NAVIGATING FLOOD CHALLENGES THROUGH VULNERABILITY AND RESILIENCE ASSESSMENT IN PAIKGACHHA UPAZILA

Tahdia Tahmid*[1], Md. Mustafa Saroar [2]

[1] *Undergraduate Student, Department of Urban and Regional Planning, Khulna University of Engineering & Technology, Bangladesh, e-mail: tahmid1817021@stud.kuet.ac.bd*

[2] *Professor, Department of Urban and Regional Planning, Khulna University of Engineering & Technology, Bangladesh, e-mail: saroar.mustafa@urp.kuet.ac.bd*

***Corresponding Author**

ABSTRACT

Coastal region of Bangladesh is worrisomely exposed to flood disasters due to land subsidence, erosion-accretion, saltwater intrusion, and water logging. The crippling effects of floods and other natural calamities place additional strain on the finances of nation. In Paikgachha, Bangladesh, the regular flooding has become a significant obstacle to sustainable development. Conventional flood defenses have failed, with disastrous results. Alarming recent occurrences like house collapses and dam breaks have highlighted how urgent this investigation is. Numerous families have been impacted by these incidents, which have caused significant financial losses and food insecurity. The Deluti union and Lata union identified as high-risk areas by GIS are the subject of this study. After selecting the relevant indicators and variables related to flood resilience through literature research, 100 randomly chosen households in Deluti and Lata provided the primary data for these indicators via a questionnaire survey. Then, a subjective method (based on expert judgment) had been employed to assign weights for the selected factors for vulnerability (exposure, susceptibility, and adaptive capacity) and resilience (using social, physical, economic, and institutional components). According to this study, Lata union being closer to the river was found to have higher exposure (0.99) than Deluti union (0.96). Vulnerabilities in both the areas have been determined by sensitivity factors (Deluti 0.59, Lata 0.54). Lata union had a higher adaptive capacity (0.79) than Deluti union (0.66) due to factors like income sources, education, and social networks. The Social Resilience Index (SRI), which is correlated with social capital and health insurance, shows low levels of social resilience in both the unions (Deluti 0.57, Lata 0.46). The economic resilience was found to be varried largely for the study sites (Deluti 0.58, Lata 0.80) because of the employment and livelihood opportunities for women. The low institutional resilience (Deluti 0.43, Lata 0.37) can be attributed to deficiencies in infrastructure. Because less durable housing materials are more common in Deluti (0.44) than in Lata (0.47), physical resilience is slightly lower in Deluti. The results of this survey suggested that both the study areas possess low resilience to flood disasters and were extremely vulnerable. Thus, the physical, institutional, economic, and social conditions of the households in this flood-prone region of Bangladesh need to be improved substantially to cope with the flood situations in a sustainable manner.

Keywords: *Flood disaster, Indices, Paikgachha, Resiliency, Vulnerability.*

1. INTRODUCTION

1.1 Background

Understanding and tackling the complex issues raised by floods which are occurring more frequently worldwide requires an understanding of flood vulnerability and resilience (World Health Organization, 2020). With the frequency of extreme weather events rising, flood vulnerability is a global concern (Jerin et al., 2023). The Intergovernmental Panel on Climate Change (IPCC) estimates that by 2050, there will be approximately 1.6 billion people at risk of flooding, up from 1.2 billion in 2010. This indicates a marked rise in the susceptibility of populations across the globe to the effects of flooding. Furthermore, estimates indicate that if appropriate action is not taken, the annual economic losses from floods could surpass $1 trillion by 2050 (Climate Home News, 2023). Flood resilience is essential for reducing the effects of floods on economies and communities around the world (Zhu et al., 2023). The World Bank estimates that for every $1 invested in resilience measures, up to $4 in losses can be prevented. Additionally, compared to non-resilient communities, resilient communities knowledge, on average, 60% fewer fatalities and lower economic losses, according to the Global Facility for Disaster Relief and Recovery (GFDRR). Due to its monsoonal climate, South Asia is especially vulnerable to flooding. About 40% of people in South Asia are at risk of flooding, and the region is responsible for 45% of all flood-related deaths worldwide (Shah et al., 2020). Factors like population growth, fast urbanization, and poor infrastructure make the vulnerability worse (Rahaman et al., 2023). South Asian floods cause significant economic losses; estimates place the immediate annual damage at approximately $19 billion, with the most affected sectors being farming, housing, and transport (ESCAP, 2020). According to the Asian Development Bank (ADB), resilient infrastructure of the region can minimize flood-related damage by as much as 90%. The socio-economic stability of South Asian countries depends on developing resilience because floods frequently cause disruptions to important industries like transportation and agriculture. Because of their lack of resources and less durable infrastructure, developing nations are disproportionately affected by floods (Rahman & Rahman, 2014). Floods can cause severe food insecurity in Sub-Saharan Africa, where a large percentage of the population depends on agriculture (Baptista et al., 2022). Furthermore, 80% of flood-related deaths worldwide are thought to occur in developing nations, highlighting these areas' increased susceptibility (Fatemi et al., 2020). Coastal regions in Bangladesh, where flood-related issues are a recurring concern, are more vulnerable because of things like rising seas, tropical cyclones, and erosion of riverbanks (Rahman & Rahman, 2014). Bangladesh is a developing nation in South Asia that is extremely vulnerable to flooding. Millions of people are impacted by the yearly flooding that threatens about 20% of the nation (Hossain et al., 2020). The Khulna district and other coastal regions are particularly vulnerable to the effects of rising sea levels, tropical cyclones and riverbank erosion. Flooding is thought to cause Bangladesh to lose between 1% and 2% of its GDP each year in economic losses (The World Bank Group, 2021). Resilient embankments and flood control structures, as per the recommendations of the Bangladesh Water Development Board (BWDB), can greatly lessen the effects of cyclones and tidal surges in coastal areas. The goal of Coastal Embankment Improvement Project of Bangladesh is to strengthen coastal embankments, which are essential for shielding local populations from storm surges.

