (LVI), livelihood security index LSI and Garret Ranking Method.

Keywords: Flood, agriculture, riverine tract, Atrayee, Punarbhaba.

1.0 Introduction

The different social and economic traits that make up the population in a given area are referred to as socio-economic components. As could be expected, the way individuals and groups interact with each other and the environment has a direct impact on how they live, work, learn, get health care, and access resources. Since these factors directly affect policies, development plans, and sustainable growth to satisfy community demands, it is imperative that these components be understood. The present study is aimed to assess the socio-economic vulnerability of the people depending on agriculture for their

livelihood in the riverine tract of Atrayee and Punarbhaba of Dakshin Dinajpur. Being one of the most frequently occurring and destructive natural phenomena, flooding exerts a more serious impact on agriculture-based economies. As many as 1.47 billion people are said to inhabit flood-prone areas; and a majority of these people make their living through farming (World Bank, 2021). In flood-affected areas along rivers such as Ganga, Brahmaputra, Mekong, Mississippi, and Nile, farmers lose their crops, animals, and infrastructure time and again, compromising immediate sustenance and further development. To a large extent, such disasters victimize the rural poor, especially small and marginal farmers, on account of their limited coping capacities and reduced levels of socio-economic resilience (UNDRR, 2019). Here we try to see the complicated intersections of environmental vulnerability and the socio-economic conditions affecting farmers who stay by flood-prone rivers. Flood-prone river basins are usually fertile alluvial plains, which attract dense agricultural population due to the richness of soil and the availability of water. The collection of land found in such areas is, of course, fertile, but, given their riverine nature, they are subject to seasonal flooding aggravated by monsoons, glacial melting, cyclones, or dual mismanagement (Adger, 2006; Agarwal, 2010). Indian flood-prone areas alone account for more than 40 million hectares of area, which equals 12% of its total geographical area (National Disaster Management Authority, 2021).

The geography of these regions also includes wetlands, backswamps, low-lying polders, and riverine islands, called chars, which have differing agricultural practices and differing vulnerability profiles. In Bangladesh and Assam, for instance, the char lands go under floodwater every year, with floods affecting ownership of land, cycles of crops, and settlement patterns (Choudhury & Haque, 2016). Riverbank erosion, accompanied by floods, displaces thousands of farmers every year and also leads to landlessness and indebtedness. In the flood-prone river basins of these lands, agriculture is the mainstay of life and is characterized by subsistence or semi-subsistence type of cultivation, itinerant migration, and dependence on common property resources. Most farmers in these lands are small farmers with less than 2 hectares of land. Multi-cropping and rain-fed cultivation are practiced by them. The idea of vulnerability, therefore, conceptually varies away from exposure alone to incorporate social, economic, and political aspects that enter in determining how communities act against environmental stresses. Farmers residing near rivers that are flood-prone are often socio-economically marginalized because of their multiple vulnerabilities, i.e., little income, illiteracy, uncertain land tenure, poor infrastructure, and lack of access to credit and insurance (Birkmann et al., 2013).

Outdated or incomplete land records exist in many countries, thereby barring farmers from claiming compensation after disasters (Deshingkar & Start, 2003; Paul & Routray, 2011; Shah & Jain, 2018; IFAD, 2022). Unaware of their benefits, or lacking collateral, almost all smallholders are likewise excluded from formal institutions of finance. Thus, smallholders resort to informal moneylenders whose exorbitant

interest rates plunge these holders further into miseries. Social identity has a role as well. Scheduled castes, tribal communities, or ethnic minorities are usually located in more hazard-prone areas and receive lesser or delayed relief when floods occur (Blaikie et al., 1994). Climate change, through irregular monsoons, glacial melt, sea-level rise, and changes in rainfall patterns, has only worsened the frequency and intensity of flooding in river basins (IPCC, 2021). The two stated rivers namely Atrayee and Punarbhaba experience extreme flood events even after the construct of dams (Fig. 1). So, it is very urgent to assess the socio-economic vulnerability of the farmers along with their securities against natural disasters like flood.

