Chapter 6
Livelihood Vulnerability Assessment of Fishing Communities: Evidence from Deepor Beel of Assam, India

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6.1 Introduction

Wetlands are significant ecosystems for human well-being, economic development, climate change adaptation, and mitigation (Dinsa & Gemeda, 2019). They sustain numerous plant and animal species that rely on them for survival (Arya et al., 2020). Wetlands play a key role in sequestering carbon and restricting release of carbon dioxide in the atmosphere (Salimi et al., 2021). The conservation and sustainable use of wetlands are pivotal for realizing objectives of sustainable development goals of (SDGs) related to climate, water, ecosystems, and marine resources (Seifollahi-Aghmiuni et al., 2019). By safeguarding wetlands, we can directly contribute to 10 of the 17 SDGs, underscoring their significance in fostering sustainable development worldwide. Hence, it is imperative to integrate wetland conservation within the global SDG framework to ensure the protection of these vital ecosystems (Ramsar, 2018). In recent decades, there has been a notable increase in the frequency and intensity of natural disasters affecting wetlands functions and dependent communities (Das & Bhattacharjee, 2015). Wetlands serve as a critical natural buffer against water-related hazards. Wetlands are pivotal in mitigating disaster impacts, making community resilient and ensuring sustainable ecosystem (Kumari et al., 2023). Nearly 50% of wetlands have been lost at global scale due to human activities (Daniels & Cumming, 2008). This loss of wetlands is intricately linked with the decline of ecosystem functions, which in turn has increased the vulnerability of communities. This has significant implications for both biodiversity and community livelihoods (Zekarias et al., 2021).

Wetland-dependent fishing communities find themselves vulnerable to various environmental, economic, and social adversities that threaten their livelihoods and way of life (Saikia et al., 2019; Das & Bhattacharjee, 2015). The ecosystems such

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as mangroves, peatlands, and freshwater marshes are significant for their livelihood but are vulnerable to disturbances such as climate change, sea-level rise, pollution, and unsustainable land use practices (Zekarias et al., 2021). The increase in area under agriculture, urban expansion, and release of pollutants from industrial sources significantly deteriorate these environments (Briffa et al., 2020). Overfishing and transformation of wetlands for immediate returns erode the long-term viability of these habitats (Zekarias et al., 2021). The communities often face discrimination in terms of limited access to resources needed to adapt to changing conditions such as technology, education, and financial services (Makwinja et al., 2021). The interplay of these factors makes wetland-dependent fishing communities vulnerable to disruptions, leading to significant challenges for their livelihood sustainability and resilience.

Assessing the livelihood vulnerability of wetland-dependent fishing communities involves a multifaceted approach that integrates various models and methods to capture the complex interplay of environmental, economic, and social factors (Sujakhu et al., 2019). Index-based methodology offers a credible and scientific approach for evaluating the extent of vulnerability (Sahana et al., 2019). Both quantitative and qualitative methods have been utilized for examining livelihood vulnerability. Livelihood Vulnerability Index (LVI) and Climate Vulnerability Index (CVI) have been widely employed for livelihood vulnerability assessment (Aazami & Shanazi, 2020; Zekarias et al., 2021; Hempattarasuwan et al., 2021; Majumdar et al., 2023; Bhuiyan et al., 2017; Singha & Pal, 2022). The qualitative methods, on the other hand, involve participatory rural appraisals (PRAs) and focus group discussions for the collection of in-depth insights from the communities themselves about the specific challenges perceived vulnerability (Sajjad & Nasreen, 2016). Various scholars have also utilized remote sensing and geographical information systems to map and analyze changes in wetland ecosystems (Sahana et al., 2021; Abd Majid et al., 2019; Barua & Rahman, 2019). These approaches allow researchers and policymakers to gain a holistic understanding of vulnerability encompassing both the measurable and experiential aspects of how wetland-dependent fishing communities are affected by and respond to various stressors. Thus, the integrated assessment is crucial for designing targeted interventions that may enhance the resilience and adaptation of these communities.

Deepor Beel located in the Brahmaputra valley of Assam was recognized as Ramsar site in 2002 (Saikia et al., 2019). Its inclusion in the Ramsar list acknowledges its critical role in conserving biodiversity, supporting a myriad of aquatic and terrestrial life forms and offering essential services such as flood mitigation, water purification, and livelihood support to the local communities. The wetland serves as a sanctuary for numerous endangered species namely Asiatic elephants, fishing cats, and migratory birds. The ecology and environment are increasingly affected by various anthropogenic activities within and surrounding the wetland. These disturbances are adversely affecting its ecosystem services, biological diversity, and environmental quality, signifying the need for enhanced protective measures to safeguard this vital wetland. There is a need for the development of a sustainable management plan and new policies that include the local community leveraging the multifaceted values of the wetland. Such an approach will ensure the conservation efforts of protecting the wetland's ecological integrity, supporting the livelihoods and maintaining cultural heritage of those who depend on it. In this current investigation, the focus is on evaluating the vulnerability of the fishing community in the Deepor Beel of Assam in India. This is achieved through the construction of a Livelihood Vulnerability Index (LVI) using the IPCC approach. The adoption of this index-based methodology has not only helped in assessing livelihood vulnerability of fishing communities but also prioritizing specific thematic domains where interventions can effectively reduce vulnerability.

6.2 Study Area

Deepor Beel is located in the south-western part of Guwahati, Assam, in India. It extends from 26°06′03″N to 26°08′35″N latitudes and from 91°36′28″E to 91°42′23″E longitudes. It is one of the largest and most important ecological wetlands in the Brahmaputra valley. The total area of the wetland is approximately 10 km^2. Deepor Beel is situated within the boundaries of the Jalukbari Mouza, which is a part of the Kamrup district. Due to its distinctive social, ecological, and cultural benefits, it holds international significance and was recognized as Ramsar site in 2002 (listed 1207). The wetland is encompassed by numerous villages and an array of natural landscapes, contributing to its rich and diverse ecological environment. These include Paschim Jalukbari, which lies directly northward, providing a rural lifestyles and traditional practices that are interwoven with the wetland. Dharapur serves as another important bordering village where the local community is dependent on it for fishing and agricultural activities. Maz Jalukbari is also situated along the northern edge, playing a crucial role in supporting the biodiversity and ecological balance of the region. Moving eastward, it adjoins Dakshin Jalukbari, Tetelia, Paschim Boragaon, Pub Boragaon, and Pamahi. To the south, Deepor Beel is flanked by the Rani Reserve Forest and Chakordew Hill, serving as natural barriers and contributing significantly to the ecological dynamics of the wetland. On its western side, Deepor Beel is connected with the villages of Kahikuchi, Jugipara, Azara, and Garalgaon (Fig. 6.1). The surrounding villages with 1100 families around Deepor Beel directly or indirectly dependent on it for their livelihood.

