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Research Article

Impacts of climate change on riverine fisheries: A study of the fishers' community in Darbhanga district, Bihar

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Abstract

This study investigates the socio-economic conditions of fishers and their perception regarding impacts of climate change on riverine fisheries in Darbhanga district, Bihar, a region prone to floods and climatic variability. Employing a descriptive-diagnostic design, 120 fishers from six villages in Kiratpur and Benipur blocks were surveyed using semi-structured interview schedule. The study used the Perceived Impact of Climate Change Index (PICCI) to evaluate how climate change affects riverine fisheries in the study area, specifically across three dimensions: economic, social, and environmental. Results revealed that 50.83% of respondents experienced high overall climate impact, with economic and environmental domains registering the highest perceived severity (47.5% and 53.3%, respectively). Key concerns included declining fish catch, reduced income, fish habitat degradation, and increased migration. A Kruskal-Wallis H test confirmed significant differences between impact domains (p=0.0066), particularly between social and environmental perceptions. The findings highlight the urgent need for climate-resilient fishery management, enhanced financial inclusion, and ecosystem restoration to ensure sustainable livelihoods in Darbhanga's riverine systems.

Key words: Climate change, Fishers' community, Perceived impact, Riverine fisheries, Socio-economic conditions

Highlights

- Climate change has significantly impacted fishers' livelihoods in Darbhanga's riverine ecosystems.
- Developed and applied the PICCI to assess domain-specific perceived climate impacts.
- 50.83% of respondents experienced high overall impact; economic and environmental domains were most affected.
- Major perceived issues included decline in fish catch, income loss, fish biodiversity reduction, and forced migration.

INTRODUCTION

Climate change has emerged as a pressing global issue, reshaping ecosystems and livelihoods across the world. According to the IPCC (2021), global temperatures have risen by approximately 1.1°C since pre-industrial times, primarily due to human activities such as fossil fuel combustion, deforestation, and agriculture. These changes have triggered extreme weather events, altered precipitation patterns, and disrupted ecosystems-posing a significant threat to food and water security (Trenberth *et al.*, 2013).

Fisheries, especially small-scale riverine systems, are highly sensitive to climate variability. In South Asia, climate change has impacted fish breeding, migration, and habitats, with inland fisheries facing reduced productivity and economic losses (FAO, 2013; Patra *et al.*, 2020). In India, erratic monsoons and rising temperatures are altering river flows and increasing the frequency of floods and droughts, disproportionately affecting vulnerable fishing communities (IMD, 2022; NDMA, 2023).

Bihar, located in the Indo-Gangetic floodplains, is highly vulnerable to climate extremes such as floods, droughts, and heatwaves. Riverine fisheries in Darbhanga-fed by the Kamala, Bagmati, Gehua, and Kosi riversplay a vital role in supporting rural livelihoods. These rivers harbor over 50 fish species, including commercially important ones like Rohu (*Labeo rohita*), Catla (*Catla catla*), and Hilsa (*Tenualosa ilisha*), with an annual fish production of approximately 12,000 metric tons (CIFRI, 2020). The fishers' community, comprising nearly 30% of the rural population, is primarily dependent on these resources (Kumar and Sinha, 2018).

However, frequent flooding recorded in 12 of the last 20 years has caused significant siltation and habitat

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loss, disrupting breeding cycles and reducing fish stocks (BSDMA, 2021). The Bihar State Action Plan on Climate Change, 2015, identifies 76% of the state's area as flood-prone, with Darbhanga among the most affected districts. As a result, fish production has declined by 40–50%, intensifying poverty, indebtedness, and migration among fishers.

Keeping the background in mind the study was conducted with the objectives of study the socio-economic conditions of riverine fishers in Darbhanga and analyze their perceived impacts of climate change on riverine fisheries.

MATERIALS AND METHODS

Study area and sampling: The study was conducted in Darbhanga district, Bihar, targeting riverine areas along the Kamala, Gehua, Kareh, and Kosi rivers, classified as high flood-risk zones (MoHUA, 2019). Two Community Development Blocks, Kiratpur and Benipur, were purposively selected for their significant fishery activities and climate vulnerability. Six villages (four from Kiratpur, two from Benipur) were selected purposively based on the population of fishers and 120 fishers (60 fishers per block) were selected through simple random sampling method.

Research design: This study adopted a descriptive-cum-diagnostic research design. The descriptive design was used to document the socio-economic profile of the fisher community and their perceived impacts of climate change on riverine fisheries in Darbhanga district. The diagnostic design supported the development and application of the Perceived Impact to Climate Change Index (PICCI), enabling classification of fishers into different impact categories and identification of major impact areas across economic, social, and environmental domains (Ray and Mondal, 2006). Data were collected through semi- structured interview schedule developed in local dialects. Before administering the interview schedule among the respondents the validity and reliability of the measures were analysed.