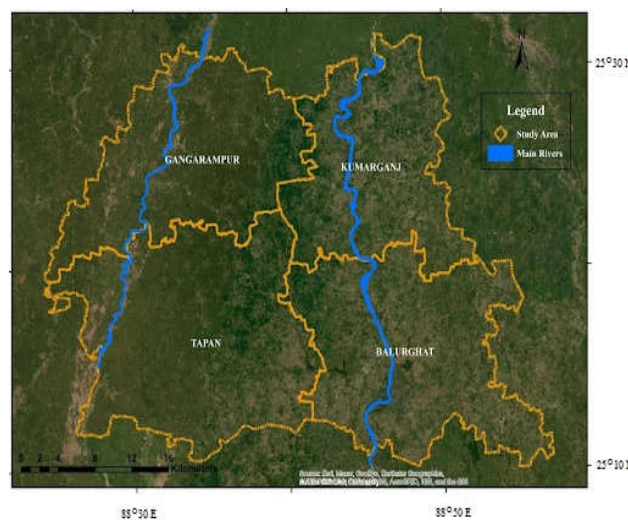


Fig. 1 Location map of the study area

2.0 Materials and methods

2.1 SWOT

SWOT analysis is a methodology used in strategic planning to determine and analyze the strengths, weaknesses, opportunities, and threats of a business or project. This method provides a platform for decision-making by identifying the internal and external factors affecting said decision. Strengths and weaknesses are internal factors. Strengths are anything that an organization excels at, such as a strong brand name, skilled labour, or proprietary technology. Weaknesses are where the organization falls short, such as limited financial resources, poor location, or outdated systems. Opportunities and threats are outside of the organization. Opportunities are favourable trends or market niches which a company can capitalize upon, for instance, emerging markets or a breakthrough in technology. Threats are unfavourable external forces, such as heightened competition, regulatory changes, or recessions.

2.1.1 External factors evaluation matrix (EFEM)

- i) In the first stage, we list the opportunities and threats.
- ii) Each factor is given a weight from 0 to 1. A weight of 0 means the factor is not important, while a weight of 1 shows that the factor is very influential. The total of all the weights should equal 1.
- iii) Next, we assign a rating to each factor, which ranges from 1 to 4. For threat factors, we use ratings 1 and 2. A rating of 1 indicates a major threat, and a rating of 2 indicates a minor threat. Minor opportunities and major opportunities are represented by ratings of 3 and 4, respectively.
- iv) In the fourth stage, we multiply each factor's weight by its rating to get that weighted score.
- v) We then add the weighted scores of all the factors to calculate the total weighted score.

2.1.2 Internal factor evaluation matrix (IFEM)

- i) At the first stage, we identify all the strengths and weaknesses of a system.
- ii) Each factor is assigned a weight ranging from 0 to 1. A weight of 0 means the factor is not important, while a weight of 1 indicates it is very important.
- iii) Each factor then receives a rating from 1 to 4. For strengths, we use ratings of 3 and 4. Generally, we assign minor strengths a rating of 3 and major strengths a rating of 4. For weaknesses, we assign ratings of 1 and 2.
- iv) Next, each factor's weight is multiplied by its rating to determine the weighted score for that factor.
- v) In the fifth stage, we add the weighted scores of all the factors to get the total weighted score.

To identify the best strategy, we use the strategic position and action evaluation (SPACE) matrix. This matrix has four quadrants namely aggressive, conservative, defensive, and competitive. Based on where the total weighted score values from the internal and external factors evaluation matrix fall within the SPACE matrix, we determine the type or nature of the strategy.

2.1.3 Quantitative strategic planning matrix (QSPM)

Typically, we choose the best strategy for a system using the QSPM approach. The left column of the matrix lists the internal and external factors. The top row shows the alternative strategies. Each alternative strategy receives an attractiveness score (AS) that ranges from 1 (not attractive) to 4 (highly attractive). These scores reflect how appealing each factor is to each alternative strategy. We multiply the weight of each key factor by the AS of each feasible alternative strategy to find the total attractiveness score (TAS) for each strategy. Afterward, we add the TASs of each strategy to get the sum of total attractiveness scores (STASs). These STASs indicate the most attractive strategy for the business system.

