



Article

Sustainable Livelihoods under Water: The Case of Waterlogging in Barishal City Corporation, Bangladesh

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Abstract: The recent emergence of seasonal waterlogging in urban areas of Bangladesh has had a significant impact on the daily lives of urban dwellers, posing substantial challenges to their livelihoods. This study investigated how seasonal waterlogging affected sustainable livelihood capitals in the Barishal City Corporation (BCC) area and provided a comprehensive assessment of livelihood vulnerability. Data were collected through semi-structured interviews with 100 respondents using an indicator-based questionnaire informed by respondents' lived experiences, and the data were statistically analyzed to derive livelihood vulnerability indices. Results demonstrate that the study area is highly susceptible to waterlogging, as the Total Livelihood Vulnerability Index (TVI) of the Barishal City Corporation area stands at 0.58. In the study area, the vulnerability indices differ across the five livelihood capitals, with physical capital being the most susceptible capital, accompanied by social capital, while natural capital is comparatively less vulnerable. The findings further revealed that the livelihood vulnerability varies according to the socioeconomic characteristics of the respondents and is largely driven by inadequate drainage systems, poor road conditions, and ineffective canal management. Overall, the study provides rigorous information on livelihood vulnerability associated with seasonal waterlogging and offers policy recommendations for enhancing resilience in waterlogging-prone urban environments.

Keywords: livelihood capitals; mitigation measures; total vulnerability index; waterlogging

1. Introduction

Bangladesh is the most vulnerable country in the world to disasters associated with natural hazards, due to its geographic location and socioeconomic standing [1–4]. Rising temperatures and altered precipitation patterns



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will cause progressive changes, including sea-level rise and shifts in climatic zones [5–7]. Consequently, coastal residents are continuously experiencing waterlogged conditions, which have significantly impaired the way of life and means of sustenance of people in southern Bangladesh [8]. Although waterlogging is not an unfamiliar problem in Bangladesh, its incidence and severity are growing every day [9]. Waterlogging has been demonstrated to exert deleterious effects on economic growth, the environment, and human populations [10].

Over the past few decades, waterlogging has been a significant problem in urban regions of Bangladesh. Additionally, increased urbanization, poor governance, inadequate drainage infrastructure, and light rainfall leave certain urban centers submerged for days [11–15]. Even in comparatively well-drained towns like Sylhet, the unplanned expansion of city structures and poor maintenance of existing drainage facilities have exacerbated waterlogging [16,17]. A study in Noakhali Pourashava reported that waterlogging regularly occurs, disrupting the earnings of rickshaw pullers [17]. In the city of Khulna, the rainy season has been observed to result in waterlogging due to inadequate drainage, which in turn has been found to lead to the infiltration of pollutants into the groundwater [18]. Waterlogging is also reported to be a major problem for the residents of Dhaka city [19]. Consequently, residents' livelihood capitals, such as natural, physical, human, financial, and social, become vulnerable [20–22].

The Barishal City Corporation area, particularly around College Row, College Avenue, Sadar Road, Fakirbari Road, Battala, Baidyapara, Sagardi, Oxford Mission, Bogura Road, Munshi Garage, Gorosthan Road, and Katpotti, regularly suffers from significant waterlogging. This happens during the monsoon season from May to October, as the water level of the nearby rivers remains higher than the internal drainage level [23]. As a result, buildings, homes, schools, universities, stores, and commercial spaces are submerged with three to four feet of water, ultimately generating misery for the local population [24]. Low-income groups, such as domestic workers, day laborers, grocery store owners, and vegetable vendors, are affected [16]. The consequences include waterborne illnesses, contaminated sanitation facilities, financial hardship, and a rise in worry [25]. One emergency concern now is the impact of waterlogging on livelihoods [26]. Despite this, there haven't been systematic efforts to reduce livelihood vulnerability to waterlogging.

Livelihoods are the resources and abilities needed to maintain people's fundamental requirements across time [27,28]. The capacity for obtaining food and other essential requirements calls for capital. The United Kingdom Department for International Development (DFID) and Institute of Development Studies (IDS) distinguished five types of capital of sustainable livelihood, such as financial (cash, savings, credit, jewelry, and other valuables); human (health, knowledge, and skills); social (family, social networks, and associations); physical (housing, infrastructure, work tools, livestock, and household utensils); and natural (agricultural land, water, trees, air, and other natural resources) [29–31]. A sustainable livelihood can deal with and rebound from unexpected events and stresses, and continue to improve its strengths, assets, and entitlements, without compromising the natural resource base [29,32]. When it comes to handling stress and shocks, the sustainability of livelihoods has frequently been linked to vulnerability [33,34].

The Barishal City Corporation area was selected as the study area because it is a low-lying coastal city that frequently experiences waterlogging, which disrupts housing, transportation, and the income sources of its residents. This area's recurrent vulnerability makes it an ideal case for assessing the impact on livelihoods. Moreover, no research has examined livelihood vulnerability to waterlogging. The study aims to assess the vulnerability of five livelihood capitals: natural, physical, human, financial, and social, to waterlogging in the study area. The objectives are: (i) to assess capital-specific vulnerabilities of sustainable livelihoods, and (ii) to analyze the total vulnerability index (TVI) for seasonal waterlogging in the Barishal City Corporation area. The study sought to provide a guide for other vulnerable locations globally to evaluate sustainable livelihood vulnerability due to waterlogging. These resources are intended to provide researchers with useful knowledge to improve assessment methods, build resilient models, and guide targeted policy interventions, resource allocation, and sustainable planning in urban areas affected by waterlogging.

2. Materials and Methods

This study examined household-level waterlogging vulnerability in 10 wards, specifically 9, 12, 14, 16, 17, 18, 20, 21, 22, and 25, by constructing a composite vulnerability index based on five sustainable livelihood capitals: human, natural, financial, physical, and social capital. The vulnerability level was assessed by averaging weighted and normalized indicator scores for each capital, allowing a comparative assessment of how different livelihood dimensions contribute to waterlogging-related difficulties.

2.1. Description of the Study Area

The Barishal City Corporation area is a significant city located on the banks of the Kirtankhola River with an average height of one to three meters above mean sea level in south-central Bangladesh. Different images of the study area during waterlogging are given in Figure 1. It consists of 58.05 square kilometers [35,36]. The Barisal City Corporation is located between 22°38' and 22°45' north latitude and 90°18' and 90°23' east longitude (Figure 2) [37]. Approximately 419,484 people were living in the city [38]. The population was 49% female and 50.9% male [39,40]. The Barishal City Corporation consists of 30 wards (Figure 3). The region has a tropical dry and wet climate, with an average annual temperature of 25 to 30 °C [41]. Every year, the district receives an average of 2184 mm of rainfall. In addition, the study area is vulnerable to waterlogging because of its low elevation, particularly during tidal surges and the monsoon season [42].



