**Commented [BN1]: Please a**dded information in the methodology section, whether to use the Explanatory Sequential Mixed Method (phase 1 quantitative stage, followed by phase 2 qualitative stage), or vice versa Exploratory Sequential Mixed Method, or Convergent Mixed Method (quantitative and qualitative phases are carried out simultaneously, not sequentially).

**Commented [BN2]:** It would be good to include the obstacles and limitations of the research in the abstract, so that it can be valuable input for readers who will research similar themes, so that the results will be even better.

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| --- |
| **Original Research Article****Determining Factors of Livelihood Resilience of Flood-affected Households in North-Western****Bangladesh** |
| **ABSTRACT** |
| **Aims:** This study examines the key factors of livelihood resilience of flood-affected households innorthwestern Bangladesh, a region recurrently impacted by flood hazards. |
| **Study design:** The research employed mixed-methods | approaches | , combining quantitative |
| analysis of household surveys (n=220) with qualitative insights from 12 focus group discussions (FGDs) and 8 key informant interviews (KIIs).**Place and Duration of Study:** This study was conducted in Gaibandha and Lalmonirhat, two districts of Bangladesh, from April to June 2017.**Methodology:** The Composite Livelihood Resilience Index approach was adapted to assess absorptive, adaptive, and transformative capacity by combining 4 dimensions (e.g., social, economic, ecological, and institutional) with 12 indicators.**Results:** This study determined the overall livelihood resilience index of flood-affected households to be 33.33% in northwestern Bangladeshi areas. Absorptive ability was identified as the most important factor in total livelihood resilience, followed by adaptive and transformational capacity. The results demonstrate that social factors consistently dominate across all three capacities, highlighting their critical importance in building resilience against flood shocks and stresses. Economic dimensions are also significant, indicating that financial stability and adaptability are key components of resilience strategies. However, ecological contributions vary across capacities, while institutional contributions are consistently low, indicating a need for stronger governance frameworks and institutional interventions. In strengthening the livelihood resilience of flood- affected households, the regression analysis identified 4 key factors involving human capital (β=0.278), non-farm income-generating activities (β= 0.251), social capital (β= 0.224), and |
| infrastructure (β= 0.220), | respectively | . |
|  |
| **Conclusion:** This research concludes that the north-western community people have limited livelihood resilience capacity, positively influenced by four crucial determinants. The study recommends enhancing institutional support, boosting ecologically smart strategies adoption, strengthening transformative capacity, and fostering social networks for building resilient livelihoods of flood-affected households. Policymakers could be1 |

aided with critical insights that could foster equitable resilience-building strategies tailored to the north-western regional context of Bangladesh.

*Keywords:* Livelihood resilience, Flood, Regression analysis, North-western Bangladesh.

## INTRODUCTION

Bangladesh is one of the most flood-prone countries in the world, with its geographical location and climate making it highly susceptible to frequent and severe flooding (Rahman & Salehin, 2013; Uddin & Matin, 2021). These floods profoundly impact households' livelihoods, particularly in rural areas where agriculture is the primary source of income (Parvin et al., 2016). The north-western region of Bangladesh is especially vulnerable due to its proximity to major rivers and the annual monsoon rains, which often lead to devastating floods (Hossain et al., 2011). Bangladesh ranks ninth globally and second in Asia (Welle & Birkmann, 2015) as the most flood-prone country. Nayem et al. (2021) reported 4 million annual flood-affected residents and up to 5.6 million exposed individuals. Paul (1997) documented historical river floods inundating 20% of the country’s landmass. Floods cause immense human suffering and disrupt socio-economic, environmental, and cultural sectors (Billah & Ansary, 2018).

Floods in Bangladesh not only cause immediate damage to crops and infrastructure but also have long-term effects on food security, economic stability, and rural employment (Hoq et al., 2021). For instance, recent floods have resulted in significant losses in the agricultural sector, with households engaged in fishery, crop, and livestock production being particularly affected (Rakib et al., 2017). However, it is essential to build up livelihood resilience among flood-affected households to inform policy interventions aimed at enhancing their capacity to withstand and recover from such disasters. Climate resilience is defined as a system’s capacity to absorb disturbances while retaining core functions, self-organizing, and adapting to stressors (IPCC, 2007). This concept emphasizes anticipating, preparing for, responding to, and recovering from shocks (Pain & Levine, 2012), while maintaining structural integrity despite disruptions (Walter et al., 2006). In climate contexts, it specifically refers to socio-economic systems’ ability to sustain shocks from climate change through adaptation (Tompkins & Adger, 2004).