2.2 Garrett Ranking Method

The Garrett Ranking Method is a statistical technique used to convert qualitative rankings into quantitative scores. Named after Henry Garrett, this method is widely applied in agriculture, social sciences, education, rural development, and marketing research to analyze the perception, preferences, or constraints as ranked by respondents. It enables researchers to understand the relative importance of different factors or problems as viewed by study participants. This method is especially beneficial when the sample respondents are asked to rank a list of factors based on preference, severity, or importance, allowing those rankings to be converted into scores and ultimately into a comparable mean score for each factor.

The percent position is calculated using the formula:

$$\text{Percent Position (P)} = N_j 100 (R_{ij} - 0.5) \dots\dots\dots (i)$$

Where:

R_{ij} = Rank given for the i -th factor by the j -th individual

N_j = Number of factors ranked by the j -th individual

2.3 Livelihood vulnerability index (LVI)

Livelihood vulnerability has become an important global topic in light of growing climate variability, poverty and related natural disasters. Vulnerability is the degree to which a system, community or household is likely to be negatively impacted by external stresses, which may be due to climate change, socio-political insecurities or economic shocks. The Livelihood Vulnerability Index (LVI) is a composite index that is designed to evaluate and describe the vulnerability of households or communities by linking different aspects of livelihood such as social, economic, environmental, and institutional aspects. LVI differs from unidimensional evaluations because it considers a holistic approach, provides quantifiable data describing vulnerability and allows comparisons between different groups or geographical areas.

$$S_{ij} = (X_{\max} - X_{\min}) / (X_{ij} - X_{\min}) \dots\dots\dots (ii)$$

Where:

S_{ij} = Standardized value for indicator i in location j

X_{ij} = Actual value

X_{min} , X_{max} = Minimum and maximum observed values

3.0 Results and discussions

3.1 SWOT

3.1.1 Strengths

With a weight of 0.27, the existence of advantageous government policies and subsidies has been regarded as the most significant agricultural strength in the region under study. This suggests that investment, adoption of technology and agricultural progress have all benefited from government intervention. In a similar vein, subsidies can lower the cost of an input, shield farmers from danger, and allow them to receive credits. With a weighted score of 0.24, the report also identifies the simple and easy procedures for getting agricultural loans from the banks as another positive. This suggests that banks are helping farmers make investments in irrigation systems, high-quality seeds, fertilizer, and equipment. Fertile soils and uniform terrains were other noteworthy assets, but their weight of 0.135 was lower than that of characteristics relating to finances and policy. Uniform terrains suggest easy irrigation and mechanization, which is crucial for water management and control, and fertile soils suggest high output with minimal reliance on artificial inputs (Ray et al., 2020). Another feature of the area is its financial support for youth and women empowerment. The weighted score of 0.14 for this category indicates the regional progress toward inclusive agricultural development (Table 1). The agricultural workforce will become more resilient and diversified if the marginalized are empowered. Reduced labor costs for agriculture in comparison to other states will also assist create competitive advantages, which will raise profit margins and draw more capital to agricultural endeavors.

Table 1 Strengths listed for the area

SL.NO.	ELEMENTS OF STRENGTHS IN AGRICULTURE	SCORE	WEIGHTAGE	WEIGHTED SCORE
1	Fertile soil and homogeneous terrain properties	3	0.045	0.135
2	Ample amount of rainfall	4	0.04	0.16
3	Supply of formidable amount of water from reliable sources	3	0.025	0.075
4	Healthier seed supplied by the government	3	0.05	0.15
5	Empowering women and encouraging young groups through financial support	4	0.035	0.14

6	Lower rate of agricultural labour compared to other states	4	0.035	0.14
7	Easy and simple process of agricultural loan from banks	3	0.08	0.24
8	Helpful Government policies and Govt. provided subsidies	3	0.09	0.27
9	Lack of other economic activities	3	0.06	0.18
10	Growing local and regional markets with improving marketing facilities	4	0.05	0.2
			0.51	1.69

3.1.2 Weakness

The sustainability and effectiveness of the regional agriculture are still threatened by a number of flaws, though. With a weighted score of 0.08, one of the most serious flaws is crop cultivation using subpar methods. It refers to practices that may lead to water waste, low agricultural yields, and soil degradation that are either out-of-date or inappropriate. The disadvantage brought about by the dams built over international rivers was another significant flaw that was found, and it also received a score of 0.08. Therefore, if the river in question is crossing an international boundary, dams may cause issues in the common distribution of waters. This would reduce working downstream users capacity and, for that matter, their ability to irrigate during critical times. With a lower weighted score of 0.07, capital flow into agriculture has also been identified as a weakness (Table 2). Insufficient funding restricts research and development, prevents access to new technology, and prevents the modernization of agricultural processes. Farmers cannot transition to more profitable and sustainable techniques without adequate funding. When taken as a whole, some of those shortcomings highlight structural problems with agricultural practices, geopolitical conflicts over water resources, and underinvestment that need to be resolved in order to fully realize the regional agricultural potential.