Figure 1. The pictures represent the waterlogged situation of the Barishal City Corporation (Source: Author, 2025).

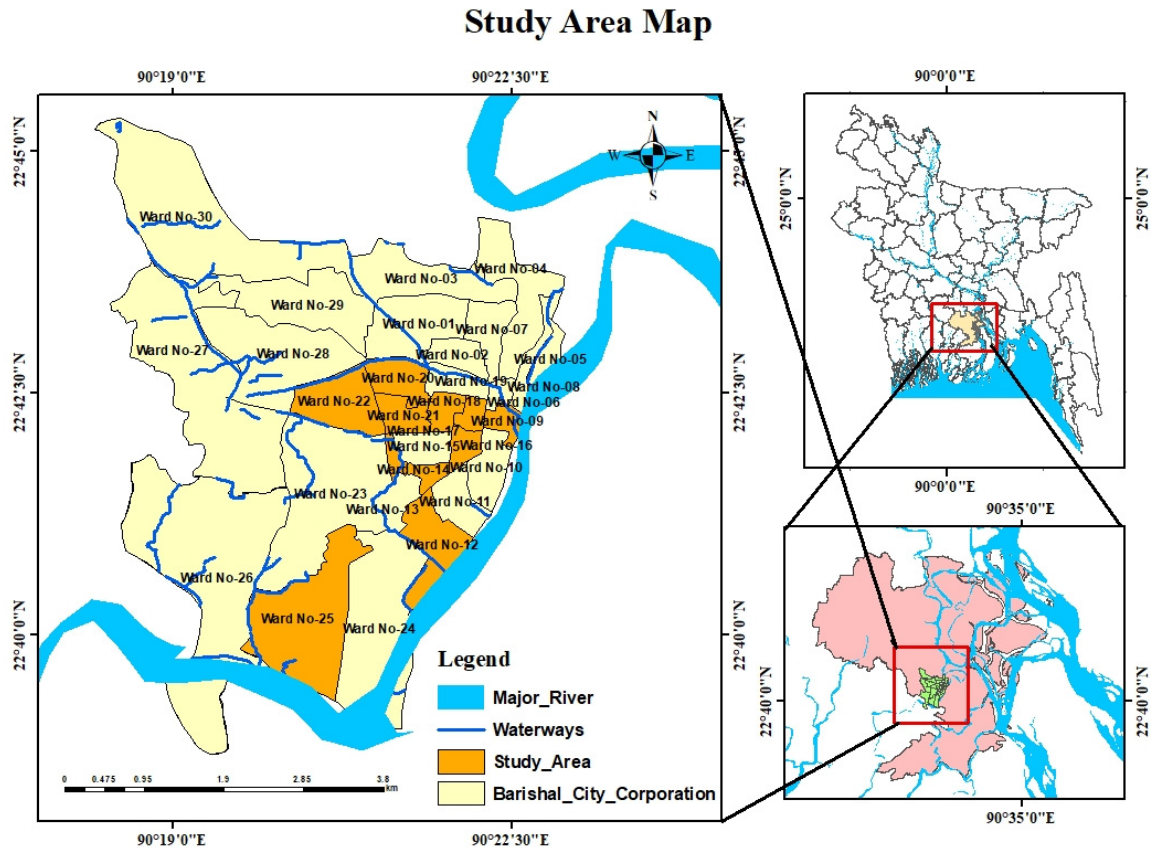


Figure 2. The map represents the study area: Wards no. 9, 12, 14, 16, 17, 18, 20, 21, 22, 25 of the Barishal City Corporation (Author-generated, 2025).

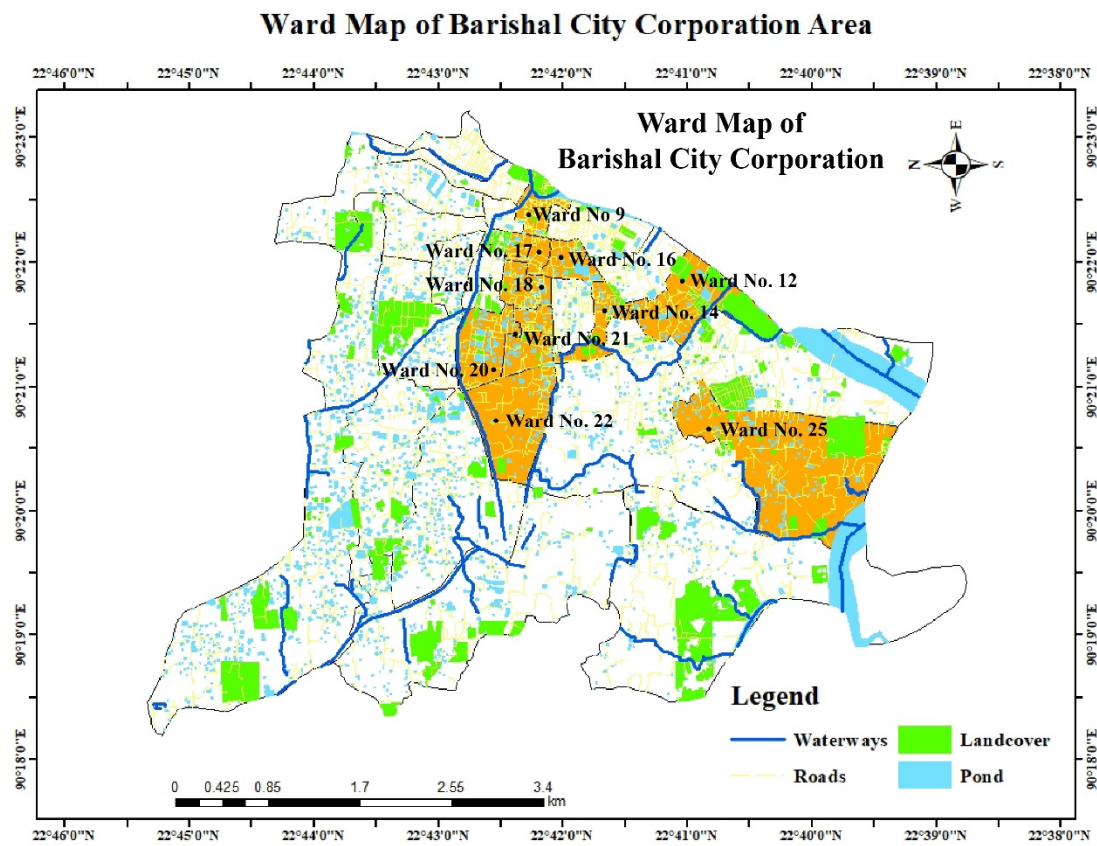


Figure 3. The map represents the study area of Barishal City Corporation (Author-generated, 2025).