According to the Dhaka Tribune, Paikgachha has seen a number of recurrent flood incidents in recent years, including a house collapse in 2021, an embankment failure in 2022, and a dam break caused by a tidal surge in 2020. Hundreds of families have been left stranded as a result of these incidents, highlighting the critical need to evaluate and improve flood resilience of the area. Flood vulnerability and household resiliency have received fewer resources in Bangladeshi flood research than the financial effects of floods on the lives of individuals or productivity in agriculture. This is the first study of its kind, looking at household resilience and flood vulnerability in two unions that are vulnerable to flooding in Paikgachha upazila of Khulna. The study aims to achieve three objectives: (1) to assess the exposure, susceptibility, adaptive capacity, and other aspects of household vulnerability ability; (2) to evaluate the social, economic, physical, and infrastructure resilience of households in relation to flood risks; and (3) to compare the resilience and vulnerability levels of the two unions.

1.2 Study area

Two rural areas of Paikgachha Upazila, Deluti union and Lata union have been shown in Figure 1, which are situated between 22.5889°N and 89.3361°E in southwest and on the southern edge of Khulna District of Bangladesh. The Shipsa River divides Paikgachha Upazila, with most households living on both banks of the river. The area is 411.19 km2 in total and includes 59,873 households. The demographics of this area are comparable to those of other Bangladeshi coastal regions, and because it is situated in a flood-prone area, it frequently floods every year. This upazila frequently floods with Deluti and Lata being the most affected areas. Lata has 2739 households and 14,379 residents spread across 43.47 sq. km., while Deluti has 3896 households and 19,805 residents spread across 43.58 sq. km. Dam collapses worsen the flooding, resulting in the loss of fish enclosures and widespread submersion of crops. The Shibsha River frequently rises above its danger level, which exacerbates widespread flooding into residential areas.Although the local government is aware of the problem and is getting ready to fix the dam.

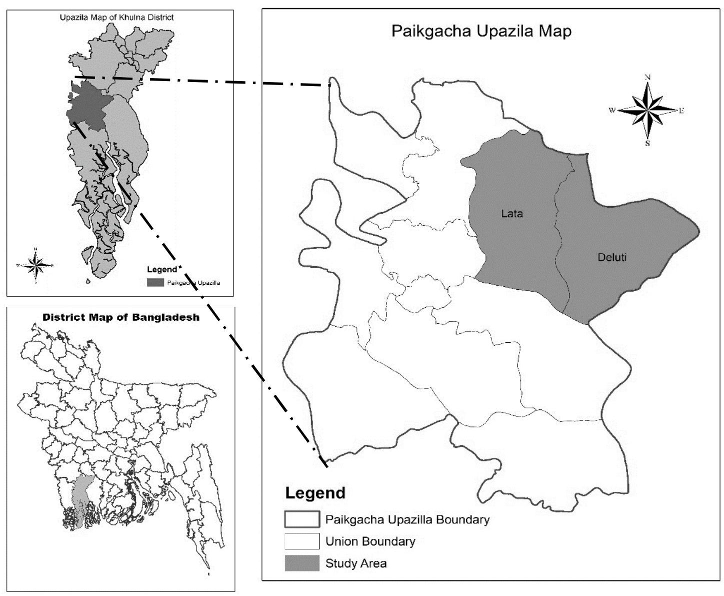

Figure 1: Study area map (Deluti and Lata Union of Paikgachha Upazila)

2. METHODOLOGY

2.1 Sampling strategy and data collection

This investigation collected primary and secondary data, including reports, books, and research articles. It focused on flood vulnerability elements which are adoptive capacity, exposure, and sensitivity determined through a literature review on flood resilience. Data was gathered from August to November 2023, surveying 100 households in Deluti and Lata unions, known for severe weather hazards like flood and cyclone. A multistage sampling technique selected study locations and households, with the main focus on household heads. The sampling process involved selecting the entire Paikgachha upazila initially through purposive sampling. Using GIS analysis, two flood-prone Unions were chosen in the second stage, and two villages were arbitrarily selected. In the final stage, about 50 households from each village were randomly sampled. To assign weights to variables, a separate questionnaire for expert opinions was created alongside the household questionnaire. Household heads were surveyed using a pretested questionnaire, and MS Excel Spreadsheet calculated vulnerability and resilience indices after importing data into SPSS software. Formal permission was obtained before interviews in the Union Council. Substitute household heads, mostly females, were included for those who declined participation during the briefing phase.