Throughout the year, the water level in the wetland undergoes considerable fluctuations between the dry and wet seasons. The level is generally high during monsoon season. During the monsoon season, the depth of Deepor Beel is reached to the level between 4 and 5 meters whereas in the dry season it is reduced to approximately 1 meter (RIS, 2002). Deepor Beel provides a range of benefits to the city in numerous ways, enhancing both the environmental landscape and the quality of life of the people residing around the wetland. Deepor Beel has become a hub for biodiversity, attracting over 19,000 migratory water birds annually (Sharma, 2011). Its rich biodiversity and scenic beauty have made it an increasingly popular destination for tourists from around the world. The influx of tourists to the wetland plays a

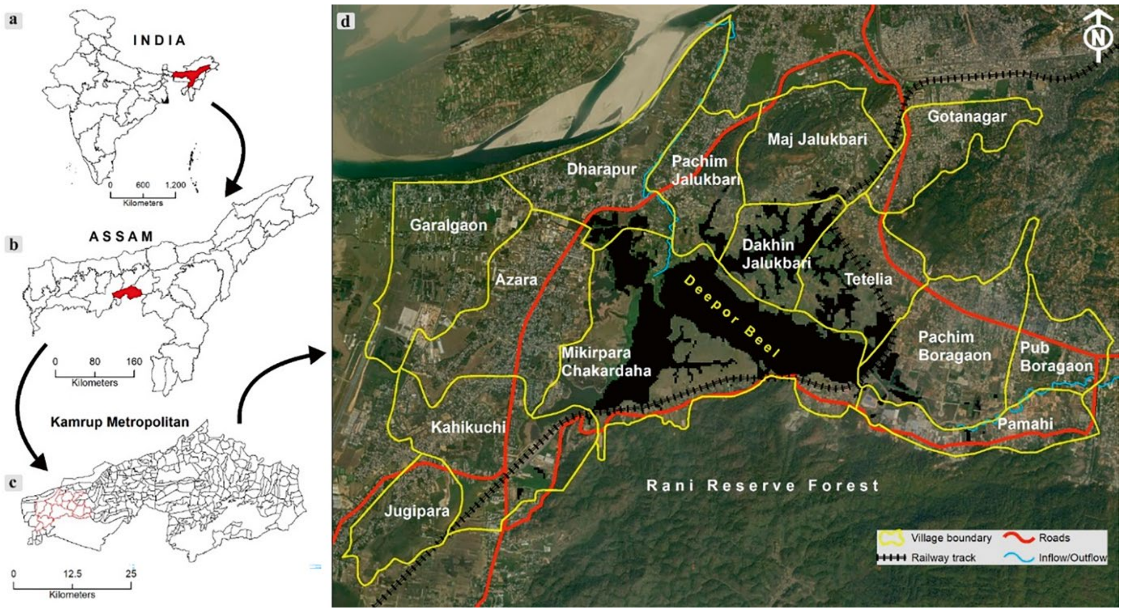

Fig. 6.1 Location of the study area: (**a**) location of Assam in India, (**b**) location of Kamrup Metropolitan in Assam, (**c**) location of villages in Kamrup Metropolitan, and (**d**) areal view of Deepor Beel and surrounding villages

significant role in boosting the revenue of tourism industry through various forms of spending and engagement with local services (Saikia & Bhattacharjee, 1987). The Beel provides distinct habitats that are essential for various fish species and plays a significant role in maintaining the healthy and diverse aquatic ecosystem. A significant part of the wetland during the monsoon season is enriched with a diverse array of water lilies, water hyacinth, aquatic grasses, hydrilla, aquatic vegetation, nymphaea, and various floating plant species contributing to the ecological richness of the wetland (Saikia, 2005).

6.3 Methodology

The methodology adopted for this study is comprised of four stages. In the first stage, site-specific indicators for exposure, sensitivity, and adaptive capacity were chosen based on existing literature and expert knowledge. In the second stage, selection of fishing community households was made. In the third stage, the data was collected through fieldwork using questionnaire. In the final stage, the Livelihood Vulnerability Index (LVI) was constructed to assess the vulnerability levels of the households in the selected villages (Fig. 6.2).

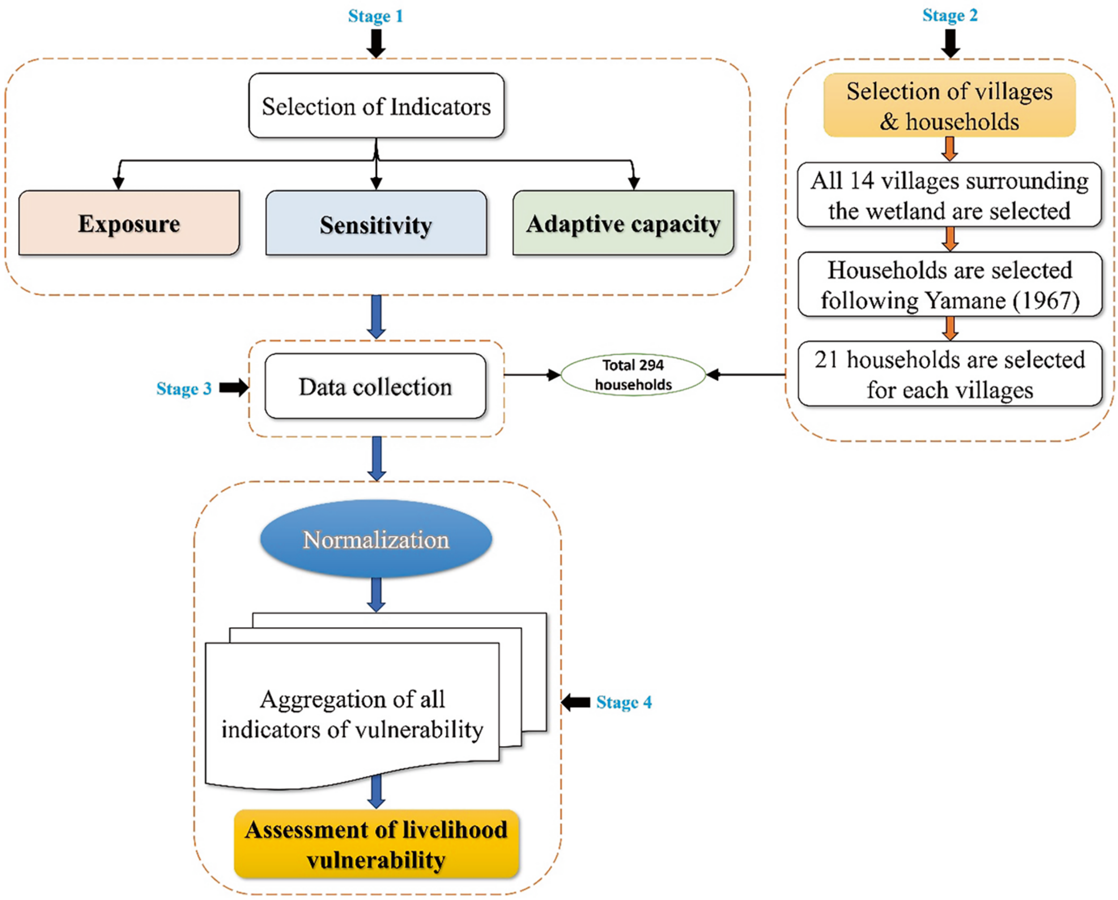

Fig. 6.2 Methodological flow chart of the study

6.3.1 Rationale for the Selection of LVI Indicators

Understanding of the vulnerability of a community or household heavily relies on components such as exposure, sensitivity, and adaptive capacity (Parry, 2007; Islam et al., 2014). The selection of site-specific indicators of these components was made based on past vulnerability studies and a comprehensive understanding of the study area (Table 6.1). Residential status, reduction in wetland area, alterations in fishing grounds, degradation of water quality, decline in fish quality, and changes in fish diversity indicators were selected for examining exposure.