2.2. Research Design

A quantitative, cross-sectional household survey was conducted to capture livelihood vulnerabilities associated with recurrent waterlogging in the study area. This approach enabled systematic measurement and aggregation of multiple indicators into composite indices.

2.3. Sampling Strategy and Data Collection

The sample size was determined using the formula proposed by [43]. The following equation determined the sample size:

$$\text{Sample Size, } n = \frac{z^2 pqN}{(e^2(N-1) + z^2 pq)} \quad (1)$$

where, total targeted households $N = 20,918$; Confidence level = 95%; Margin of error, $e = 10\%$; 95% level of significance; $Z = 1.96$; $p = 0.5$; $q = 0.5$.

The calculated sample size was 95.61, which was rounded to 100 households. As the primary objective of this study was to capture overall regional trends rather than to support statistically robust comparisons between individual areas, the sample size was viewed as sufficient and was comparable with those previously used in similar studies in Noakhali Pourosova and Dhaka city [17,44]. A total of 100 households were surveyed, with 10 wards of varying socioeconomic characteristics randomly selected, to gain an overall understanding of livelihood vulnerability across the study area. The samples were evenly distributed across wards. Face-to-face interviews were conducted using a structured questionnaire (Table S1).

2.4. Survey Instrument Development

The survey questionnaire was developed through an extensive review of the literature on urban waterlogging, livelihood capitals, and their vulnerability, as well as the Sustainable Livelihood Framework [30,45,46]. The questionnaire comprised closed-ended questions covering socio-demographic characteristics, climatic information, and capital-specific livelihood impacts. Based on this review and local context, some indicators were identified as relevant to the five livelihood capitals (Table 1). The questionnaire was pre-tested with 15 households to assess clarity, relevance, and contextual appropriateness. As no major issues were identified, the instrument was finalized without modification. The participants in this study were selected independently, and they provided their responses to the questionnaire. Additionally, the respondents' involvement was entirely voluntary, and no financial compensation was provided. Furthermore, no funds were used for creating the manuscript, report writing, data collection, or analysis.

2.5. Indicators and Scoring Procedure

A total of 24 indicators (Table 1) were chosen to assess waterlogging-induced livelihood vulnerability: six for human capital, four for natural capital, three for physical capital, seven for financial capital, and four for social capital. Each indicator was operationalized using one or more structured questionnaire items reflecting the local vulnerability context [45,47]. To minimize potential bias, the questionnaire was pre-tested. Responses were ordinal or categorical and converted into numerical scores ranging from 0 to 1, where higher values represent higher levels of vulnerability. Ordinal perception-based indicators with four responses (e.g., High-Medium-Low-None or Often-Sometimes-Seldom-Never) were scored as 0, 0.33, 0.67, and 1, whereas five-category indicators were scored as 1, 0.80, 0.60, 0.40, 0.20, and Binary yes/no were scored 0 and 1, respectively (Table 1). In contrast, income-related indicators were scored based on predefined socioeconomic thresholds to reflect relative economic vulnerability. This standardized scoring approach allowed the transformation of qualitative responses into comparable quantitative indicators suitable for subsequent weighting and aggregation in the vulnerability assessment.

2.6. Livelihood Vulnerability Assessment

Composite indices for each livelihood capital were computed using Equation (2) [47]:

$$CI = \frac{W_1 + W_2 + W_3 + W_4 + W_5 + \dots + W_n}{n} = \sum_{i=1}^n \frac{W_i}{n} \quad (2)$$

where, CI = The Composite Index, W_1 to W_n = numerical weights used for indicators, and n = the number of indicators. Based on this method, five capital-specific indices, the Human Index (HI), Natural Index (NI), Financial Index (FI), Physical Index (PI), and Social Index (SI) were computed (Equations (3)– (7)). The total Vulnerability

Index (TVI) was calculated as the average of these five indices (Equation (8)). Vulnerability levels were classified as low ≤ 0.25 , medium 0.26–0.50, high 0.51–0.75, and extremely high > 0.75 , respectively.

$$\text{Human Index, HI} = \frac{\sum_{i=1}^6 HW_i}{n} \tag{3}$$

$$\text{Natural Index, NI} = \frac{\sum_{i=1}^4 NW_i}{n} \tag{4}$$

$$\text{Financial Index, FI} = \frac{\sum_{i=1}^7 FW_i}{n} \tag{5}$$

$$\text{Physical Index, PI} = \frac{\sum_{i=1}^3 PW_i}{n} \tag{6}$$

$$\text{Social Index, SI} = \frac{\sum_{i=1}^4 SW_i}{n} \tag{7}$$

$$\text{Total Vulnerability Index (TVI)} = \frac{\text{HI} + \text{NI} + \text{FI} + \text{PI} + \text{SI}}{5} \tag{8}$$

Table 1. Sustainable livelihood vulnerability index.

Capitals	Indicators/Questions	Classes	Weights	Sources
Human	Level of education	Illiterate	1	[48]
		Primary	0.80	
		Secondary	0.60	
		Undergraduate	0.40	
		Other	0.20	
	Children have no access to education	>1 week	1	[48]
		5–7 days	0.75	
		3–5 days	0.50	
		1–3 days	0.25	
	Attacked by reptiles or insects	Often	1	[49]
Sometimes		0.67		
Seldom		0.33		
Chronic health problems become an issue	Never	0	[49]	
	High	1		
	Medium	0.67		
	Low	0.33		
Admitted to the hospital for waterborne diseases	None	0	[50]	
	Often	1		
	Sometimes	0.50		
The time range of food insufficiency	Seldom	0	[49]	
	>5 days	1		
	3–5 days	0.67		
	1–3 days	0.33		
	Never	0		
Physical	Condition of the main road	Poor	1	[49]
		Average	0.67	
		Good	0.33	
		Excellent	0	
Condition of the lanes	Poor	1	[50]	
	Average	0.67		
	Good	0.33		
	Excellent	0		
Damage to the road	High	1	[51]	
	Medium	0.67		
	Low	0.33		
	None	0		

Table 1. Cont.