Table 2 Weaknesses listed for the area

SL.NO.	ELEMENTS OF WEAKNESSES IN AGRICULTURE	SCORE	WEIGHTAGE	WEIGHTAGE SCORE
1	Variable and unpredictable rainfall patterns	1	0.06	0.06
2	Insufficient availability of irrigational infrastructure	1	0.06	0.06
3	Flawed techniques employed in crop cultivation	2	0.04	0.08
4	Large number of small firms with weak organisational set up	1	0.06	0.06

5	Financial investment in agriculture is insufficient	2	0.035	0.07
6	Prices of agricultural product is not satisfactory	1	0.06	0.06
7	Cost of fertilizers and pesticides increases day by day	1	0.045	0.045
8	Sizable portion of agricultural outcome goes to waste during transportation and storage	2	0.02	0.04
9	Lack of research in agriculture	2	0.03	0.06
10	Disadvantage of dam created on international rivers	1	0.08	0.08
			0.49	0.615

3.1.3 Opportunities

The first mediator in the process was access to remote sensing technology for flood, soil, and climate evaluations, which came in at 0.32 among the opportunities. Accurate and real-time agricultural status monitoring is made possible via remote sensing. As a result, farmers are able to decide on crop selection, irrigation, and pest management. Reducing environmental dangers and increasing productivity are two other benefits of using such remote sensing devices to get the most water possible from the rivers. Crops that weigh 0.32 and are less vulnerable to weather disturbances present another significant possibility (Table 3). Crop diversification would ensure steady earnings and food security by drastically reducing agricultural susceptibility to climate fluctuation.

Table 3 Opportunities listed for the area

SL.NO.	ELEMENTS OF OPPORTUNITIES IN AGRICULTURE	SCORE	WEIGHTAGE	WEIGHTAGE SCORE
1	Remote sensing based assessment of climate, soil, flood etc	4	0.08	0.32
2	Additional income of farmers through agro-forestry and agro-tourism	3	0.04	0.12
3	Drastic development in agro- industry and food processing industry	3	0.05	0.15
4	Changes in type of crops ,those are less affected by climatic disruption	4	0.08	0.32
5	Large private organisational investment in agriculture	3	0.05	0.15
6	Agricultural insurance enhancing the security	4	0.065	0.26

7	Market information through social media	4	0.07	0.28
8	Remarkable development in transport and communication.	4	0.065	0.26
.			0.5	1.86

3.1.4 Threats

There are certain significant risks that could prevent this region's agriculture from developing further. The weighted score of 0.12 indicated that the primary concern was the lack of interest in agriculture (Table 4). This has been influenced by urbanization, the impression of agriculture as a low-paying and labor-intensive profession, and improved employment opportunities elsewhere. Labor shortages and the sectoral gradual demise are inevitable if the issue is not addressed. Erosion has the same score of 0.12, making it another significant hazard. In addition to harming irrigation systems and causing silting in rivers and dams, soil erosion lowers soil fertility. Despite these issues, deforestation and poor farming methods are the main causes of erosion, necessitating the use of sustainable land management techniques. With a weighted score of 0.28, social media use for market information offers farmers a contemporary way to interact with buyers directly, monitor pricing trends, and gain access to agricultural knowledge networks. Social media may give farmers access to knowledge that strengthens their negotiating position and promotes the use of best practices.