The distance of residence from the wetland is an important indicator for assessing the dependence on wetland for livelihood. The reduction in wetland area leads to a decrease in the availability of fish and fishing grounds. Thus, changes in area under wetland is an important indicator of livelihood vulnerability. The decline in water quality results in deterioration of livelihood vulnerability and diminish fish diversity. A reduction in fish diversity further decreases the income of the fishing community, thereby increasing vulnerability. Sensitivity indicators included demographic profile, educational status, economy, health facility, and dietary habit. The households run by women as head and large number of dependent members (children and elderly persons) increase livelihood vulnerability. The health care centers

Table 6.1 Site specific indicators utilized for livelihood vulnerability assessment

Components	Indicators	Functional relationship with vulnerability
Exposure	Reduction in area under wetland	+
	Loss of fishing area	+
	Changes in water quality	+
	Fish quality degradation	+
	Reduction in fish diversity	+
	Distance of residence from wetland (in m)	+
Sensitivity	Female-headed households (HHs)	+
	Dependent population	+
	Distance from nearest healthcare facility (in km)	+
	Health insurance	+
	Educational attainment	+
	Distance from nearest school (in km)	+
	Experience in the fishery sector	+
	Income level (1 US$ = Indian rupees)	+
	Per capita consumption of fish	+
Adaptive capacity	Adequate income from fishing activities	–
	Livelihood diversification	–
	Health status of HHs head	–
	Engagement in different income sources by one family member	–
	Per capita income from fishing	–
	Accessibility to market	–
	Well-connected market	–
	Cold storage for fish conservation	–
	Proper fishing equipment	–
	Participation in the community activities	–
	Received help from their relatives during their needs	–
	HHs having other options than fishing activities	–
	HHs having the confidence of getting work elsewhere if necessary	–
	Financial security	–
	Participation in restoring/maintaining the fishing grounds	–
	Capacity to enhance the value of their products	–
	Adapting alternative fishing methods	–
	HHs wish to move to different fishing grounds	–
	Migration	–
	Shifted from fishing to other occupations	–
	Sustained more in fishing activities	–

and with no health insurance are more vulnerable (Rehman et al., 2023; Singha & Pal, 2022). The low educational status leads to lack of skills, unemployment, and poor decision-making (Islam et al., 2019). High number of days of work in fishing and resultant high income reduce livelihood vulnerability. Further, higher per capita consumption contributes to enhanced food security.

Physically fit household heads, earning satisfactory income from fishing along with other sources, exhibit reduced vulnerability by minimizing the tendency to shift to alternative professions. Diversifying income sources beyond the primary ones not only enhances household economic conditions but also contributes to a potential reduction in vulnerability. The combination of close market, efficient road accessibility reducing travel time, the presence of cold storage, and access to proper fishing equipment collectively leads to heightened profits and diminished vulnerability for fishermen. Implementing proper management and restoring fishing grounds not only provides additional livelihood options for households but also contributes to a decrease in vulnerability, especially when receiving help during times of need. Financial savings to handle unexpected hazards, restoring fishing grounds on both the quantity and quality of fish species, and the increase in product value, all work together to reduce vulnerability significantly. Adopting new technologies and altering fishing methods, along with transitioning from primitive fishing grounds, is instrumental in increasing household income, enhancing community livelihood opportunities, minimizing migration rates, and preventing occupation shifts due to weakened fishing activities, thereby sustaining more fishing activities and decreasing vulnerability.

6.3.2 Data Collection

The data on the indicators of exposure, sensitivity, and adaptative capacity were collected through field survey using questionnaire containing both closed-ended and open-ended questions. There are 14 villages around the Deepor Beel. The questionnaire was divided into three sections: Sect. 6.1 covered respondents' demographic information, including age, gender, and education level; Sect. 6.2 addressed the socioeconomic status of fishermen; and Sect. 6.3 concentrated on current problems and perception of possibilities to overcome these problems. A pilot survey was conducted before finalizing the questionnaire. Since 14 villages are directly dependent on this wetland and requirement of the study objective, all the villages were considered for the present study (Table 6.2) and for determining the sample size we adopted Eq. (6.1) of Yamane (1967):

$$n = \frac{N}{1 + N(a)^2} \tag{6.1}$$

Table 6.2 List of the surveyed villages located around the Deepor Beel

State	District	Village/ward	Latitude	Longitude
Assam	Kamrup Metro	Azara	26°7′29.29″N	91°36′54.96″E
		DakhinJalukbari	26°7′52.23″N	91°39′19.88″E
		Dharapur	26°8′29.43″N	91°37′41.36″E
		Garalgaon	26°7′52.25″N	91°36′10.57″E
		Gotanagar Gaon	26°8′48.91″N	91°40′52.63″E
		Jugipara	26°5′36.16″N	91°35′45.76″E
		Kahikuchi	26°6′10.49″N	91°36′33.43″E
		Maj Jalukbari	26°8′43.09″N	91°39′54.60″E
		MikirparaChakarda	26°6′39.15″N	91°38′30.85″E
		PachimBoragaon	26°7′07.85″N	91°41′12.31″E
		PachimJalukbari	26°8′26.14″N	91°38′38.70″E
		Pamahi	26°6′13.11″N	91°41′30.12″E
		Pub Boragaon	26°6′56.64″N	91°42′06.38″E
		Tetelia	26°7′37.98″N	91°40′12.58″E

where "n" is sample size, "N" is households' number, "a" is margin of error, and 1 is a constant. Out of a total of 1100 households (source: Guwahati Wildlife Division), the optimal sample size has been calculated as 293.33, rounded up to 294 samples for equal representation from each village. The selection of sample households will follow a simple random sampling method, with 21 households being randomly chosen from each village.

6.3.3 Construction of Livelihood Vulnerability Index (LVI)

The Livelihood Vulnerability Index (LVI) was developed following the IPCC approach, incorporating the components of exposure, sensitivity, and adaptive capacity. To ensure consistency and avoid biases or missing data, equal weights were assigned to the chosen indicators (Masroor et al., 2023). Standardizing the indicators became imperative due to variations in measurement scales (Bhuiyan et al., 2017; Hahn et al., 2009). The standardization technique employed in this study was adapted from the United Nations Development Programme (UNDP, 2007), similar to techniques used by Sajjad et al. (2014) for the Sustainable Livelihood Security Index (SLSI) and Singha and Pal (2022) for livelihood vulnerability assessment. The indicators were standardized using Eq. (6.2):

$$\text{Index}_T = \frac{T - T_{\min}}{T_{\max} - T_{\min}} \quad (6.2)$$

where Index_T is standardized value for the indicators, T is actual value of the indicators, and $T_{\max}$ and $T_{\min}$ are the maximum and minimum values of the indicators, respectively. For indicators measured in percentages, the minimum and maximum values were set at 0 and 100, respectively. After standardization, the average of these indicators was calculated to derive the index value for each subcomponent (Hahn et al., 2009), using Eq. (6.3):

$$C_s = \sum_{i=1}^{n} \text{Index}_T / n \tag{6.3}$$

where C_s is the subcomponent, Index_T is the index value of the indicator, and n is the number of indicators for each subcomponent. After determining the values for each subcomponent, Eq. (6.4) was applied to calculate the values associated with exposure, sensitivity, and adaptive capacity components.