Capitals	Indicators/Questions	Classes	Weights	Sources
Natural	The extent of damage to the homestead vegetable garden	High	1	[52]
		Medium	0.67	
		Low	0.33	
		None	0	
	The extent of the fishing pond's destruction	High	1	[48]
		Medium	0.67	
		Low	0.33	
		None	0	
	The extent of damage to the bird's nest	High	1	[52]
		Medium	0.67	
		Low	0.33	
		None	0	
The level of change in the quality of drinking water (taste, color, and odor)	High	1	[52]	
	Medium	0.67		
	Low	0.33		
	None	0		
Financial	Monthly income per capita	0–15,000	1	[52]
		15,000–25,000	0.75	
		25,000–30,000	0.50	
		>30,000	0.25	
	The extent of damage to the asset	High	1	[52]
		Medium	0.67	
		Low	0.33	
		None	0	
	The money spent to repair the damage	>5000	0.25	[53]
		5000–10,000	0.50	
		10,000–15,000	0.75	
		>15,000	1	
The level of loan obtained for repairing the damage	Often	1	[54]	
	Sometimes	0.67		
	Seldom	0.33		
	Never	0		
The level of income shrinks	High	1	[52]	
	Medium	0.67		
	Low	0.33		
	None	0		
Logged water becomes an obstacle to going to work	Often	1	[49]	
	Sometimes	0.67		
	Seldom	0.33		
	Never	0		
Level of changing occupation	Often	1	[47]	
	Sometimes	0.67		
	Seldom	0.33		
	Never	0		
Social	Support and help from neighbors	Yes	0	[47]
		No	1	
	Attempts implemented by the government to regenerate the drainage system	Yes	0	[22,55]
		No	1	
	Efforts taken by the government	Yes	0	[46]
	No	1	[46]	
	Support and help from NGO's	Yes	0	[46]

2.7. Data Analysis

To analyze the data, Microsoft Office Excel was used to compute the vulnerability indices and descriptive statistics. Frequencies and percentages were used to calculate capital-specific vulnerabilities in the study area. Besides, IBM SPSS 26 was used to perform Spearman's rank Correlation. Spatial visualization and ward-level mapping were performed using ArcGIS 10.8.2.

3. Results

3.1. Respondent's Profile

The varying degrees of vulnerability towards disasters within various categories of individuals fluctuate by age, gender, level of schooling, occupation, and income (Table 2).

Table 2. Respondents' profile.

Characteristics	Category	Frequency (n)	Percentages (%)
Gender	Male	41	41%
	Female	59	59%
Age	21–30	15	15%
	31–40	35	35%
	41–50	22	22%
	51–60	16	16%
	61–70	9	9%
	71–80	3	3%
Education	Non-literate	4	4%
	Primary	24	24%
	Secondary	35	35%
	Undergraduate	25	25%
	Other	12	12%
Income per month	\$0–\$122.7 USD	25	25%
	\$122.7–\$204.5 USD	45	45%
	\$204.5–245.4 USD	18	18%
	>\$245.4 USD	12	12%
Occupation	Rickshaw Puller	6	6%
	Day Laborer	9	9%
	Hawking	5	5%
	Businessman	22	22%
	Government Officer	8	8%
	Domestic Worker	12	12%
	Private service holder	13	13%
	Student	10	10%
	Teacher	9	9%
	others	6	6%
House Type	Concrete Building	46	46%
	Tin shed with a Concrete floor	43	43%
	Tin shed with Mud floor	11	11%

3.2. Rainfall and Waterlogging Perceptions

3.2.1. The Highest Rainfall Month in the Study Area

Since the Bay of Bengal is in Bangladesh's southern area and the Himalayas are in the country's northeast, the Barishal region experiences heavy rains. The intensity of the rainfall is high during the monsoon. 47% of participants reported that July and August (Figure 4) were the heaviest rainfall months, while 35% noted that June-July had the highest rainfall (Figure 4). As reported by the Bangladesh Meteorological Department, July and August received the most rainfall, with a precipitation count of 386.33mm in Barishal [56].

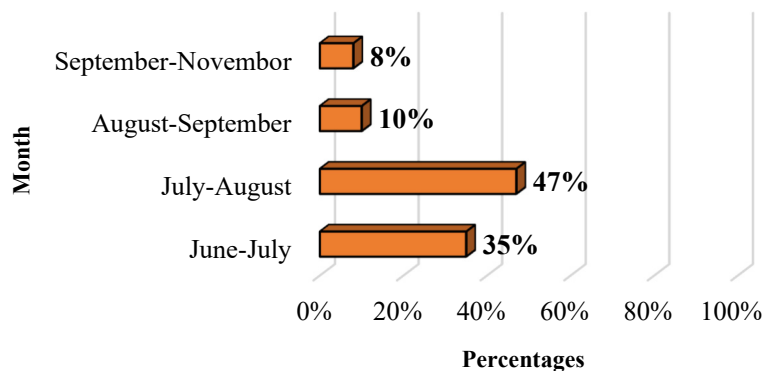


Figure 4. Months when Rainfall was usually reported (Source: Household Survey).

3.2.2. Factors Associated with Statutory Water

During the Monsoon, due to heavy rainfall, rivers in Barishal often overflow and face tidal influences. Together with all these weather events, conditions created an environment for waterlogging. According to the survey, 89% of respondents (Figure 5) reported that continuous rainfall led to increased levels of stationary water in their living area, with periods ranging from 6–12 h to 1–3 days. Consequently, the stagnant water increases the risk of waterborne illnesses, including dengue, diarrhea, and skin diseases. The inundation of water, ranging from two to four feet in depth, has had a profoundly detrimental impact on the low-lying neighborhoods within the Barishal City Corporation area, resulting in significant hardship for the local people.

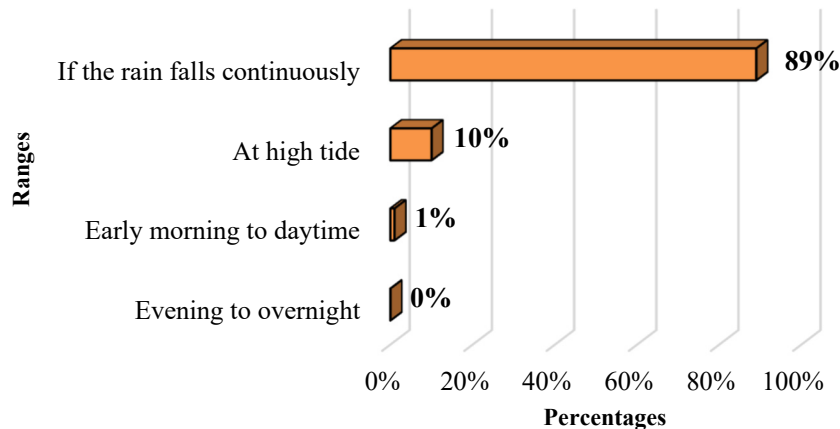


Figure 5. Factors Associated with Statutory Water (Source: Household Survey).

3.2.3. Height of Rising Water

Numerous storage and suspension areas, such as *khals* (canals), which were connected to the nearby rivers, made up the natural drainage system. However, the water bodies were not in their former condition, which was the primary cause of waterlogging. With heavy rainfall, people face a huge rise in water levels in the residential area. The survey results indicated that 70% of respondents reported elevated water levels during rainy days (Figure 6). According to the reports of other respondents, medium and low levels of rising water were observed in Barishal.