2.2 Indicators for vulnerability and resilience

2.2.1 Vulnerability

Table 1: Indicators and their concerned variables for vulnerability assessment

Indicator	Variable & sources	Weights by experts	Explanation and Justification
Adaptive capacity	Information about Flood (Haase, 2011, Qasim et al., 2017, Shah et al., 2018)	80	Percentage of the population with knowledge and awareness about floods to take necessary precautions, thereby reducing vulnerability.
	Social networks (Qasim et al., 2017, Shah et al., 2018, Thanvisitthpon et al., 2020)	80	Percentage of population with connectivity of community to provide emotional and practical support during and after floods.
	Education (Jung et al., 2014, Qasim et al., 2017, Shah et al., 2018)	80	Percentage of the population with different educational backgrounds within a community to correlate improved decision-making
	Working age group (Jung et al., 2014, Shah et al., 2018	60	Percentage of the population within the working age range (typically 18-60 years old) to contribute to a community resilience.
	Multiple income sources(Jung et al., 2014, Qasim et al., 2017, Shah et al., 2018)	60	Percentage of population with the diversity of income sources available which can provide financial resilience recover from flood-related economic losses.
	Employment (Jung et al., 2014, Qasim et al., 2017, Shah et al., 2018)	70	Percentage of population who have any income source contribute to economic stability, reducing vulnerability.
Exposure	Past Flood Experience (McKinney, 2013, Jung et al., 2014, Qasim et al., 2017, Shah et al., 2018)	100	Percentage of the population experienced a flood event in the past here may have a heightened awareness of flood risks, better knowledge of effective coping strategies.
	House Near River (Jung et al., 2014, Nicholls et al., 2015, Qasim et al., 2017, Shah et al., 2018)	80	Percentage of the population living in houses located in 1km close proximity to rivers are more susceptible to flooding and direct exposure to floodwaters.
Sensitivity	Poor building materials ((Gallopín, 2006, Shah et al., 2018)	60	Percentage of households using poor-quality building materials in construction may result in weaker structures that are more susceptible.
	Disabled people (Jung et al., 2014, Qasim et al., 2017)	60	Percentage of the population with disabilities within a community may face challenges
	Dependents (Jung et al., 2014, Qasim et al., 2017, Shah et al., 2018)	50	Percentage of households children or elderly family members may face challenges in evacuation increasing vulnerability
	Illiteracy (Jung et al., 2014, Shah et al., 2018)	70	Percentage of the population with low or no literacy levels may have difficulty.
	Household coping mechanism (Jung et al., 2014, Qasim et al., 2017)	60	Percentage of coping mechanism households can mitigate the impact of floods.
	Household single-unit (Jung et al., 2014)	80	Percentage of households living in single-unit may be more vulnerable to flood damage
	Human loss (Jung et al., 2014, Qasim et al., 2017, Shah et al., 2018)	80	Percentage of the population that experienced human loss during past flood events indicates the severity of the impact of floods.

2.2.2 Resilience

Table 2: Indicators and their concerned variables for resilience assessment

Indicator	Variable & sources	Weight by experts	Explanation and Justification
Social Resilience	Healthcare (Jung et al., 2014, Shah et al., 2018)	60	Percentage of the population with access to medical facilities for addressing injuries and illnesses resulting from floods.
	Disability of residence(Jung et al., 2014, Shah et al., 2018)	50	The vulnerability percentage of residences to flood impact to assess the vulnerability of residences to enhance preparedness.
	Transportation means(Jung et al., 2014, Shah et al., 2018)	60	Percentage of the population with access to functional transportation infrastructure which aids in evacuation and post-flood recovery efforts.
	Health insurance (Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018)	40	Percentage of the population with health insurance coverage to mitigate financial burdens related to healthcare during and after floods.
	Educational Status(Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018)	82	Percentage of the population with different levels of education to better understanding and adherence to preparedness measures.
	Social Capital(Maguire & Hagan, 2007, Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018,)	70	Percentage of the population participating in strong social networks and community cohesion which enhances collective resilience and recovery.
	Past Flood Experience(Jung et al., 2014, Shah et al., 2018)	100	Percentage of the population with a history of exposure to floods can better inform preparedness and response measures.
	Own Vehicle(Jung et al., 2014, Shah et al., 2018, Saja et al., 2018)	50	Percentage of individuals or households owning a vehicle aids in evacuation and accessing essential services.
	Social network(Maguire & Hagan, 2007, Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018,)	88	Percentage of the population participating in strong social networks facilitate information exchange and mutual assistance.
Economic resilience	Employment status(Jung et al., 2014, Shah et al., 2018)	80	Percentage of the population with various employment statuses. It contributes to economic stability and recovery capacity.
	Livelihood opportunities(Jung et al., 2014, Shah et al., 2018)	80	Percentage of the population with access to diverse income-generating opportunities. It enhance economic resilience.
	Multiple income source(Jung et al., 2014, Shah et al., 2018)	50	Percentage of households with more than one income source. It reduce economic vulnerability.
	Homeownership(Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018)	80	Percentage of households that own their homes. It is a stabilizing factor for community resilience.
	Female Labor Force(Jung et al., 2014, Shah et al., 2018)	60	Percentage of the female population engaged in the workforce. It contributes to community economic resilience.
Institution al	Infrastructure Road(Jung et al., 2014, Shah et al.,	70	Percentage of the critical infrastructure that is well-maintained and accessible. It supports