$$C_j = \sum_{k=0}^{n} X_i C_s / \sum_{k=0}^{n} W_{\text{si}} \tag{6.4}$$

where C_j is indicating the exposure, sensitivity, or adaptive capacity for village j and Cs is the subcomponent for village j. The weights (W_{si}) assigned to the components are determined based on the number of subcomponents that make up each of the exposure, sensitivity, and adaptive capacity components. Following the computation of exposure, sensitivity, and adaptive capacity values, the LVI values for each village were calculated using Eq. (6.5):

$$\text{LVI} = (\text{Exposure} - \text{Adaptive capacity}) \times \text{Sensitivity} \tag{6.5}$$

LVI represents the Livelihood Vulnerability Index (LVI) for the fishing activity-based village. The LVI values ranges from −1 to 1, where −1 indicate least vulnerability and 1 denotes the most vulnerability.

6.4 Results

Different components of exposure, sensitivity, and adaptive capacity along with several relevant indicators are described in this section. Tables 6.3, 6.4, and 6.5 represent the index value of components and spatial distribution of those indices are presented in Figs. 6.3, 6.4, and 6.5. Overall, 14 villages of fishing activity-based community were surveyed surrounding the Deepor Beel wetland.

Table 6.3 Indexes values of indicators used in determining the exposure

Villages	HHs facing problems due to wetland area reduction	Changes in the fishing ground	Degradation of water quality	Degradation of fish quality	Reduction of fish diversity	Distance from the wetland	Exposure index (EI)
Azara	0.57	0.62	0.67	0.86	0.48	0.25	**0.57**
DakhinJalukbari	0.71	0.67	0.76	0.71	0.62	0.05	**0.59**
Dharapur	0.67	0.52	0.81	0.9	0.43	0.34	**0.61**
Garalgaon	0.76	0.57	0.48	0.86	0.67	1	**0.72**
Gotanagar Gaon	0.43	0.67	0.48	0.81	0.57	0.79	**0.62**
Jugipara	0.81	0.57	0.71	0.86	0.76	0.87	**0.76**
Kahikuchi	0.67	0.67	0.52	0.9	0.67	0.42	**0.64**
Maj Jalukbari	0.76	0.67	0.86	0.62	0.52	0.83	**0.71**
MikirparaChakarda	0.52	0.52	0.57	0.71	0.57	0	**0.48**
PachimBoragaon	0.71	0.62	0.76	0.95	0.52	0.41	**0.66**
PachimJalukbari	0.71	0.57	0.71	0.9	0.48	0.52	**0.65**
Pamahi	0.9	0.62	0.81	0.81	0.71	0.62	**0.75**
Pub Boragaon	0.71	0.71	0.76	0.81	0.9	0.85	**0.79**
Tetelia	0.81	0.71	0.71	0.9	0.67	0.2	**0.67**

6.4.1 Exposure

The values of the exposure index range from 0.48 to 0.79. The analysis of exposure revealed that of the total surveyed villages, five villages namely Jugipara, Garalgaon, Maj Jalukbari, Pamahi, and Pub Boragaon were highly exposed to livelihood vulnerability (Table 6.3 and Fig. 6.3). These villages were situated at a considerable distance away from the wetland and faced various socioeconomic challenges. Encroachment on fishing grounds due to haphazard urban development have further disrupted social cohesion and degraded the wetland ecosystem.

Eight villages, namely Azara, Dharapur, Kahikuchi, PachimJalukbari, DakhinJalukbari, Gotanagar, Tetelia, and PachimBoragaon experienced moderate level of exposure. This was primarily due to changes in fishing grounds, degradation of water quality, and a reduction in the diversity of fish. The poor water quality has influenced the growth of water hyacinth, which has negatively affected the fish quality. Low exposure was found in MikirparaChakardaha village owing to fewer changes in fishing grounds and area under wetland. However, the respondents disclosed a high incidence of fish quality degradation.

Table 6.4 Indexes values of indicators used in determining the sensitivity

Villages	Demographic profile	Health status	Educational status	Employment dependency	Economic dependency	Food dependency	Sensitivity index (SI)
Azara	0.22	0.22	0.34	0.82	0.52	1	**0.43**
DakhinJalukbari	0.27	0.18	0.38	0.64	0.67	0.73	**0.41**
Dharapur	0.03	0.17	0.26	0.64	0.62	0.67	**0.32**
Garalgaon	0.49	0.51	0.54	1	0.57	0.33	**0.55**
Gotanagar Gaon	0.03	0.1	0.26	0.09	0.62	0.47	**0.22**
Jugipara	0.41	0.76	0.69	0.91	0.71	0.73	**0.68**
Kahikuchi	0.55	0.46	0.76	0.82	0.67	0.6	**0.62**
Maj Jalukbari	0.31	0.19	0.41	0	0.76	0.6	**0.35**
MikirparaChakarda	0.16	0.32	0.51	0.91	0.67	0	**0.39**
PachimBoragaon	0.22	0.17	0.46	0.09	0.81	0.93	**0.39**
PachimJalukbari	0.11	0.15	0.31	0.73	0.38	0.33	**0.29**
Pamahi	0.35	0.86	0.93	1	0.81	0.67	**0.75**
Pub Boragaon	0.57	0.46	0.66	0.73	0.76	0.67	**0.62**
Tetelia	0.17	0.34	0.48	0.45	0.71	0.87	**0.45**

Table 6.5 Indexes values of indicators used in determining the adaptive capacity

Villages	Natural asset	Human asset	Economic asset	Physical asset	Social asset	Risk perception	Planning skills	Flexibility	Adaptive capacity index (ACI)
Azara	0.67	0.71	0.81	0.69	0.5	0.83	0.68	0.43	**0.63**
DakhinJalukbari	0.31	0.71	0.18	0.35	0.36	0.36	0.46	0.31	**0.36**
Dharapur	0.6	0	0.72	0.61	0.52	0.71	0.76	0.46	**0.58**
Garalgaon	0.24	0.86	0.2	0.34	0.21	0.52	0.44	0.22	**0.33**
Gotanagar Gaon	0.65	0	0.56	0.48	0.55	0.76	0.67	0.45	**0.53**
Jugipara	0.29	0.43	0.15	0.42	0.19	0.43	0.46	0.21	**0.32**
Kahikuchi	0.26	0.71	0.11	0.39	0.24	0.55	0.51	0.21	**0.34**
Maj Jalukbari	0.45	0.43	0.38	0.35	0.5	0.4	0.76	0.29	**0.43**
MikirparaChakarda	0.62	0	0.77	0.4	0.4	0.69	0.62	0.49	**0.52**
PachimBoragaon	0.57	1	0.35	0.52	0.36	0.36	0.59	0.31	**0.46**
PachimJalukbari	0.6	0.43	0.47	0.51	0.48	0.69	0.62	0.39	**0.51**
Pamahi	0.22	0.29	0.07	0.28	0.24	0.5	0.43	0.24	**0.28**
Pub Boragaon	0.24	0.29	0.18	0.31	0.21	0.52	0.52	0.18	**0.3**
Tetelia	0.38	0.86	0.4	0.39	0.38	0.5	0.51	0.38	**0.44**