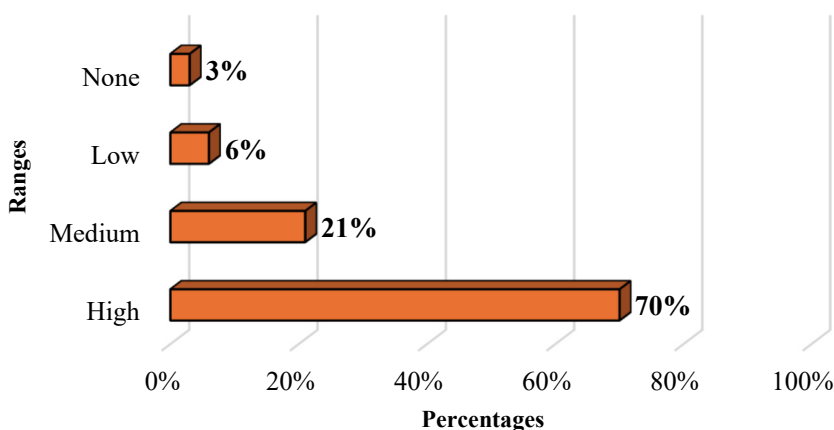


Figure 6. Extent of Rising Water (Source: Household Survey).

3.3. General Pattern of Capital-Specific Livelihood Vulnerability Index of Different Wards

Considering the analysis of livelihood vulnerability, each of the five capitals' respective contributions to this vulnerability was investigated.

3.3.1. Natural Capital

In this study, the vulnerability score of natural capital in the studied 10 wards ranged from 0.2 in Wards 12 and 16 to 0.59 in Ward 22 (Figure 7). As wards 12 and 16 have less open space, people were unable to have their own gardens and fishing ponds, and their vulnerability was lower.

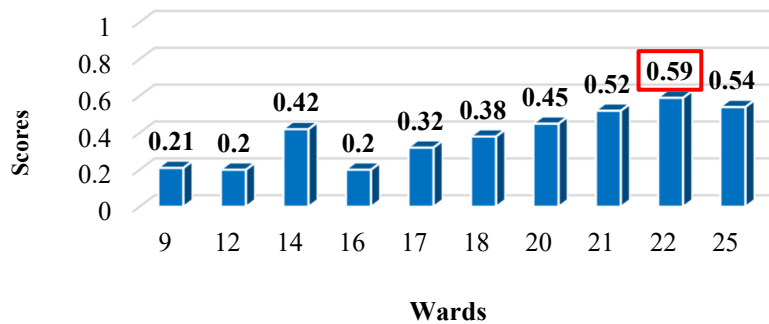


Figure 7. Vulnerability of natural capital in the studied 10 Wards and the highest score is highlighted (Source: Household Survey).

3.3.2. Human Capital

The vulnerability score of human capital ranged from 0.33 in Ward 9 to 0.55 in Ward 21 (Figure 8). This result indicates that waterlogging hindered children’s access to school, madrasa, and the university in all wards. Participants also reported that children were unable to attend educational institutions for 1–3 days or more than a week.

The incidence of diseases such as diarrhea, cold, itching, and dengue increases during waterlogged periods. About 63% of respondents (Figure 9) reported that they were affected by diarrheal disease during waterlogging events. Respondents also reported that insects and reptiles allegedly entered homes through windows, doors, and water taps during times of waterlogging. Waterlogging prevents 60% of children from attending school, madrasa, or university for one to three days (Figure S1).

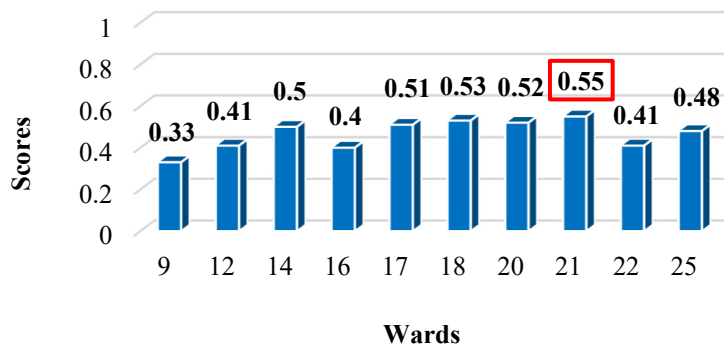


Figure 8. Vulnerability of human capital in the studied 10 Wards and the highest score is highlighted (Source: Household Survey).

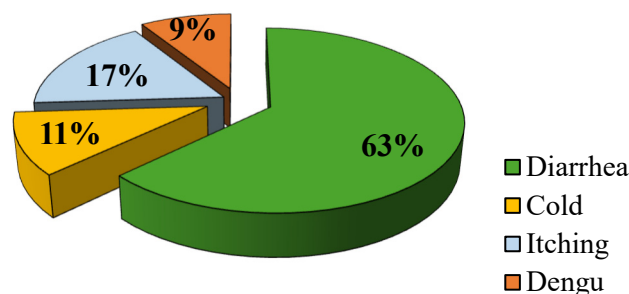


Figure 9. Diseases encountered during and after the waterlogging events (Source: Household Survey).

3.3.3. Financial Capital

According to Figure 10, Ward 22 had the lowest financial capital vulnerability score (0.34), while Ward 17 had the highest (0.54) (Figure 10). The majority of respondents from Ward 17 encountered financial difficulties due to their inability to commute to their places of employment. This resulted in diminished sales revenue and considerable impairment to their assets. Many respondents were compelled to allocate considerable financial resources toward repairs and restoration following waterlogging events.

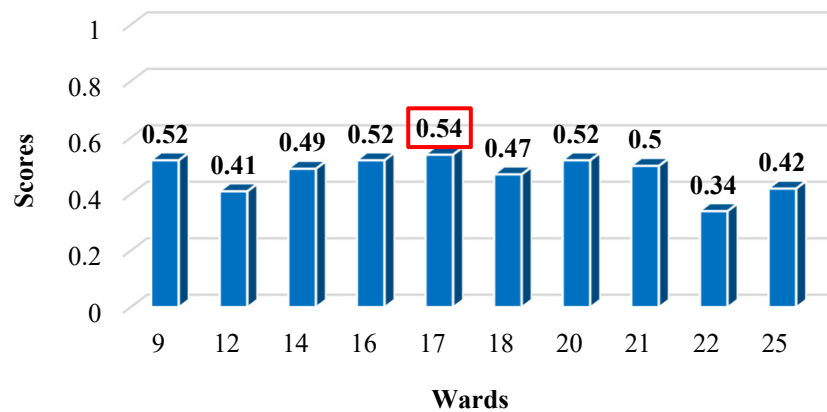


Figure 10. Vulnerability of financial capital in the studied 10 Wards and the highest score is highlighted (Source: Household Survey).