Indicator	Variable & sources	Weight by experts	Explanation and Justification
resilience	2018)		evacuation and recovery efforts.
	Infrastructure Bridge (Jung et al., 2014, Shah et al., 2018, Ro & Garfin, 2023)	60	Percentage of the critical infrastructure that is well-maintained and accessible. It supports evacuation and recovery efforts.
	Infrastructure School (Jung et al., 2014, Shah et al., 2018)	60	Percentage of the critical infrastructure that is well-maintained and accessible. It supports evacuation and recovery efforts.
	Infrastructure Hospital (Jung et al., 2014, Shah et al., 2018)	70	Percentage of the critical infrastructure that is well-maintained and accessible. It supports evacuation and recovery efforts.
	Power supply (Jung et al., 2014, Shah et al., 2018)	70	Percentage of the population with reliable electrical power. It is crucial for communication during flood.
	Water service (Jung et al., 2014, Shah et al., 2018)	80	Percentage of the population with access to reliable water supply. It ensures basic needs are met during and after a flood.
	Sanitation service (Jung et al., 2014, Shah et al., 2018)	80	Percentage of the population with access to functional sanitation facilities. It prevents the spread of waterborne diseases in the aftermath of floods.
	First aid (Jung et al., 2014, Shah et al., 2018, Ro & Garfin, 2023)	60	Percentage of the population with knowledge of basic first aid. These are crucial for immediate response to flood-related injuries.
	Preparedness measure (Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018)	60	Percentage of the population adopting preparedness measures. It enhance community resilience and recovery.
	Flood warning (Jung et al., 2014, , Shah et al., 2018)	80	Percentage of the population get warnings before flood. It enable proactive evacuation and preparedness
	Assistance (Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018)	60	Percentage of the population get assistance during flood. It enhance community resilience and recovery.
	Livelihood restoration (Jung et al., 2014, Shah et al., 2018, Ro & Garfin, 2023)	70	Percentage of the population get livelihood restoration. It contribute to economic recovery, helping communities rebuild.
Physical resilience	Flood experience (Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018, Vinck et al., 2020)	85	Percentage of people with prior exposure to floods. It inform preparedness and response, improving community resilience.
	Warning (Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018)	90	Percentage of people with access to timely flood warnings. It reduce the impact of floods.
	Flood duration (Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018)	80	Monitoring the percentage of people exposed to prolonged flood events. It increase vulnerability.
	Infrastructure Damage (Jung et al., 2014, Qasim et al., 2021, Shah et al., 2018, Vinck et al., 2020)	80	Assessing the percentage of damaged infrastructure. It hampers recovery; mitigation efforts depend on understanding the scale.

Indicator	Variable & sources	Weight by experts	Explanation and Justification
	Knowledge (Jung et al., 2014, Shah et al., 2018)	70	Percentage of people with flood-related awareness. They are better prepared to flood .
	Initiatives (Jung et al., 2014, Shah et al., 2018)	70	Percentage of people engaged in flood-related initiatives. It enhance overall flood resilience
	Building strong Materials (Jung et al., 2014, Qasim et al., 2021)	60	Percentage of buildings using resilient materials. It reduce structural vulnerability during floods.
	Building Multiple Floor (Qasim et al., 2021)	60	Percentage of buildings with multiple floors. It reduce flood impact on living spaces.
	Building Multiple Unit (Jung et al., 2014, Qasim et al., 2021)	50	Percentage of buildings with multiple housing units. It encourage resource-sharing
	Location of house ((Jung et al., 2014, Qasim et al., 2021)	100	Percentage of the population living in houses located close to rivers. These are more susceptible to flooding