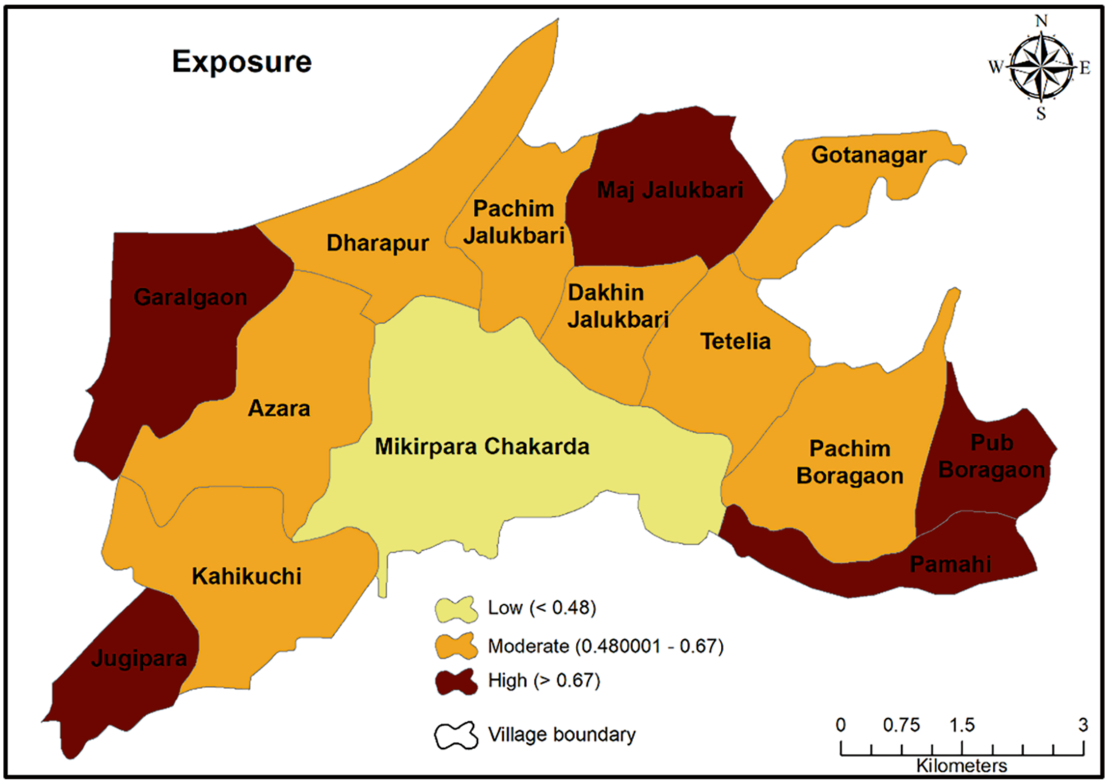

Fig. 6.3 Exposure level in the villages

6.4.2 Sensitivity

The sensitivity index value varies from 0.22 to 0.75 (Table 6.4). A high level of sensitivity was found among the sampled households of Jugipara, Kahikuchi, Garalgaon, Pamahi, and Pub Boragaon villages (Fig. 6.4). Poor health status, lower education attainment, and higher proportions of female-headed households contributed to high sensitivity. Furthermore, their high reliance on fishing activity makes them highly sensitive to fluctuations in fish availability, market demand, and environmental stressors.

Moderate sensitivity was observed in Azara, MikirparaChakardaha, Maj Jalukbari, DakhinJalukbari, Tetelia, and PachimBoragaon villages due to high employment, economic, and food dependencies. However, the health status in these villages was better than in highly sensitive villages. Dharapur, PachimJalukbari, and Gotanagar villages were found to have low sensitivity. Residents in these villages have access to regular health check-ups, preventive care services, and health education programs, leading to better health outcomes and lower sensitivity to environmental stressors. Furthermore, the lower sensitivity can also be attributed to the strong community support systems and social networks that aided during the times of need.

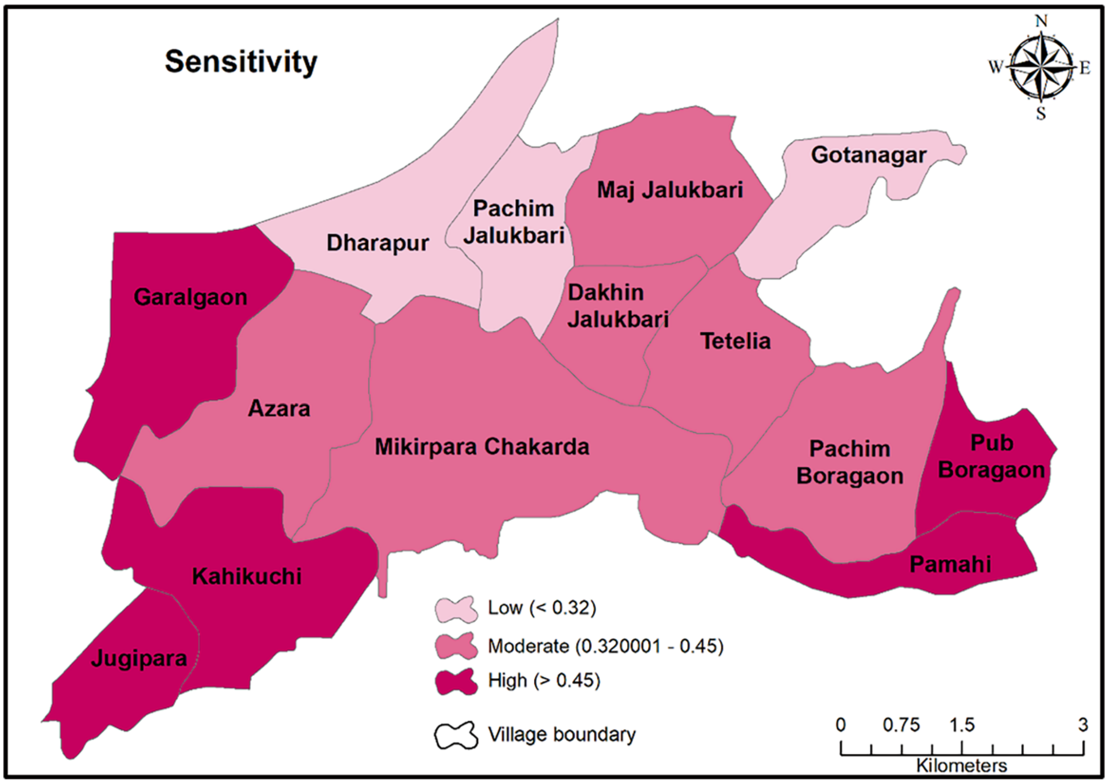

Fig. 6.4 Sensitivity level in the villages

6.4.3 Adaptive Capacity

High adaptive capacity was found in five villages, namely Azara, Dharapur, PachimJalukbari, MikirparaChakardaha, and Gotanagar Gaon. Efficient road accessibility, proximity to markets, proper fishing equipment, and access to cold storage facilities contributed to high adaptive capacity. The other reason for high adaptation is the strong natural, economic, and physical assets. Moreover, the respondents are engaged in varied livelihood strategies and have relocated to urban areas for improved earnings prospects (Table 6.5 and Fig. 6.5). Maj Jalukbari, Tetelia, and PachimBoragaon villages have moderate adaptive capacity due to moderate levels of social and human assets. However, strategic perception and planning regarding income generation and fishing activities were evident in these villages. Low adaptive capacity was found in Jugipara, Kahikuchi, Garalgaon, DakhinJalukbari, Pamahi, and Pub Boragaon villages. The index values for natural, economic, and social assets were low in these villages. Ineffective planning skills and insufficient understanding of possible risks and vulnerabilities limited their capacity to cope with varied problems.