3.3.4. Physical Capital

Physical infrastructure was notably vulnerable, with scores ranging from 0.63 in Ward 12 to 0.95 in Ward 20 (Figure 11). According to the survey, poor road conditions and inadequate drainage systems in Ward 20 exacerbated the waterlogging problem, causing water to rise to dangerous levels and sometimes enter homes.

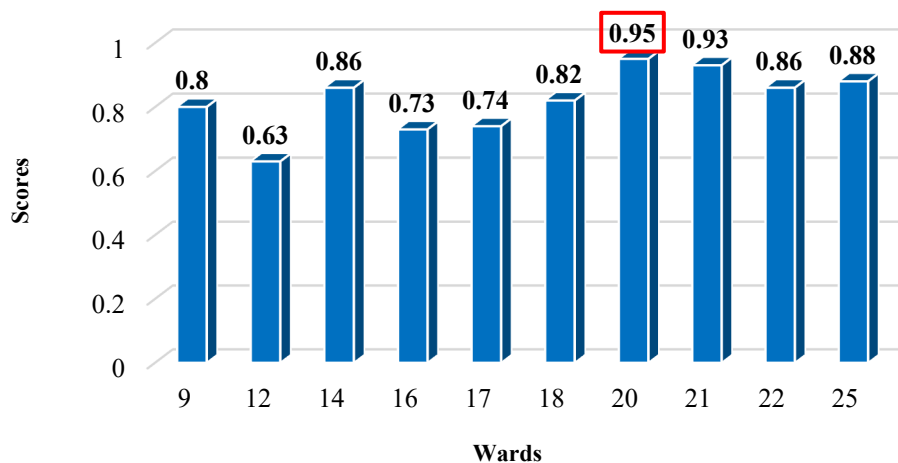


Figure 11. Vulnerability of physical capital in the individual 10 Wards and the highest score is highlighted (Source: Household Survey).

Thirty-three percent of the respondents (Figure 12) reported that water entered roads, garages, and houses, creating a terrible situation in their daily lives. Participants also reported that the degradation of physical infrastructure due to waterlogging not only hampered daily activities but also increased the risk of accidents and diseases. During and after waterlogging, numerous challenges were encountered by individuals.

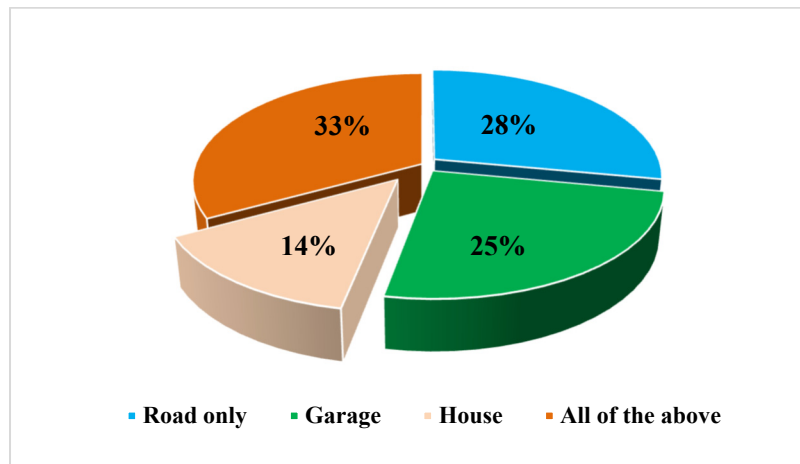


Figure 12. The extent of rising water during waterlogging (Source: Household survey).

3.3.5. Social Capital

Social capital was crucial for community resilience, yet it showed high vulnerability to waterlogging with scores ranging from 0.60 in Ward 16 to 0.88 in Ward 9 (Figure 13). According to the survey, the lack of community support and inadequate governmental and non-governmental interventions exacerbated the residents' plight during waterlogging events in wards 9, 21, and 25.

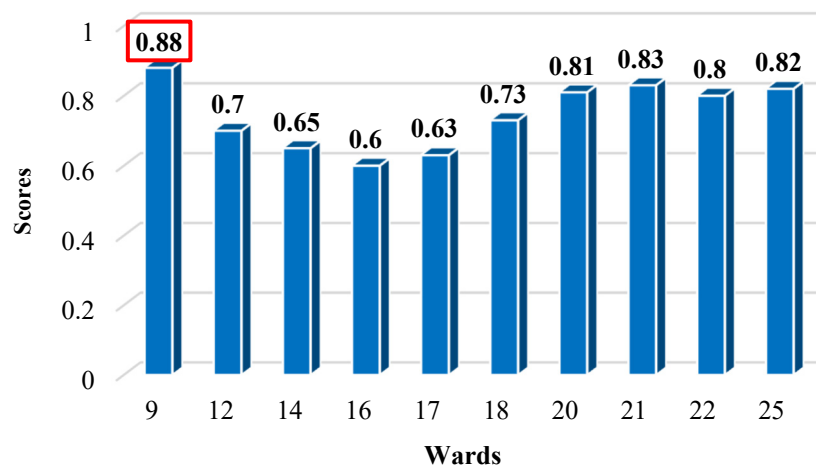


Figure 13. Vulnerability to social capital in the individual 10 Wards and the highest score is highlighted (Source: Household survey).

3.4. Total Livelihood Vulnerability Index in the Study Area

The total vulnerability index (TVI), which was 0.58, provided an overall assessment of the Barishal City Corporation area's level of vulnerability. TVI is the average of the five capitals, giving people an understanding of the effects of seasonal waterlogging. After calculating and summarizing the livelihood vulnerability index for the study area, a spider diagram (Figure 14) was created to demonstrate the significance of the key components and the consequent vulnerabilities. The number of vulnerabilities in each capital was different, which showed that the vulnerabilities are different in each ward. However, physical capital was the most vulnerable, with a score of 0.82. Social capital was the second most vulnerable, with a score of 0.75 (Figure 14). There were fewer natural resources in the study area. Because of this, natural capital had a lower vulnerability score (0.38) compared to other capitals (Figure 14). This means that, even though waterlogging had negative effects, the natural environment was relatively less vulnerable because there was a small amount of natural diversity in the area. So, the research area's physical asset-related vulnerabilities demonstrate an overstressed living situation.