Table 4 Threats listed for the area

SL.NO.	ELEMENTS OF THREATS IN AGRICULTURE	SCORE	WEIGHTAGE	WEIGHTAGE SCORE
1	Migration of young labour force in western provinces	1	0.08	0.08
2	Increasing temperature and heat waves in summer	1	0.075	0.075
3	Changing pattern and timing of rainfall	1	0.08	0.08
4	Decrease in total cultivable land	2	0.04	0.08
5	Higher risk of man induced flood due to dam constructions in neighbouring country	1	0.06	0.06
6	Lack of interest of young generations in agriculture	2	0.06	0.12
7	Soil erosion	2	0.06	0.12

8	Scarcity of research studies for agricultural studies	2	0.045	0.09
			0.5	0.705

3.1.5 QSPM

In the majority of developing nations, agriculture has numerous vulnerabilities and difficulties that impede growth, food security, and sustained productivity. Issues include inadequate crop diversity, water scarcity, labor shortages, traditional agricultural practices, and a lack of research capacity hinder the ability to adapt to changing environmental and economic realities. The present work has employed a quantitative strategic planning matrix (QSPM) to objectively analyze and rank potential strategies in accordance with these issues. Decision-makers can compare strategy options based on their relative attractiveness and anticipated effectiveness for managing both internal weaknesses and external threats according to the objective format provided by the QSPM. With an overall strategic attractiveness score (STAS) of 5.36, non-traditional cash crops are ranked highest by the QSPM. The plan is clearly aimed at resolving the primary problems found in the SWOT analysis. Agricultural ability to survive is threatened by water scarcity and wasteful use. With a STAS of 4.575, water conservation is therefore regarded as the second most important approach according to QSPM (Table 5 & 6). Agricultural productivity is under tremendous strain due to variations in rainfall, inadequate irrigation infrastructure, and growing competition for water supplies. With a score of 4.485, mechanization of farming and training of agricultural labourers stand third in their importance. Labour shortage, aging population, and movement of workers to urban centres have severely constrained the availability of skilled agricultural labour. Mechanization is a solution to this issue. The use of modern agricultural machinery will add efficiency to agricultural operations, reducing the cost of production, and allowing the farmer to work on a larger land area with fewer labourers. However, for any mechanization operation to be successful, an adequate training program will be required for agricultural labourers so that they may be able to use the equipment properly, carry out simple maintenance work, and operate manufacturing machinery where necessary. Improvement of the agricultural studies and research comes as fourth in its list, with the STAS being rated at 4.255. The strategy recognizes the existing gap in local research and development related to agriculture that hampers the adoption of innovative practices and technologies.

With a score of 4.485, the mechanization of farming and the training of agricultural workers rank third in importance. Labor shortages, an aging population, and the movement of workers to urban areas have severely limited the availability of skilled agricultural labor. Improving agricultural studies and research

rank fourth, with a score of 4.255. This strategy notes a gap in local research and development related to agriculture. This gap hinders the adoption of new practices and technologies.

Table 5 Weaknesses threat strategies

WT 1. Introduction of non-traditional cash crops
WT 2. Water conservation
WT 3. Promotion of alternative livelihood in the area
WT 4. Farm mechanization and training of agricultural labourers
WT 5.Improvement in agriculture related studies and research

Table 6 QSPM decision support system

Key factors	Key Factor	Weight	WT1		WT2		WT3		WT4		WT 5	
			A S	TAS	A S	TAS	A S	TAS	A S	TAS	A S	TAS
Fertile soil and homogeneous terrain properties	S1	0.045	4	0.18	3	0.135	1	0.045	3	0.135	1	0.045
Ample amount of rainfall	S2	0.04	4	0.16	4	0.16	1	0.04	3	0.12	1	0.04
Supply of formidable amount of water from reliable sources	S3	0.025	4	0.1	4	0.1	1	0.025	3	0.075	1	0.025
Healthier seed supplied by the government	S4	0.05	3	0.15	1	0.05	1	0.05	3	0.15	3	0.15
Empowering women and encouraging young groups through financial support	S5	0.035	2	0.07	1	0.035	3	0.105	2	0.07	2	0.07
Lower rate of agricultural labour compared to other states	S6	0.035	3	0.105	1	0.035	3	0.105	3	0.105	1	0.035
Easy and simple process of agricultural loan from banks	S7	0.08	3	0.24	1	0.08	1	0.08	4	0.32	2	0.16
Helpful Government policies and Govt. provided subsidies	S8	0.09	4	0.36	3	0.27	2	0.18	3	0.27	4	0.36
Lack of other economic activities	S9	0.06	2	0.12	1	0.06	3	0.18	1	0.06	1	0.06
Growing local and regional markets with improving marketing facilities	S10	0.05	4	0.2	1	0.05	1	0.05	1	0.05	2	0.1
Variable and unpredictable rainfall patterns	w1	0.06	4	0.24	3	0.18	1	0.06	3	0.18	2	0.12
Insufficient availability of irrigational infrastructure	w2	0.06	2	0.12	3	0.18	1	0.06	3	0.18	3	0.18
Flawed techniques employed in crop cultivation	w3	0.04	3	0.12	1	0.04	1	0.04	3	0.12	3	0.12