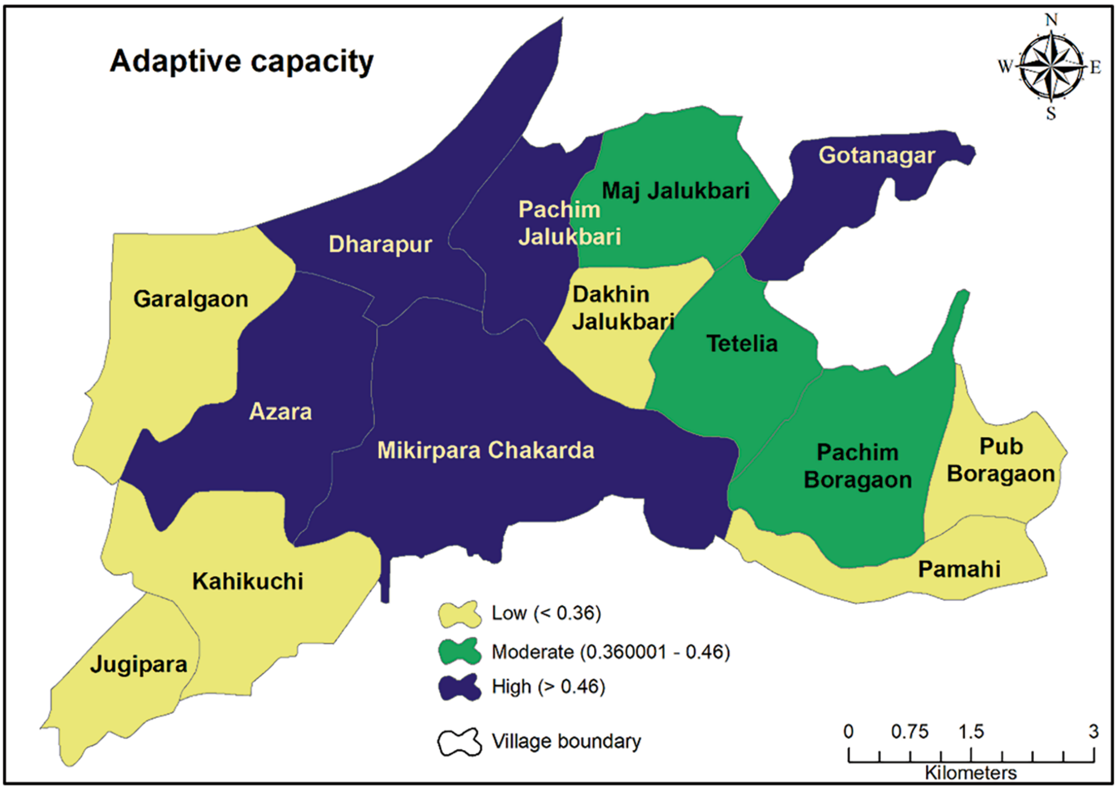

Fig. 6.5 Adaptive capacity level in the villages

6.4.4 Livelihood Vulnerability of the Fishing Communities

The livelihood vulnerability analysis revealed high vulnerability in Jugipara followed by Garalgaon, Pamahi, and Pub Boragaon villages. High exposure and sensitivity and low adaptive capacity attributed to high vulnerability (Table 6.6 and Fig. 6.6).

Less demand of fish in market, less income opportunities, absent of nearby market, and cold storage further disrupted the socioeconomic conditions of the households. The respondents in these villages were located away from the wetland, which increases their vulnerability in accessing essential resources. Kahikuchi, Tetelia, Maj Jalukbari, DakhinJalukbari, and PachimBoragaon villages are moderately vulnerable due to their proximity to wetland areas and the subsequent impact on their fishing-based livelihoods. Despite variations in their exposure indices, ranging from moderate to high, these villages suffered from degraded water quality and a decrease in fish diversity, which severely impacted their livelihoods. While there are variations in specific indicators across these villages, such as demographic profiles and health statuses that attribute to moderate vulnerability. The respondents are significantly reliant on wetland ecosystem for employment and economic activities, as indicated by high employment, economic, and food dependencies. Low vulnerability was found in PachimJalukbari, Gotanagar Gaon, Dharapur, MikirparaChakarda, and Azara villages due to higher degree of adaptation. The residents were better

Table 6.6 Index scores of components and Livelihood Vulnerability Index (LVI) of different villages

Villages	EI	SI	ACI	LVI
Azara	0.57	0.43	0.63	**−0.026**
DakhinJalukbari	0.59	0.41	0.36	**0.094**
Dharapur	0.61	0.32	0.58	**0.010**
Garalgaon	0.72	0.55	0.33	**0.215**
Gotanagar Gaon	0.62	0.22	0.53	**0.020**
Jugipara	0.76	0.68	0.32	**0.299**
Kahikuchi	0.64	0.62	0.34	**0.186**
Maj Jalukbari	0.71	0.35	0.43	**0.098**
MikirparaChakarda	0.48	0.39	0.52	**−0.016**
PachimBoragaon	0.66	0.39	0.46	**0.078**
PachimJalukbari	0.65	0.29	0.51	**0.041**
Pamahi	0.75	0.75	0.28	**0.353**
Pub Boragaon	0.79	0.62	0.3	**0.304**
Tetelia	0.67	0.45	0.44	**0.104**

equipped with natural, human, economic, physical, and social assets, alongside their perceived lower risk and enhanced planning capabilities.