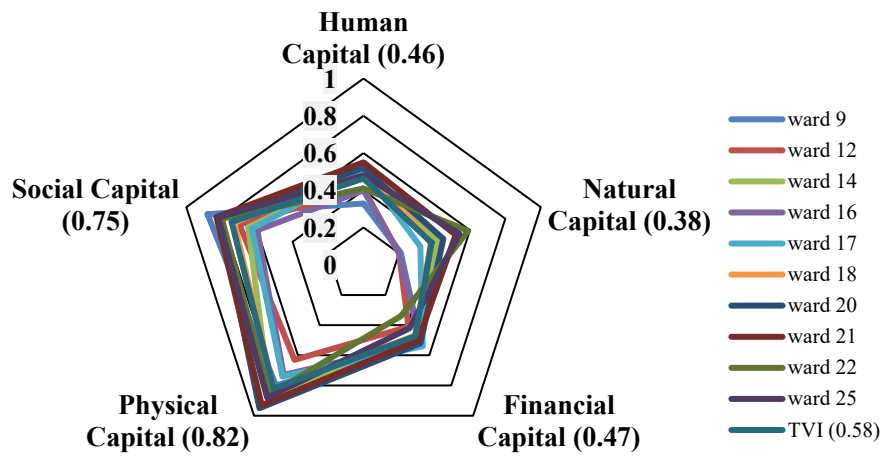


Figure 14. Capital-specific livelihood vulnerability in the studied 10 wards (Source: Household Survey).

3.5. Spearman Correlations between Sustainable Livelihood Capital and Outcomes

The Spearman correlation analysis explores the relationship between different types of livelihood capital vulnerabilities and sustainable livelihood outcomes, revealing several statistically significant associations (Table 3). Physical capital vulnerability shows a strong negative correlation with earnings sustainability ($r = 0.765, p < 0.001$) and well-being sustainability ($r = -0.704, p < 0.001$), and a strong positive correlation with migration rate ($r = 0.687, p < 0.001$), indicating that poor infrastructure greatly undermines livelihood stability and increases the likelihood of migration.

Table 3. Spearman correlation between sustainable livelihood outcome and capital vulnerability.

Sustainable Livelihood Capital Vulnerability	Indicators ↓	Status ⇌	Sustainable Livelihood Outcome				Sustainable Use of Natural Resources
			Earnings Sustainability	Well-Being Sustainability	Migration Rate	Food Sustainability	
Natural Capital Vulnerability	Correlation Coefficient		-0.029	-0.327 **	0.136 *	-0.026	-0.321 **
	Sig. (2-tailed)		0.776	0.000	0.000	0.799	0.000
Human Capital Vulnerability	Correlation Coefficient		-0.137 *	-0.319 **	0.895 ***	-0.125 *	-0.097
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.338
Financial Capital Vulnerability	Correlation Coefficient		-0.450 **	-0.135 *	0.184 *	-0.530 ***	-0.007
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.947
Physical Capital Vulnerability	Correlation Coefficient		-0.765 ***	-0.704 ***	0.687 ***	-0.216 *	-0.314 **
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000
Social Capital Vulnerability	Correlation Coefficient		-0.065	-0.132 *	0.581 ***	-0.165 *	-0.080
	Sig. (2-tailed)		0.521	0.000	0.000	0.000	0.427

* Weak (0.10–0.29), ** Moderate (0.30–0.49), and *** Strong Correlation (0.50–1.00). N = 100, (+) Positive Correlation, and (-) Negative Correlation.

Financial capital vulnerability also demonstrates a strong negative correlation with food sustainability ($r = -0.530, p < 0.001$), along with a moderate negative relationship with earnings sustainability ($r = -0.450, p < 0.001$) and a weak negative correlation with well-being sustainability ($r = -0.135, p < 0.001$), highlighting the critical importance of financial resources for income, food access and overall well-being. Human capital vulnerability presents a strong positive correlation with migration rate ($r = 0.895, p < 0.001$), suggesting that lower levels of education and health lead to increased migration. Additionally, it had weak negative correlations with earnings sustainability ($r = -0.137, p < 0.001$) and food sustainability ($r = -0.125, p < 0.001$). Social capital vulnerability was strongly and positively associated with migration rate ($r = 0.581, p < 0.001$) and showed weak negative correlations with well-being sustainability ($r = -0.132, p < 0.001$) and food sustainability ($r = -0.165, p < 0.001$), underlying the role of community support in maintaining livelihood security.

Lastly, natural capital vulnerability had moderate negative correlations with well-being sustainability ($r = -0.327, p < 0.001$) and sustainable use of natural resources ($r = -0.321, p < 0.001$), and a weak positive correlation with migration rate ($r = 0.136, p < 0.001$), reflecting how environmental degradation contributes to both human and ecological instability. Overall, the findings suggest that higher vulnerability across all livelihood capitals was generally associated with poorer livelihood outcomes and increased pressure.

4. Discussion

This study aimed to understand urban waterlogging by identifying its impacts through the Sustainable Livelihoods Approach (SLA), thereby moving beyond infrastructure-focused assessments to capture the multidimensional nature of livelihood vulnerability in Barishal City Corporation (BCC). A change in the rainfall pattern was seen at the study area, and if there is significant rainfall, water remains for three to a week [15,57]. The Total Vulnerability Index (TVI = 0.58) (Figure 14) indicates a high level of vulnerability, which indicates inadequate drainage systems, poor drinking water, barriers to accessing educational institutions, and damage to their houses and businesses. These findings are comparable to other waterlogging-prone urban areas in Bangladesh, such as Dhaka, Noakhali, and Jashore, where frequent inundation has been shown to reduce household resilience and economic stability [18,19,22,34,36]. These findings demonstrate that urban waterlogging in Bangladesh is not only an isolated hazard but also a chronic stressor that progressively undermines livelihood systems.

The dominance of physical capital vulnerability (0.82) shows structural weaknesses in urban infrastructure, particularly insufficient drainage networks, poor road conditions, and unplanned construction. 84% of residents (Figure S2) stated that due to continuous waterlogging, roads have become very poor. Similarly, 44% of respondents indicated that household assets were severely affected (Figure S3). Similar patterns have been reported in Chittagong, Dhaka, and other cities, where the expansion of impermeable surfaces and encroachment on natural drainage channels exacerbate water retention during monsoon rainfall [12,58–60]. Cities that have successfully reduced waterlogging impacts typically combine drainage improvements with long-term land-use planning and enforcement of development controls [7,15,51,61]. The absence of such integrated approaches in the Barishal City Corporation (BCC) helps explain the persistent and severe physical exposure identified in this study.

Social capital emerged as the second most vulnerable dimension (0.75), demonstrating weak neighborhood support systems and limited institutional assistance during waterlogging events. 69% of respondents mentioned they do not receive any help or encouragement from their neighbors (Figure S4). This result suggests that rapid urbanization often reduces social cohesion by decreasing the effectiveness of informal coping mechanisms that are critical during environmental issues [22,27]. The limited coordination between government agencies, NGOs, and community networks in the Barishal City Corporation (BCC) further exacerbates household vulnerability, highlighting the importance of governance and institutional capacity in urban resilience. However, some of the respondents reported that they noticed construction of new drains and high roads, cleaning and re-excavation of existing drains and canals. Engineers from the Barishal City Corporation reported that the 2010–12 master plan had expired and was being modified five years later. The authorities are focusing on unlawful constructions and narrow roadways. Furthermore, the 100-km drain construction project is still in progress before the appointment of the next mayor in the study area. Due to the authority's lack of funding for land purchase and relocation expenses, there may be certain issues once these plans are implemented [44].