Large number of small firms with weak organisational set up	w4	0.06	2	0.12	2	0.12	1	0.06	3	0.18	1	0.06
Financial investment in agriculture is insufficient	w5	0.035	3	0.105	1	0.035	2	0.07	4	0.14	3	0.105
Prices of agricultural product is not satisfactory	w6	0.06	3	0.18	1	0.06	1	0.06	1	0.06	1	0.06
Cost of fertilizers and pesticides increases day by day	w7	0.045	3	0.135	3	0.135	1	0.045	1	0.045	2	0.09
Sizable portion of agricultural outcome goes to waste during transportation and storage	w8	0.02	1	0.02	1	0.02	1	0.02	2	0.04	3	0.06
Lack of research in agriculture	w9	0.03	2	0.06	2	0.06	1	0.03	2	0.06	4	0.12
Disadvantage of dam created on international rivers	w10	0.08	2	0.16	3	0.24	2	0.16	2	0.16	2	0.16
Remote sensing based assessment of climate, soil, flood etc	O1	0.08	3	0.24	4	0.32	1	0.08	4	0.32	4	0.32
Additional income of farmers through agro-forestry and agro- tourism	O2	0.04	1	0.04	2	0.08	1	0.04	3	0.12	3	0.12
Drastic development in agro- industry and food processing industry	O3	0.05	3	0.15	2	0.1	3	0.15	3	0.15	3	0.15
Changes in type of crops ,those are less affected by climatic disruption	O4	0.08	4	0.32	3	0.24	1	0.08	2	0.16	3	0.24
Large private organisational investment in agriculture	O5	0.05	2	0.1	4	0.2	1	0.05	3	0.15	2	0.1
Agricultural insurance enhancing the security	O6	0.065	3	0.195	3	0.195	1	0.065	1	0.065	2	0.13
Market information through social media	O7	0.07	2	0.14	1	0.07	1	0.07	1	0.07	1	0.07
Remarkable development in transport and communication.	O8	0.065	2	0.13	1	0.065	2	0.13	1	0.065	2	0.13
Migration of young labour force in western provinces	T1	0.08	1	0.08	1	0.08	4	0.32	1	0.08	1	0.08
Increasing temperature and heat waves in summer	T2	0.075	3	0.225	3	0.225	1	0.075	2	0.15	1	0.075
Changing pattern and timing of rainfall	T3	0.08	2	0.16	4	0.32	1	0.08	1	0.08	1	0.08
Decrease in total cultivable land	T4	0.04	2	0.08	2	0.08	3	0.12	3	0.12	1	0.04
Higher risk of man induced flood due to dam constructions in neighbouring country	T5	0.06	3	0.18	3	0.18	2	0.12	1	0.06	3	0.18
Lack of interest of young generations in agriculture	T6	0.06	2	0.12	1	0.06	3	0.18	1	0.06	1	0.06
Soil erosion	T7	0.06	2	0.12	3	0.18	1	0.06	3	0.18	3	0.18
Scarcity of research studies for agricultural studies	T8	0.045	3	0.135	3	0.135	1	0.045	3	0.135	4	0.18
			5.36	1	4.575	2	3.13	5	4.485	3	4.255	4

3.2 Garret's Ranking Method

The study finds that among all the strategies evaluated, water conservation is the most vital (55.78%), followed by water flow diversion (55.19%) and cultivation of crops that use less water (53.97%). Other notable strategies include organic farming and sustainable water resource use, while practices like riverbank protection and rainwater harvesting are lower on the priority list. Respondents view water conservation as their main concern. In flood-prone areas, it is important to balance excess water and water scarcity through careful management (Table 7). Switching to crops that need less water can also help combat floods and droughts. In flood-prone regions, water-intensive crops often worsen conditions by holding too much water in the fields. Organic farming, which emphasizes soil health and sustainable practices, garnered a good amount of attention from respondents. By reducing chemical use and enhancing soil structure, organic farming improves water absorption and reduces runoff, lowering flood risk. It also boosts biodiversity and strengthens the local ecosystem resilience to flooding.