6.5 Discussion and Policy Implications

The present study employed a comprehensive approach to assess the livelihood vulnerability of wetland-dependent fishing communities surrounding the Deepor Beel wetland in Assam, India. The findings of the study revealed that the anthropogenic activities have degraded the environment, which in turn has affected the fishing activities and livelihoods of the surrounding communities. This is in tune with the studies conducted by Hidayat et al. (2022), Saikia et al. (2019), Aazami and Shanazi (2020), and Kumari et al. (2023). The assessment of livelihood vulnerability relied on the functional correlation among exposure, sensitivity, and adaptive capacity (Ding et al., 2017). The analysis was further extended to calculate index values for selected indicators and spatially visualize the distribution of these indices across the surveyed villages (Figs. 6.3, 6.4, and 6.5). The exposure analysis focused on indicators, namely residential status, reduction in wetland area, encroachment the fishing grounds for unplanned urbanization, degradation of water quality, decline in fish quality, and changes in fish diversity. Similar researches have also selected degradation of water quality and decline in fish diversity indicators for examining the impact of exposure of local communities (Hidayat et al., 2022; Saikia et al., 2019; Aazami & Shanazi, 2020). The scenario of livelihood vulnerability in the study area is primarily influenced by interconnected driving forces that functionally relate to each other. The results indicated significant variability across villages Jugipara,

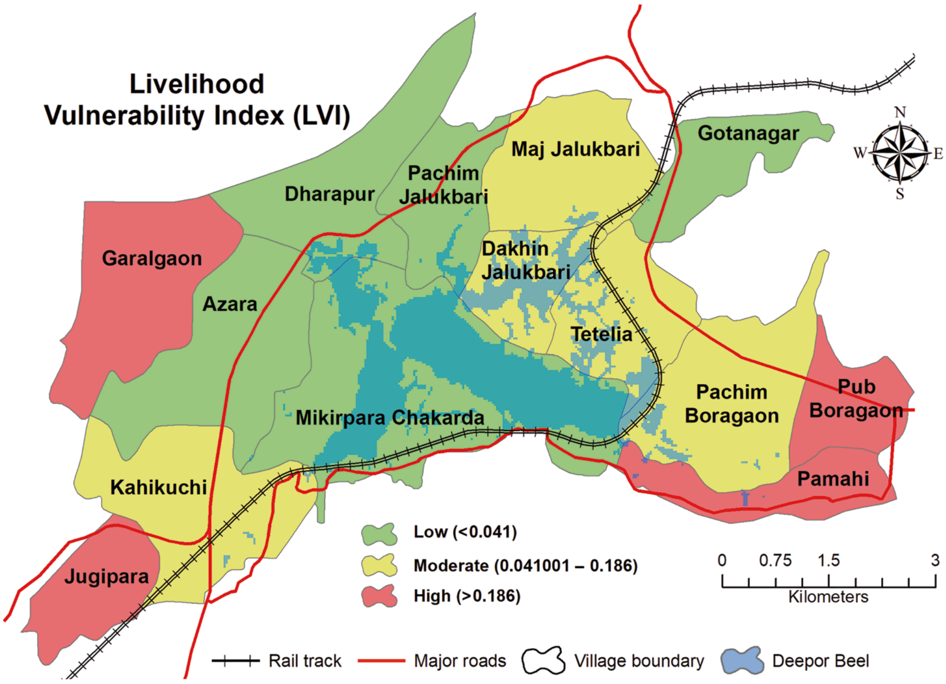

Fig. 6.6 Livelihood vulnerability of fishing community-based villages

Garalgaon, Maj Jalukbari, Pamahi, and Pub Boragaon, exhibiting high exposure levels. This high exposure could be attributed to factors such as distance from the wetland, reduction in nearby fishing grounds, deteriorating water quality, and absence of nearby market (Fig. 6.7). These findings underscore the vulnerability of these communities to economic changes and are in finding with the various studies across the world (Sarkar & Islam, 2022; Abd Majid et al., 2019; Rahman & Hickey, 2020). In the study area, poor water quality in some part lead to the abundant growth of water hyacinth, negatively impacting fishing activities. Ahmed and Haque (2023) have also examined the effect of hyacinth on fishing activities. Further, the shallowing of water and the subsequent rise in water temperature, extending even to the deeper parts of the wetland have created unfavorable conditions for fish survival. This reduction in fish growth has significantly limited the opportunities for livelihood and long-term sustainability of fishing activities. Singha and Pal (2023) have also reported the similar finding. The increasing uncertainty of water availability in Deepor Beel has created a great challenge to the stability and security of the fishermen's livelihoods. Marked variations were observed in sensitivity among the sampled respondents. Gotanagar Gaon exhibited the highest sensitivity, while Dharapur, PachimJalukbari, and Gotanagar demonstrated low sensitivity. Health status, education, and economic dependency have contributed to the overall sensitivity of the communities. In recent decades, there has been an increase in the frequency and intensity of natural disasters affecting wetlands functions and dependent communities (Das & Bhattacharjee, 2015). Five villages, namely Azara, Dharapur, PachimJalukbari, MikirparaChakardaha, and Gotanagar Gaon, have displayed high adaptive capacity, indicating their ability to cope with changing conditions (Fig. 6.7). These communities have exhibited in assets management, strategic planning, and flexibility in adapting to new challenges. The fishing communities residing in Jugipara, Kahikuchi, Pamahi, and Pub Boragaon have struggled to find strategies