Financial capital vulnerability (0.47) demonstrates the indirect economic consequences of waterlogging, particularly for informal workers, transport-dependent occupations, and small business owners. In Dhaka and Noakhali Pourashava, income losses arise not only from direct damage to assets but also from restricted mobility, disrupted supply chains, and reduced customer access during inundation periods [17,19,36,62]. These results align with broader livelihood vulnerability research, which emphasizes that frequent, low-intensity hazards disproportionately affect economically marginal urban communities [48].

Human capital vulnerability (0.46) is obvious through inadequate access to education, increased incidence of waterborne diseases, and heightened health risks during waterlogging events. During recent cyclones Remal (May 2024), Sitrang (October 2022), Amphan (May 2020), and Bulbul (November 2019), residents have faced these kinds of challenges [63–65]. 37% respondents claimed that they experienced a moderate alteration in the color and odor of drinking water as dirty water enters their drinking water during waterlogging (Figure S5). They are unable to adequately consume the water for two days. Similar health and educational impacts have been shown in waterlogged and flood-affected urban settings across Bangladesh, where stagnant water amplifies exposure to infectious diseases and interrupts schooling, particularly among children and adolescents [13,66–68]. These cumulative effects define how seasonal waterlogging can trigger long-term developmental consequences even in the absence of extreme flood events.

In contrast, natural capital vulnerability was comparatively lower (0.38), highlighting the urban context of the study area, where livelihoods are less directly dependent on natural resource-based assets. This result diverges from rural waterlogging studies, where agricultural land and ecosystem services are heavily affected [20], but is consistent with urban studies showing that limited green space and the adoption of rooftop gardening reduce direct exposure of natural capital to inundation [36,60]. Yet, localized impacts on water quality and small-scale household food production indicate that natural capital vulnerability remains relevant, although secondary, in dense urban environments.

The application of the Sustainable Livelihoods Approach proved valuable in identifying how vulnerabilities across different capitals interact and reinforce one another. By disaggregating impacts across physical, financial, human, natural, and social capitals, the SLA enabled a more holistic understanding of waterlogging-induced livelihood stress than would have been possible using a hazard- or infrastructure-based framework [29,30]. By conceptualizing vulnerability as an outcome of interacting livelihood capitals, the SLA enables a more nuanced understanding of how frequent, low-intensity hazards accumulate into long-term urban livelihood insecurity. However, the use of SLA at the ward level also introduces limitations. Composite indices may mask intra-ward heterogeneity, potentially underrepresenting the experiences of households with intersecting vulnerabilities, such as female-headed households, the elderly, or highly informal workers. Similar concerns have been raised in vulnerability assessment literature, which cautions that index-based approaches can obscure differentiated vulnerability at finer social scales [50,69].

Despite the potentialities of the study, this study has several limitations. The relatively small sample size restricts the capability to generalize findings across all wards of Barishal City Corporation (BCC). In addition, reliance on perception-based indicators may introduce subjective bias, although this approach is widely accepted in livelihood vulnerability research [47]. Future studies could strengthen the evidence base by considering larger samples, mixed-method designs, and finer spatial resolution to capture household-level heterogeneity more effectively.

Overall, these results suggest that effective management of urban waterlogging requires integrated interventions that address not only physical infrastructure but also economic security, public health, and social support mechanisms. Evidence from better-managed urban contexts indicates that improvements in drainage systems, enforcement of land-use regulations, and coordinated institutional action are critical for reducing livelihood vulnerability [61,70–74].

5. Conclusions

The effects of seasonal waterlogging on residents' livelihoods in urban areas, such as the Barishal City Corporation area of Bangladesh, are a significant problem in the context of climate change and rapid urbanization. The study aimed to assess the perceived vulnerability of the five livelihood capitals: human, natural, physical, financial, and social, through surveying households. It concluded that people in this study area are highly vulnerable, as the TVI of waterlogging is 0.58. With this high vulnerability score, the study area is facing significant challenges in continuing its daily activities during waterlogging periods. However, the capital-specific results indicate significant variations in vulnerability. Physical capital was the most vulnerable among the five sustainable livelihood capitals, and the score was 0.82. The problem varies according to the respondents' socioeconomic profile. The more problems people have, the more likely they are to have issues with roads, housing structures, and a lack of a proper drainage system. This research enables an understanding of the effects of seasonal waterlogging on the sustainable livelihood capitals in the Barishal City Corporation area. Therefore, to further reduce the chance of waterlogging in the study area, the current study recommends that the identified issues be considered by policymakers, urban planners, and community stakeholders and acted on.

Supplementary Materials

The additional data and information can be downloaded at: <https://media.sciltp.com/articles/others/2603231649090387/JHRR-25100079-SM1.pdf>.

Author Contributions

I.Z.O.: Investigation, methodology, Formal analysis, Data curation, Resources, Software, Validation, Writing—original draft. M.S. (Md. Shamsuzzoha): Methodology, Conceptualization, Data curation, Supervision, Writing—original draft, Writing—review & editing. M.T.I.: Investigation, Methodology, Conceptualization, Resources, Software, Validation, Supervision, Writing—original draft, review & editing. M.A.A.: Conceptualization, Resources, Software, Validation, Writing—original draft, review & editing. M.S. (Mawya Siddeqa): Formal analysis, Data curation, Visualization, Writing—original draft. K.I.: Formal analysis,

Visualization, Writing—original draft. S.H.S.: Formal analysis, Visualization, Writing—original draft. M.N.B.N.: Formal analysis, Writing—original draft. M.R.: Formal analysis, Writing—original draft. R.S.: Writing—original draft, Writing—review & editing. All authors have read and agreed to the published version of the manuscript.

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Not applicable to the ethical review and approval process, as the research was classified as empirical social science research. The authors of this study have also been recognized as practitioners of non-destructive, computer-based analysis approaches that did not harm any humans or animals.

Informed Consent Statement

Informed consent was obtained verbally from all the subjects involved in the research. A total of 100 households were surveyed, with 10 wards of the study area.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The authors declare no conflict of interest. Given their editorial roles, Rajib Shaw (Editor-in-Chief) and Md. Shamsuzzoha (Editorial Board Member) had no involvement in the peer review of this paper and had no access to information regarding its peer review process. Full responsibility for the editorial process of this paper was delegated to another editor of the journal.

Use of AI and AI-Assisted Technologies

The authors used Grammarly, Quill Bot, and DeepL to correct sentences and remove grammatical mistakes. All content was reviewed and approved by the corresponding author using a licensed Microsoft 365 subscription product.

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