Development of the Perceived Impact to Climate Change Index (PICCI)

Statement development: To quantify the fishers' perceptions of climate change impacts, a Perceived Impact to Climate Change Index (PICCI) was constructed through a structured multi-step process. Initially, a total of 33 potential impact statements were formulated under three thematic domains-economic (13 statements), social (10), and environmental (10)-based on review of scientific literature, government reports, expert opinions, and preliminary consultations with local fishers. These statements were then refined using a set of established item construction criteria, ensuring clarity, simplicity, and content relevance.

Relevancy test: To assess the suitability of each statement, a relevancy test was conducted with a panel of 50 subject matter experts, including university faculty and fisheries professionals. Experts rated each statement as either relevant (score=2) or irrelevant (score=1). Based on these ratings, the Relevancy Weight (RW) for each statement was calculated using the formula:

$$\textit{Relevancy weightage (RW)} = \frac{(\textit{relevant response} * 2 + (\textit{irrelevant response} * 1)}{\textit{maximum possible score}}$$

Statements with RW > 0.80 were retained for final inclusion. As a result, 24 statements were finalized and incorporated into the interview schedule for the study region: 9 economic, 7 social, and 8 environmental.

Scoring: Each of the final 24 statements was measured on a 4-point Likert-type scale-

- Fully Affected (3),
- Somewhat Affected (2),
- Affected (1), and
- Not Affected (0).

Respondents rated each item, and individual PICCI scores were calculated using the formula:

$$\textit{Perceived Impact to Climate Change Index (PICCI)} = \frac{\textit{Obtained score}}{\textit{maximum obtainable score}}$$

Validation: The content validity of the index was ensured by literature support and expert judgement. The internal consistency and reliability of Index was evaluated using Ordinal Alpha after data collection.

Categorization: To analyze the severity of impact, domain-wise PICCI scores were used to rank perceived issues. Additionally, respondents were categorized into Low, Medium, and High impact perception groups using the Cumulative Square Root Frequency (CSRF) method.

$$Y_i = \frac{L_{i\text{-}1} - L_i}{\sqrt{f_i}}\left[\left\{\left(\frac{S_k}{L}\right) * n_i\right\} - S_{i\text{-}1}\right]$$

Where, Y_i = Upper limit of the i^{th} strata; $L_{i-1} - L_i$ = Width of the class; f_i = frequency of the class; S_k = Cumulative square root frequency value; L = Number of strata; n_i = strata value; and S_{i-1} = Cumulative square root frequency of the preceding class.

This non-parametric stratification technique was applied to the frequency distribution of PICCI scores, allowing for equitable classification based on score distribution.

Finally, to determine whether fishers perceived impacts differently across the economic, social, and environmental domains, a Kruskal-Wallis H test was employed. Where significant differences were observed ($p<0.05$), post hoc pair wise comparisons were conducted to identify specific group-level variations.

Statistical analysis: Descriptive statistics (mean, standard deviation, percentages) summarized socio-economic and PICCI data. Differences in PICCI scores across domains were tested using the Kruskal-Wallis H test, with Mann-Whitney U tests for pair wise comparisons (Bonferroni-adjusted á = 0.0167) at $p<0.05$ significance.

RESULTS

Socio-Economic Characteristics: All 120 respondents were male, reflecting traditional gender roles in Darbhanga's fisheries. The mean age was 41.74 years (SD=14.13) (Table 1). Education levels were low, with 66% having no formal schooling. Family structures were predominantly joint (55%), with an average subsistence ratio of 5.49 (SD=2.68), indicating high dependency on fishers' income.

Table 1. Socio-economic characteristics of fishers of Darbhanga

S. No.	Indicator	Mean	Standard deviation (SD)
1.	Age (years)	41.74	14.13
2.	Education	1.49	0.80
3.	Subsistence Ratio	5.49	2.68
4.	Fishing Experience (years)	19.87	12.91
5.	Annual Fishing Days	176.3	28.6
6.	Monthly Fish Catch (kg)	52.1	23.8
7.	Annual Income (INR)	1,24,500	74,351
8.	Market Distance (km)	5.33	-

Table 2. Extreme climatic events experienced

S. No.	Events	Percentage (%)
1.	Heavy Rainfall	100.00
2.	Floods	87.50
3.	Droughts	35.00
4.	Heat Waves	69.17
5.	Cold Waves	81.67
6.	Thunderstorms	41.67

Average fishing experience of the respondents were 19.87 years (SD=12.91), with 41% of them in the established category (11-20 years) as per FAO classification. Average annual fishing days of the fishers was found as 176.3 (SD=28.6), while, 51.7% of them used to go for fishing for 151-180 days, highlighting significant reliance on fishing. The average monthly fish catch was reportedly 52.1 kg, with 43.3% of them were catching 30-50 kg of fish indicative of small-scale operations. On an average fishing contributed 66.04% to households' total income, followed by aquaculture (16.58%) and migration-related work (14.04%). Agriculture (0.58%) and non-farm activities (2.75%) were minimal, underscoring fishery dependence.