2.3 Determination of indices

To obtain the variable values within a comparable range, a normalization process must be carried out (Nelson et al. 2010; Gbetibouo and Ringler 2009). To avoid the normalization process, we calculated the percentages of all the selected household resilience and vulnerability variables. The levels of vulnerability and resilience among households in the chosen unions were assessed using three household vulnerability elements (exposure, sensitivity, and adaptive capacity) and four resilient household components (social, physical, economic, and institutional). We employed a subjective approach for this, relying on the opinions of experts. To calculate the variable vulnerability index (VVI) and variable resilience index (VRI), they were asked to weigh each variable in Tables 1 and 2 on a scale of 0 (less vulnerability and less resilience) to 1 (high vulnerability and high resilience). These component vulnerability indices were denoted by the letters AVI, EVI, and SVI for the adaptive capacity vulnerability index, exposure vulnerability index, and susceptibility vulnerability index, respectively. Next, the three sites' composite vulnerability indices (CVI) were calculated using the formula by Shah et al. (2018). the vulnerability index can be computed as follows: $FVI = E * S/R$, where E stands for exposure, S for susceptibility/sensitivity, and R for resilience/adaptive capacity. The social resilience index (SRI), physical resilience index (PRI), economic resilience index (ERI), and institutional resilience index (IRI) comprised the component resilience indices in a similar manner. The individual VRIs were averaged to determine the component resilience index (CRI).

3. RESULTS AND DISCUSSION

3.1 Household vulnerability indices

Table 3: Household vulnerability indices for the study areas

Type of indicator	Deluti		Lata	
	% value	VVI	% value	VVI
Exposure				
Past Flood Experience	92	0.92	98	0.98
House Near River	87	1.00	80	1.00
EVI		0.96		0.99
Sensitivity/Susceptibility				
Poor building materials	71	1.00	76	1.00
Disabled people	10	0.17	4	0.07

Dependents	42	0.70	38	0.63
Illiteracy	28	0.56	26	0.52
Household coping mechanism	32	0.46	38	0.54
Household single-unit structure	75	1.00	88	1.00
Human loss	6	0.08	4	0.05
Animal loss	42	0.53	38	0.48
SVI		0.59		0.54
Adoptive capacity				
Information about Flood	42	0.53	52	0.65
Social networks	28	0.35	32	0.40
Education	72	0.90	74	0.93
Working age group	65	1.00	60	1.00
Multiple income sources	20	0.33	46	0.77
Employment	55	0.79	70	1.00
AVI		0.66		0.79
CVI		0.86		0.66

Source: Derived from our field survey 2023

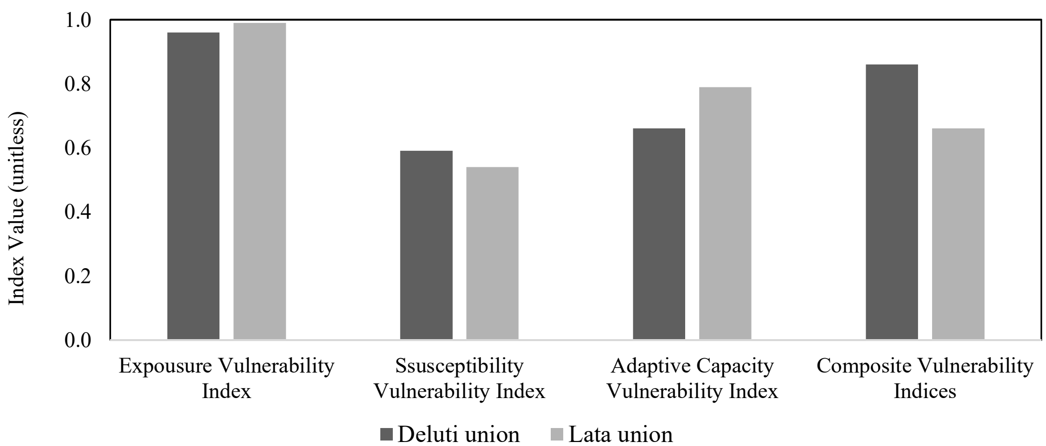

Figure 2: Household Vulnerability indices across the study sites

Household vulnerability indices including Exposure Vulnerability Index (EVI), Susceptibility Vulnerability Index (SVI), Adaptive capacity Vulnerability Index (AVI) with their Composite Vulnerability Index (CVI) across Deluti union and Lata union have been shown in Figure 2. The major indicators responsible for the higher vulnerability level in Deluti union are found to be lower susceptibility and adaptive capacity than Lata union.

Exposure

Exposure is the degree to which a community is impacted by extreme environmental stress (McKinney, 2013). In this investigation, we divided the exposure indicators into two groups: prior flood experience and home location (Table 3). Findings of Table 3 indicate that Lata unions had a higher exposure (0.99) and are more likely to experience flooding-related damages than Deluti unions (0.96). These results are consistent with research (Nicholls et al., 2015) that demonstrates that homes close to rivers have a higher risk of flood damage.