Table 7 Garret's ranking approach

Factors	F	1	2	3	4	5	6	7	8	9	10	Total	Total score/100	Rank
Water conservation	F2	2214	770	567	456	156	329	126	504	348	108	5578	55.78	1
Less water consuming crop cultivation	F3	820	560	882	1197	416	658	546	72	174	72	5397	53.97	3
Diversion of water flow	F4	820	1750	630	342	572	235	672	252	174	72	5519	55.19	2
Sustainable use of water resource	F5	902	1050	630	342	208	235	420	792	319	108	5006	50.06	6
Continuous measurement of run-off	F6	1148	490	126	228	572	282	1176	360	58	288	4728	47.28	8
Shift towards organic farming	F7	902	980	126	399	1508	517	168	288	174	144	5206	52.06	5
Rainwater harvesting	F8	574	980	693	228	312	470	336	252	638	198	4681	46.81	9

Protection of river bank	F9	820	140	441	627	260	517	84	504	290	504	4187	41.87	10
Sustainable use of water for irrigational purpose	F10	902	490	315	627	364	1222	84	180	406	216	4806	48.06	7

3.3 Livelihood vulnerability index (LVI) and flood risk assessment

LVI is calculated based on the seven indicators of risk namely, statistically-deflected river course, dam altered water courses, contaminated groundwater, changed agricultural livelihood, standardised water level index (SWI), standardised precipitation index (SPI), and topographic wetness index (TWI). These indicators allow for the examination and summarizing of the complexity of flood vulnerability and identify the most significant risks to local livelihoods. All of the seven indicators were normalized to derive their respective LVI values. Understanding these values provides an interpretation of which vulnerabilities have the most impact on the study area. The largest parameter is agricultural livelihood transformation with the largest LVI value of 0.72 and thus a major source of agricultural livelihood vulnerability due to flood (Table 8). Disappearing rivers have extensive impacts on the erosion of agricultural lands, the relocation of families and destruction of infrastructure. Riverbank erosion initiates the displacement of a significant population in the erosion area of the riverbanks and deepens their impoverished state. While pollution is less conspicuous with a groundwater LVI of 0.38, it remains an alarming phenomenon. During inundation and flooding, most floodwaters pick-up an array of contaminants into groundwater from differing surface pollutants sources interrupting the ability to drink or irrigate from that quality of water.

Table 8 LVI factors

Indicators of LVI	High	Low	Mean	LVI
Shifting course of river	500	120	270	0.39
Variation of water flow due to dams	3000	150	2000	0.65
Groundwater Pollution	1.5	0.7	1	0.38
Agricultural livelihood transformation	30	12	25	0.72
Standardized Water level Index (SWI)	1	0.4	0.5	0.17
Standardized Precipitation Index(SPI)	2.7	-1	0.7	0.46

Topographic Index(TWI)	Wetness	1	0.2	0.4	0.25
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Conclusion

The Atrayee and the Punarbhaba rivers carry with themselves the patterns of flow of low gradient, meandering courses, silt-laden discharges, and high seasonal variability in rainfall. These physical characteristics tend to cause overbank flooding from these rivers during the monsoon months. Upper catchments in North Bengal comprising Malda, Dakshin Dinajpur, and Uttar Dinajpur receive intense rainfall on account of proximity to the Himalayan foothills and because of orographic influence, while accumulated runoff from these rivers flows down their lower reaches, i.e., Dinajpur and Naogaon districts of Bangladesh, and frequently overloads their flow capacity. The aggradation of the river bed and sedimentation causing the reduction of cross-sectional flow area shall further bring down the carrying capacity of the rivers. Thus embankments are overtopped or breached during moderate rainfall events, especially in Kushmandi, Gangarampur, and Balurghat in India, and in Birail and Dinajpur Sadar in Bangladesh. Relief from floods, therefore, remains subjected to natural factors as well as poor water governance and unmindful upkeep of embankments.

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