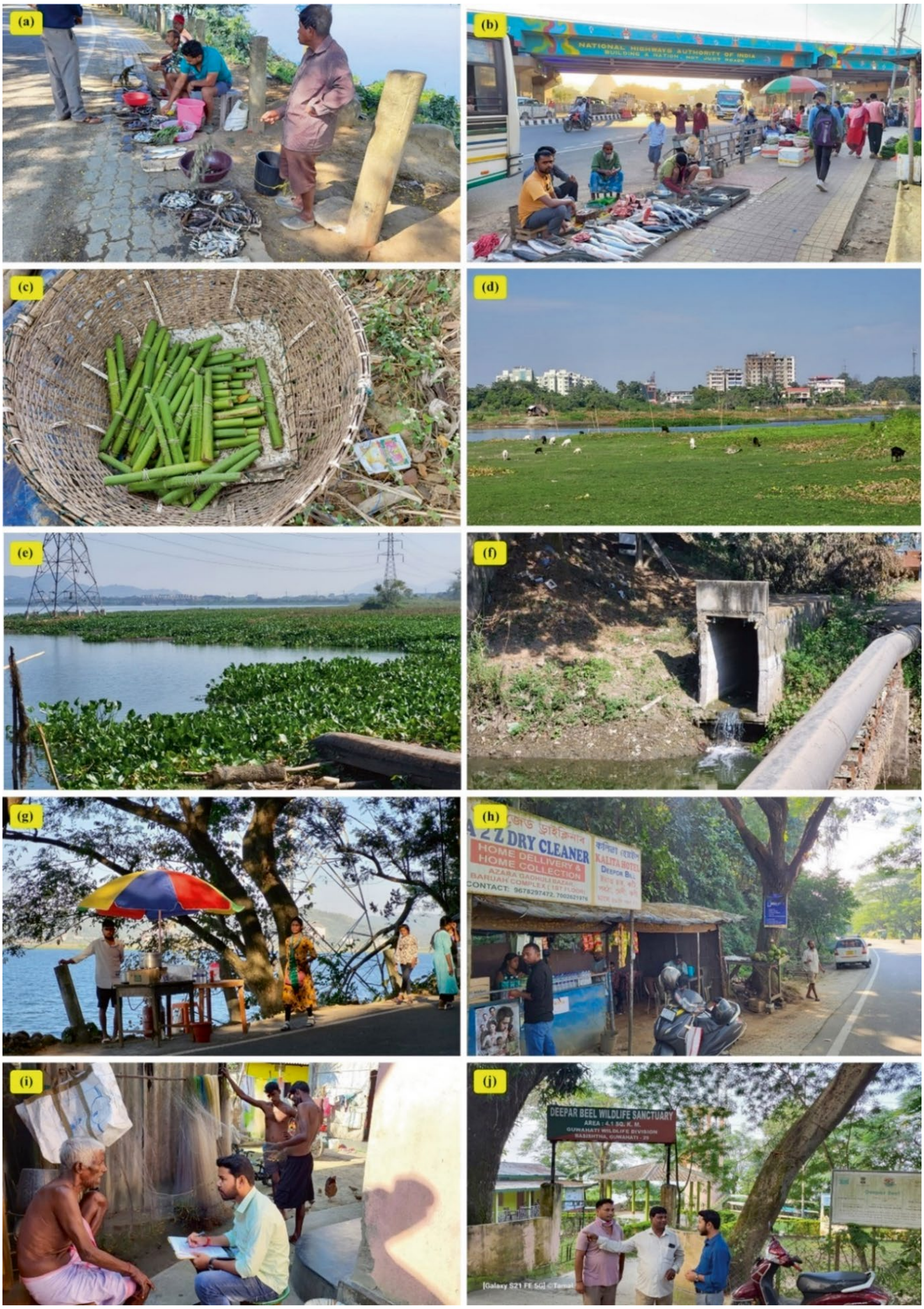

Fig. 6.7 Field photographs: (**a**) sale of fish near wetland, (**b**) sale of fish in local market, (**c**) traditional tool for catching fish, (**d**) encroachment of the fishing ground, (**e**) eutrophication, (**f**) pollution source, (**g**, **h**) alternative livelihood activity, (**i**) interaction with fishing communities, (**j**) discussion with local authority

for improving their economic condition. The degradation is linked with the ecosystem decline, which results in increased the vulnerability of communities and susceptibility to natural disasters. This has significant implications for both biodiversity and community livelihoods (Zekarias et al., 2021).

Livelihood Vulnerability Index (LVI) has helped in prioritizing thematic areas that urgently require attention to reduce the extent of vulnerability (Table 6.7). Effective strategies are suggested to address the high exposure and sensitivity observed in villages such as Garalgaon, Jugipara, Maj Jalukbari, Pamahi, and Pub Boragaon, while also enhancing adaptive capacity across all the sampled villages. To reduce exposure, interventions may focus on mitigating urban encroachment on fishing grounds and wetland areas through effective land use planning and zoning regulations. Implementation of pollution control measures and waste management systems can help restore the ecological integrity of the wetland, thereby safeguarding fish habitats and biodiversity. Promoting sustainable fishing practices and habitat restoration initiatives can further contribute to enhancing fish diversity and availability. Addressing sensitivity requires a multifaceted approach that targets socioeconomic conditions of the communities. Provision of access to health care services and insurance coverage can improve health outcomes and reduce vulnerability to health-related shocks. Similarly, investing in education and skill development programs can empower community members to diversify their livelihoods and reduce dependency on fishing activities. Promoting gender equality and empowering women as decision-makers can also enhance household resilience to socioeconomic stressors. To improve adaptive capacity, investments in infrastructural development such as roads, markets, and cold storage facilities may enhance access to markets and improve the value chain for fish products.

Providing training and capacity-building programs on climate-resilient farming practices, aquaculture, and ecotourism may offer alternative income-generating opportunities and enhance community resilience to environmental changes. Establishing community-based organizations and cooperatives may foster collective action and resource sharing, thereby strengthening social capital and enhancing adaptive capacity at the local level. Overall, a comprehensive and participatory approach that integrates environmental conservation, socioeconomic development, and community empowerment is essential for reducing vulnerability and enhancing resilience among fishing communities in the Deepor Beel. Implementation of these planning strategies and coordination among local stakeholders and policymakers may help in achieving sustainable development goals and safeguarding the livelihoods and well-being of vulnerable communities. Maintaining proper wetland health enables the sustainable realization of various social benefits (Dinsa & Gemeda, 2019). Severe and persistent wetland pollution adversely affects the economic base, social structure, and livelihoods of the communities relying on the wetland (Saikia et al., 2019; Das & Bhattacharjee, 2015). The findings of this study provide valuable insights for policy formulation and conservation efforts. The implementation of effective strategies is imperative to enhance the resilience among fishing communities in Deepor Beel. Initiatives such as advancements in healthcare

Table 6.7 Prioritization of villages for vulnerability reduction

Villages	Exposure	Sensitivity	Adaptive capacity
Azara	–	–	–
DakhinJalukbari	–	–	–
Dharapur	–	–	–
Garalgaon	✓	✓	✓
Gotanagar Gaon	–	–	–
Jugipara	✓	✓	✓
Kahikuchi	–	✓	✓
Maj Jalukbari	✓	–	✓
MikirparaChakarda	–	–	–
PachimBoragaon	–	–	✓
PachimJalukbari	–	–	–
Pamahi	✓	✓	✓
Pub Boragaon	✓	✓	✓
Tetelia	–	–	–

and education, creation of improved employment opportunities and governmental support hold the potential to significantly elevate the quality of life.

The conservation and sustainable use of wetlands are significant for realizing objectives of sustainable development goals (SDGs) related to climate, water, ecosystems, and marine resources (Seifollahi-Aghmiuni et al., 2019). Efficient measures are required for implementing comprehensive wetland conservation plans, including regular water quality monitoring and habitat restoration. Safeguard of wetlands may help in achieving the objectives of the tenth SDGs. Hence, it is imperative to integrate wetland conservation within the global SDG framework to ensure the protection of these vital ecosystems (Ramsar, 2018). Deepor Beel as a Ramsar Site is an important wetland and tourist attraction in Assam. Thus, vocational training may provide skill enhancement to the communities for exploring alternative income-generating activities. Improvement in educational status and provision specialized training may help in diversification of livelihoods in aquaculture, sustainable farming, and ecotourism. The establishment of marketing cooperatives and partnerships with private enterprises is essential for making value addition to fish products. Creation of community-based organization and provision of grants for community development projects may strengthen social bonds and resilience.

6.6 Conclusion

The assessment of livelihood vulnerability among wetland-dependent fishing communities surrounding Deepor Beel highlighted significant variation in exposure, sensitivity, and adaptive capacity across surveyed villages. LVI indicated that Jugipara, Garalgaon, Pamahi, and Pub Boragaon were highly vulnerable. The exposure analysis identified interconnected driving forces, such as distance from the wetland, reduction in fishing grounds, deteriorating water quality, and the absence of nearby markets for high livelihood vulnerability in the sampled villages. Poor water quality and environmental changes have negatively impacted fishing activities and livelihoods of the communities. The Livelihood Vulnerability Index (LVI) served as a valuable tool for prioritizing thematic areas requiring urgent attention. Villages with high exposure and sensitivity were identified as highly vulnerable, emphasizing the need for targeted interventions to reduce vulnerability. Thus, comprehensive conservation plans and provision of training programs are essential for reducing livelihood vulnerability among fishing communities. The LVI as a planning tool has helped not only in identifying livelihood vulnerable villages but also in identifying thematic areas of the livelihood vulnerability where the effective efforts may reduce the livelihood vulnerability. The other geographical regions interested in examining livelihood vulnerability may find LVI approach effective.

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