Sensitivity/susceptibility

Sensitivity or susceptibility of a system is the extent to which it is affected by various internal or external disturbances, or a series of disturbances (Gallopín, 2006). Table 3 provides a summary of the flood-sensitive factors (Deluti 0.59 and Lata 0.54), which affect vulnerability of the study area to flooding.

Adaptive capacity

Adoptive capacity can help reduce flood vulnerability. This potential could increase with the capacity to change the typical, built, human, and social capital, as well as the ability to experiment and learn how to deal with shock and pressure in a manner that reduce them over the medium to long term (Haase, 2011).Table 3 demonstrates that the adaptive capacity (0.66) in Deluti union was less than that of the Lata union (0.79). Certain factors, such as social networks, education can be recognized as leading to some households having greater adaptive capacity (Thanvisitthpon et al., 2020).

3.2 Household resilience indices

Table 4: Household resilience indices for the study areas

Type of indicator	Deluti		Lata	
	% value	VRI	% value	VRI
Social Resiliency				
Healthcare	43	0.72	8	0.13
Disability of residence	10	0.20	4	0.08
Transportation means	51	0.85	34	0.57
Health insurance	0	0.00	0	0.00
Educational Status	71	0.86	74	0.90
Social Capital	25	0.36	40	0.57
Past Flood Experience	86	0.86	84	0.84
SRI		0.57		0.46
Economic Resiliency				
Employment status	55	0.69	70	0.88
Livelihood opportunities	63	0.78	82	1.00
Multiple income source	20	0.39	46	0.92
Homeownership	73	0.91	58	0.73
Female Labour Force	8	0.13	28	0.47
ERI		0.58		0.80
Infrastructure Resiliency				
Infrastructure Road	4	0.06	6	0.09
Infrastructure Bridge	2	0.03	0	0.00
Infrastructure School	16	0.26	74	1.00
Infrastructure Hospital	0	0.00	0	0.00
Power supply	25	0.36	14	0.20
Water service	12	0.15	34	0.43
Sanitation service	76	0.96	44	0.55
First aid	29	0.49	6	0.10
Preparedness measure	39	0.65	38	0.63
Flood warning	41	0.51	34	0.43
Assistance	43	0.72	36	0.60
Livelihood restoration	69	0.98	26	0.37
IRI		0.43		0.37
Physical Resiliency				
Flood experience	100	1.00	100	1.00
Warning	42	0.47	38	0.42
Flood duration	0	0.00	0	0.00
Infrastructure Damage	82	1.00	72	0.90
Knowledge	14	0.20	42	0.60

Type of indicator	Deluti		Lata	
	% value	VRI	% value	VRI
Initiatives	10	0.14	12	0.17
Building strong Materials	29	0.48	24	0.40
Building Multiple Floor	25	0.42	22	0.37
Building Multiple Unit	29	0.58	30	0.60
Location	14	0.14	20	0.20
PRI		0.44		0.47
CRI		0.51		0.53

Source: Derived from our field survey 2023

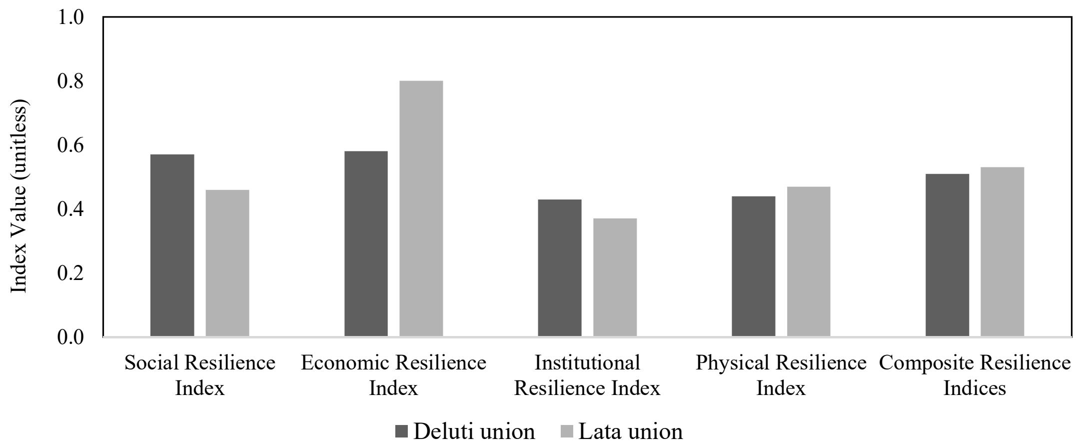

Figure 3: Household resilience indices across the study sites

Household resilience indices including Social Resilience Index (SRI), Economic Resilience Index (ERI), Institutional Resilience Index (IRI), Physical Rsilience Index (PRI) with their Composite Resilience Idex (CVI) across Deluti union and Lata union have been shown in Figure 3. The major indicator responsible for the higher resilience level in Lata union is found to be higher economic condition than Deluti union.