Average annual household income was found as INR 1, 24, 500 (SD=74,351). Credit access was reported by 73.33%, but 60.23% relied on informal sources, with only 39.77% using formal institutions. Savings were found low, with 67.5% having no savings habits.

Housing conditions reflected economic vulnerability, with 60.83% of them were living in kutcha houses. Social contact among the fishers was low (28.46%), primarily with friends/relatives (60.83% weekly contact), while contact with extension personnel was minimal. The average market distance was 5.33 km (range 1-10 km), posing challenges for remote fishers.

Extreme climatic events experienced: All respondents were reportedly experiencing extreme climatic events, with heavy rainfall (100%) and floods (87.5%) most prevalent, followed by cold waves (81.67%), heat waves (69.17%), thunderstorms (41.67%), and droughts (35%) (Table 2). Access to climatic information was reported by 81.67%, primarily through newspapers, television, and radio, with 42.85% using a single source. These events, particularly floods, disrupt fishing seasons and river ecosystems, aligning with Darbhanga's high flood risk.

Perceived climate change impacts: The PICCI revealed significant perceived impacts across three domains (Table 3, 4 and 5). Fishers unanimously reported experiencing economic impacts due to climate change, with the most severe concern being the decline in fish catch. This issue recorded the highest Perceived Impact of Climate Change Index (PICCI) value of 0.86, indicating a high intensity of perceived impact. Specifically, 72.5% of respondents stated they were fully affected, meaning nearly three-quarters of the surveyed fishers felt the decline in fish catch had a direct and serious impact

Table 3. Perceived economic impact of climate change in riverine fisheries by the fishers' community

Sr. No.	Perceived Economic Impact	FA (%)	SA (%)	A (%)	NA (%)	PICCI Index	RANK
1.	Declining in quantity of fish catch	72.50	14.17	13.33	0.00	0.86	I
2.	Declined in household income during extreme climatic events like flood	69.17	7.50	23.33	0.00	0.82	II
3.	Market prices for fish have been influenced by changing fish availability due to climate factors	54.17	14.17	20.83	10.83	0.71	III
4.	Capacity to repayment in Indebtedness becomes less	45.00	11.67	42.50	0.83	0.67	IV
5.	Fish disease outbreak	27.50	36.67	20.00	15.83	0.59	V
6.	Lack of food security by the households' members	36.67	20.00	17.50	25.83	0.56	VI
7.	Quality of fish impacting your economic returns	25.83	26.67	24.17	23.33	0.52	VII
8.	Changes in weather are basically challenges to our immune system; Cold and flu outbreaks	27.50	28.33	18.33	25.83	0.52	VII
9.	Changes in the timing and duration of fishing seasons impacted your income	21.67	30.00	16.67	31.67	0.47	IX

FA: Fully Affected; SA: Somewhat Affected; A: Affected; NA: Not Affected

Table 4. Perceived social impact of climate change in riverine fisheries by the fishers' community

Sr. No	Perceived Social Impact	FA (%)	SA (%)	A (%)	NA (%)	PICCI Index	RANK
1.	Push migration of fishers	80.00	1.67	17.50	0.83	0.87	I
2.	Loss of assets due to extreme climatic events that cause negative psychological tendency of fishers towards fisheries	60.00	5.83	25.83	8.33	0.72	II
3.	Owing to lack of money, members of family get succumbed due to chronic diseases if once appeared	35.83	30.00	19.17	15.00	0.62	III
4.	Owing to migration of male member of households only female, children and old ages remain in society	25.00	34.17	24.17	16.67	0.56	IV
5.	Fishers are having lack of interest in education to their children due to pause of earning money	19.17	31.67	43.33	5.83	0.55	V
6.	Low standard of living of fishers in respect to basic needs required to the family of household	32.50	20.00	26.67	20.83	0.55	V
7.	Due to cessation of income quarrelsome scene appeared in household	16.67	33.33	42.50	7.50	0.53	VII

FA: Fully Affected; SA: Somewhat Affected; A: Affected; NA: Not Affected

on their livelihoods. Other major issues included reduced household income during extreme events (0.82), fish market price volatility (0.71), debt burden (0.76), and difficulty accessing credit (0.74). Moderate concerns involved loan repayment challenges, fish disease outbreaks, food insecurity, and fish quality decline. Health problems and a shift from full- to part-time fishing (0.47) were also noted. Overall, all nine economic impact items reflected widespread and serious economic disruption due to climate variability.