Social resilience

Social resilience is the capacity of communities and social groups to overcome adversity or respond to it in a positive way (Maguire & Hagan, 2007). The various social characteristics of the households are captured by the social resilience results shown in Table 4. The results of the social resilience index demonstrate that the lack of health insurance (0.00) and low social capital contribute to the low SRI of the Deluti union (0.57) and Lata union (0.46) in both research areas. The high percentage of educated heads of households (0.86 and 0.90) should also be attributed to high resiliency in both study areas (Saja et al., 2018).

Economic resilience

Resilience to flooding depends on the economic ability to adjust, bounce back, and rebuild, which lowers losses to overall consumption (Hallegatte, 2014). Resilience od a population to natural disasters, such as floods, can be gauged by its economic capabilities (Ghasemzadeh et al., 2021). Economic resilience values of Table 4 demonstrate that Lata union had a significantly higher economic resilience (0.80) than Deluti union, which had a very low economic resilience (0.58). The primary factors causing differences in this case are female employment and livelihood opportunities.

Institutional resilience

In institutional components of flood resilience, economic and administrative activities of an area are based. It provides a systematic explanation of the institutional behaviours and traits that enhance community capacities to lower the risk of flooding and increase resilience (Ro & Garfin, 2023). Institutional resilience values of Table 4 demonstrate that both of the study areas possessed low institutional resilience (0.43 and 0.37 for Deluti and Lata union, respectively), which can be attributed to the lack of infrastructure facilities, first aid resources, and community preparedness for flooding. The institutional resilience in both unions is notably lower than the other types of resilience, suggesting a lack of community engagement that could safeguard the social structure within the community.

Physical resilience

It was discovered that the Deluti union physical resilience score (0.44) was marginally lower than that of the Lata union (0.47). Most of the households in both study areas were situated within a 1-kilometer radius of Shibsha, the main river source, and frequently face varying degrees of flooding disasters. Furthermore, the fact that so few households in both areas 29% in Deluti and 24% in Lata have homes made of durable materials like brick and concrete reduces their physical resilience even more. The majority of the respondents' homes are made of mud, which floods easily destroy or damage.

4. CONCLUSIONS

Three key conclusions about household resilience and vulnerability to flooding disasters can be drawn from this research study. The overall vulnerability levels in the two study areas the Deluti union and the Lata union are quantitatively represented by the composite vulnerability indices. Deluti union was found to be more vulnerable having flood vulnerability index of 0.86 than Lata union with vulnerability index 0.66. However Lata unions had a higher exposure (0.99) from the findings and are more likely to experience flooding-related damages than Deluti unions (0.96). In case of flood-sensitive factors in Deluti (0.59) which is more than Lata (0.54), which affect the vulnerability more in Deluti. Deluti union with adaptive capacity (0.66) was less than that of the Lata union (0.79) causing the grater vulnerability condition in this site. Nevertheless, Deluti and Lata unions were found to have composite resilience index values of 0.52 and 0.51, respectively, indicating lower levels of resilience. Lower resilience indices show a decreased ability to withstand and recover from flood damage. Lack of health insurance (0.00) and low social capital contribute to the lower social resiliency of the Deluti union (0.57) and Lata union (0.46). In the case of economic resiliency, Deluti union had (0.58) where Lata union shows higher value (0.80). Physical resiliency influenced by the poor quality building materials and resulted low physical resiliency of both the study area (Deluti 0.44 and Lata 0.47).

Remarkably, the Deluti union exhibits lower resilience in addition to greater vulnerability, highlighting the connection between vulnerability and resilience. Major factors that differentiates the vulnerability and resiliency are healthcare flood shelter and building Materials. In Deluti union, maximum household structure are build with mud which are highly vulnerable to the flood and reduce the flood resilience in this union. People in Lata union have more facilities for shelter and health as it is located in the mainland and Deluti union is riverside island village. For this situation, the physical, institutional, economic, and social conditions of the households in this flood-prone region of Bangladesh especially the Deluti union need to be improved substantially to cope with the flood situations in a sustainable manner.

REFERENCES

Baptista, D. M. S., Farid, M., Fayad, D., Kemoe, L., Lanci, L. S., Mitra, P., Muehlschlegel, T. S., Okou, C., Spray, J. A., Tuitoek, K., & Unsal, F. D. (2022). Climate Change and Chronic Food Insecurity in Sub-Saharan Africa. *International Monetary Fund, 2022*(016), 4-5.

Climate Home News. (2013). Flooding could cost US$1 trillion a year by 2050. *Climate News Network*.

ESCAP (2020). *The Disaster Riskscape across South-East Asia*. In *Asia-Pacific Disaster Report 2019: Pathways for resilience, inclusion and empowerment. United Nations.* (pp. 4-9).

Fatemi, M. N., Okyere, S. A., Diko, S. K., Kita, M., Shimoda, M., & Matsubara, S. (2020). Physical Vulnerability and Local Responses to Flood Damage in Peri-Urban Areas of Dhaka, Bangladesh. *Sustainability, 12*(9), 3957.

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change, 16*(16), 293-303.

Ghasemzadeh, B., Zarabadi, Z. S. S., Majedi, H., Behzadfar, M., & Sharifi, A. (2021). A Framework for Urban Flood Resilience Assessment with Emphasis on Social, Economic and Institutional Dimensions: A Qualitative Study. *Sustainability, 13*(14), 7852.

Haase, D. (2011). Participatory modelling of vulnerability and adaptive capacity in flood risk management. *Sustainability Science, 67*(1), 77–97.

Hallegatte, S. (2014). Economic resilience: definition and measurement. *World Bank Policy Research Working Paper*, (6852).

Hossain, B., Sohel, M. S., & Ryakitimbo, C. M. (2020). Climate change induced extreme flood disaster in Bangladesh: Implications on people's livelihoods in the Char Village and their coping mechanisms. *Progress in Disaster Science, 6*, 100079, 4-6.

Jerin, T., Azad, M. A. K., & Khan, M. N. (2023). Climate change-triggered vulnerability assessment of the flood-prone communities in Bangladesh: A gender perspective. *International Journal of Disaster Risk Reduction, 95*, 2-5

Jung, Y., Kim, D., Choi, M., Kim, S., & Park, M. (2014). Vulnerability Resilience in the Major Watersheds of the Korean Peninsula. *Terr. Atmos. Ocean. Sci., 25*(6), 857-868.

Maguire, B., & Hagan, P. (2007). Disasters and Communities: Understanding Social Resilience. The Australian Journal of Emergency Management, 22(2), 16–20.

McKinney, M. L. (Ed.). (2013). *Encyclopedia of Biodiversity* (2nd Ed.). Academic Press.

Nicholls, R., Zanuttigh, B., Vanderlinden, J. P., Weisse, R., Silva, R., Hanson, S., Narayan, S., Hoggart, S., Thompson, R. C., de Vries, W., & Koundouri, P. (2015). Developing a Holistic Approach to Assessing and Managing Coastal Flood Risk. In *Coastal Risk Management in a Changing Climate* (pp. 9-53).

Qasim, S., Qasim, M., Shrestha, R., & Nawaz Khan, A. (2017). An assessment of flood vulnerability in Khyber Pukhtunkhwa province of Pakistan. *AIMS Environmental Science, 4*(2), 206-216

Qasim, S., Qasim, M., & Shrestha, R. P. (2021). A survey on households' resilience to landslide hazard in Murree hills of Pakistan. *Environmental Challenges, 4*, 100202.

Rahaman, M. A., Kalam, A., & Al-Mamun, M. (2023). Unplanned urbanization and health risks of Dhaka City in Bangladesh: uncovering the associations between urban environment and public health. *Frontiers in Public Health, 11*(1269362), 12-13.

Rahman, S., & Rahman, M. A. (2014). Climate Extremes and Challenges to Infrastructure Development in Coastal Cities in Bangladesh. *Weather and Climate Extremes, 5*, 19-20.

Ro, B., & Garfin, G. (2023). Building urban flood resilience through institutional adaptive capacity: A case study of Seoul, South Korea. *International Journal of Disaster Risk Reduction, 85*, 103474

Saja, A. M. A., Teo, M., Goonetilleke, A., & Ziyath, A. M. (2018). An inclusive and adaptive framework for measuring social resilience to disasters. *International Journal of Disaster Risk Reduction, 28*, 862-873

Shah, A. A., Ye, J., Abid, M., Khan, J., & Amir, S. M. (2018). Flood hazards: household vulnerability and resilience in disaster-prone districts of Khyber Pakhtunkhwa province, Pakistan. *Natural Hazards, 93*(1), 147–165.

Shah, S. M. H., Mustaffa, Z., Teo, F. Y., Imam, M. A. H., Yusof, K. W., & Al-Qadami, E. H. H. (2020). A review of the flood hazard and risk management in the South Asian Region, particularly Pakistan. *Scientific African, 10*, 4-5.

Thanvisitthpon, N., Shrestha, S., Pal, I., Ninsawat, S., & Chaowiwat, W. (2020). Assessment of flood adaptive capacity of urban areas in Thailand. *Environmental Impact Assessment Review, 81*, 106363.

The World Bank Group. (2021). *Climate Risk Country Profile: Bangladesh.*

Vinck, P., Ferguson, S., & Bollettino, V. (2020). *Household Disaster Resilience – Bagerhat District, Bangladesh*. Harvard Humanitarian Initiative.

World Health Organization. (2020). Floods: How to protect your health. Retrieved from https://www.who.int/news-room/questions-and-answers

Zhu, S., Li, D., Feng, H., & Zhang, N. (2023). The influencing factors and mechanisms for urban flood resilience in China: From the perspective of social-economic-natural complex ecosystem. *Ecological Indicators, 147*, 1-15.