Social impacts of climate change on riverine fisheries were assessed using seven validated statements. The most severe perceived impact was worker migration due to declining fishing opportunities and income insecurity

Table 5. Perceived environmental impact of climate change in riverine fisheries by the fishers' community

Sr. No.	Perceived Environmental Impact	FA (%)	SA (%)	A (%)	NA (%)	PICCI Index	RANK
1.	Increased temperature, unpredictable rainfall, and floods affected the fish spawning season and species diversity	62.50	15.00	17.50	5.00	0.78	I
2.	Changes in fish population in recent years	54.17	20.00	25.83	0.00	0.76	II
3.	Destruction of fish habitat	61.67	0.83	36.67	0.83	0.74	III
4.	Fish behaviours, such as migration patterns or breeding seasons, been impacted	50.83	22.50	21.67	5.00	0.73	IV
5.	Decrease in fish species in rivers	48.33	15.83	35.00	0.83	0.71	V
6.	Quality and health of fish (e.g., size, health) been affected over the years	53.33	14.17	6.67	25.83	0.65	VI
7.	Insufficient rainfall leads to unavailability of water in rivers	15.00	47.50	18.33	19.17	0.53	VII
8.	River water levels changed in the last 5-10 years	23.33	22.50	35.00	19.17	0.50	VIII

FA: Fully Affected; SA: Somewhat Affected; A: Affected; NA: Not Affected

Table 6. Distribution of respondents according to differential levels of perceived impact across different domains

ECONOMIC IMPACT			SOCIAL IMPACT		
LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
(0.78 – 1.48)#	(1.49 – 1.95)#	(1.96 – 2.67)#	(1.29 – 1.67)#	(1.68 – 2.06)#	(2.07 – 2.86)#
11.67%	40.83%	47.50%	21.67%	55.83%	22.50%

ENVIRONMENTAL IMPACT			OVERALL IMPACT		
LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
(0.88 – 1.37)#	(1.38 – 2.11)#	(2.12 – 2.88)#	(1.21 – 1.65)#	(1.66 – 1.96)#	(1.97 – 2.43)#
18.33%	28.33%	53.33%	24.17%	25%	50.83%

Indicate score of categorizations

(PICCI = 0.87). This was followed by loss of assets during extreme events (0.72), limited access to healthcare (0.62), and absence of male members due to migration (0.61), increasing the burden on women and elderly. Other reported issues included low living standards (0.58), household conflicts (0.54), and reduced interest in children's education (0.51). Overall, fishers viewed climate change as a serious threat to social well-being, family stability, and community resilience.

Environmental impacts of climate change were assessed using eight validated statements. The most severe concern was disruption of fish spawning and species diversity due to rising temperatures and erratic rainfall (PICCI = 0.78), followed by changes in fish population dynamics (0.76) and habitat destruction from floods and siltation (0.74). Altered fish behaviour and migration patterns (0.73), species decline (0.71), and reduced fish health and quality (0.65) were also significant. Lower rainfall and water availability (0.53) and fluctuating river levels (0.50) were additional concerns. Overall, fishers perceived climate change as a major ecological threat to fish habitats, biodiversity, and long-term sustainability of riverine fisheries.

Differential level of perceived impact among the fishing community: To interpret the perception data, respondents were categorized into low, medium, and high perceived impact groups based on their PICCI scores for each domain and overall impact. Classification was done using the Cumulative Square Root Frequency (CSRF) method. The resulting score ranges and percentage distribution of respondents are illustrated in Table 6.

Table 6 shows that a substantial portion of the fisher community falls under the high perceived impact category, especially in the economic (47.5%) and environmental (53.3%) domains, reflecting widespread concern over declining catch, income instability, and

Table 7. Post-hoc pairwise comparison using Mann–Whitney U Test with Bonferroni Correction

Comparison	Adjusted p-value	Significance
Economic vs Social	1.0000	Not Significant
Economic vs Environmental	0.0812	Not Significant
Social vs Environmental	0.0056	Significant

ecological disruption. The social domain saw the highest concentration in the medium impact group (55.83%), indicating moderate but notable household-level effects.

Overall, 50.83% of respondents were classified as experiencing high total impact, while only 24.17% fell in the low category. These results highlight the urgency for targeted policy support, especially for highly affected fishers, and emphasize the need to build resilience among medium and low-impact groups.

Statistical comparison of perceived impacts across domains: A Kruskal-Wallis H test was performed to compare perceived climate change impacts across the economic, social, and environmental domains. The test showed a significant difference between these domains (H=10.035, p=0.0066). To identify which domains differed, pairwise Mann-Whitney U tests with a Bonferroni-adjusted significance level (α=0.0167) were conducted. Results showed a significant difference between the social and environmental domains (p=0.0056). However, no significant differences were found between the economic and social (p=1.0000) or economic and environmental domains (p=0.0812) (Table 7).

DISCUSSION

This study highlights the profound impact of climate change on Darbhanga's riverine fisheries, with a 40-50% decline in fish catch consistent with regional trends in Bihar's inland fisheries (Kumar and Sinha, 2020; Patra *et al.*, 2020). Environmental impacts, perceived as most severe (53.33% high), are driven by a 1.5°C rise in water temperatures, frequent floods causing siltation, and pollution (BSDMA, 2021; CIFRI, 2022). The near disappearance of Hilsa and a 35-40% reduction in major carps (e.g., Rohu, Catla) indicate significant biodiversity loss, threatening both food security and the cultural significance of fishing for the fishers' community (Kumar and Sinha, 2018). Fishers' observations of silted breeding grounds and disrupted spawning seasons align with studies across South Asia, where climate variability affects fish migration patterns (Islam, 2018; Panikkar *et al.*, 2022).

Under the economic dimension, 47.50% of fishers reported a high perceived impact, reflecting serious livelihood challenges. This is supported by the fact that 58.33% of respondents earn less than INR 1, 19,999 annually, indicating widespread financial vulnerability and limited capacity to cope with climate-induced economic stress. The reliance on informal credit sources by 60.23% of respondents and low savings habits reported by 32.5% of them further exacerbate financial vulnerability. Dependence on high-interest informal loans often leads to debt traps, making it even more difficult for fishers to recover from climate-related economic shocks (Chatterjee, 2022). Limited education-evident from the 66% of respondents who are illiterate-restricts access to alternative livelihood opportunities. As a result, 25% of fishers reported migrating in search of work, reflecting a growing trend in Bihar's flood-prone regions (Richa and Sen, 2024). The average monthly catch of 52.1 kg, significantly reduced from historical levels, combined with market distances (mean=5.33 km), increases transportation costs and reduces profitability (Kumar *et al.*, 2019).

Most fishers (55.83%) reported experiencing a medium level of social impact from climate change, suggesting some resilience in the community. This resilience is reinforced by strong community participation (mean=0.80), which promotes mutual support among members of the fishers' community (Kumar and Sinha, 2018). Disruptions to education and changes in household roles negatively affect long-term socio-economic prospects, especially for younger generations. The 21.67% of fishers reporting low social impact may reflect adaptive coping strategies, such as strong reliance on extended family networks, which is common in rural India (Maiti *et al.*, 2017). About 22.5% of fishers have low social participation, which, along with limited engagement with extension services, greatly reduces their access to essential adaptive knowledge and technologies-an issue frequently seen in Indian fishing communities (Karim, 2022; Roy, 2015).

The statistical analysis, with a significant Kruskal-Wallis H test (p=0.0066) and post-hoc environmental-social difference (p=0.0056), underscores ecological concerns as the dominant issue for fishers. Unlike economic and social domains, where strategies like migration and aquaculture provide some relief, environmental degradation offers little immediate recourse without external intervention (Maiti *et al.*, 2017). The Bihar government's River Ranching Programme, which released 387,000 fingerlings of major carps and Hilsa into the Ganga and its tributaries in 2023, aims to restore fish stocks (CIFRI, 2022). However, fishers report limited impact on smaller rivers like Kamala and Gehua, indicating a need for localized restoration efforts. Additional pressures from pollution and overfishing, as noted by fishers, further complicate recovery and require stringent regulatory measures.

Conflict of interest: Authors have no conflict of interest in this study.

Data availability statement: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author's contribution: MKA: Conceptualized the study, conducted fieldwork, drafted the manuscript and performed statistical analysis; BS: Supervised the research, and edited the manuscript.

Use of artificial intelligence tools: During the preparation of this work, the author(s) used Grok to assist in grammatical error correction and sentence improvement. After using this tool, the author(s) thoroughly reviewed and edited the content as necessary and take(s) full responsibility for the final version of the manuscript.

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