Livelihood resilience builds on a framework, focusing on sustainable livelihoods that adapt, reorganize, and evolve to enhance system sustainability against future climate impacts (Amin et al., 2018). The livelihoods framework supports assessing adaptive capacity by analyzing socio- ecological processes shaping resilience (Clay, 2018), with climate-resilient livelihoods defined as those that enable communities to adapt to projected climate changes through existing strategies (Roy, 2018). Speranza et al. (2014) developed a paradigm for measuring livelihood resilience that incorporates buffer capacity, self-organizing ability, and learning capacity. Smith & Frankenberger (2018) separated livelihood resilience into three categories: absorptive ability, adaptive capacity, and transformational capacity. In measuring livelihood resilience, Zhou et al. (2021) reported four dimensions involving buffer capacity, self-organizing capacity, learning capacity, and disaster resilience. Livelihood strategies encompass income generation along with socio-cultural dimensions. Rural livelihoods are complex and dynamic systems characterized by persistent day-to-day survival uncertainties (Lu et al., 2022). Thus, several factors may contribute to the livelihood resilience of flood-affected households.

Studies have also highlighted the importance of designing adaptation pathways tailored to flood- affected communities' specific needs and contexts (Roy *et al.*, 2020). Understanding the essential contributing factors to the livelihood resilience of flood-affected households is crucial for developing effective strategies to mitigate the impacts of these disasters. These may include socio-economic characteristics, such as income level and education, as well as access to resources like credit and social networks. While studies in Ethiopia (Weldegebriel & Amphune, 2017), Vietnam (Dinh et al., 2023), China (Liu et al., 2022; Lu et al., 2022), and India (Bhattacharjee et al., 2018) elucidate

resilience mechanisms, region-specific analyses for north-western flood-prone Bangladesh remain sparse.

Determining the factors of livelihood resilience among flood-affected households in north-western Bangladesh requires a comprehensive approach that considers both qualitative and quantitative data. This study aimed to investigate the determinants of livelihood resilience among flood-affected households in north-western Bangladesh. This study explores how socio-economic, environmental, and institutional factors influence livelihood resilience in the region to withstand and recover from floods. By providing insights into these factors, the research seeks to inform policy and programmatic interventions that can effectively support flood-affected households in Bangladesh. The findings could contribute to the broader literature on livelihood resilience and disaster risk reduction, offering valuable lessons for other flood-prone regions globally.

## MATERIALS AND METHODS

### Study Area

This study was conducted in two districts of Bangladesh, including Gaibandha and Lalmonirhat (Fig. 1). Sampling spots involving 2 subdistricts from two priorly selected districts following a multi-stage random sampling approach. This area was selected due to its vulnerability to flood hazards in a frequent manner. The study area consisted of a total of 4 unions. Chandipur and Kapashia union of Sundarganj upazila were selected, covering 2 villages, namely Bochagari and Lalchamar respectively; Rajpur and Harati union of Lalmonirhat upazila were selected covering 2 villages namely Rajpur and Hiramanik respectively. These 4 villages constituted the locale of the study.



**Fig. 1. Maps of the study area. Left: a map of Bangladesh, indicating the study area (green colored) with two sampling locations (light red colored), Right bottom: sampling location 1 (light red colored), Right top: sampling location 2 (light red colored)**

### Study Design and Data Collection

The household resilience index was calculated using data collected through a cross-sectional survey design. A two-stage cluster random sampling technique was implemented to estimate representative population size. The sample size was determined using the statistical formula (Eq. 1) (Yamane, 1967; Nasrnia & Ashktorab, 2021):

**Commented [BN3]: Please a**dded information in the methodology section, whether to use the Explanatory Sequential Mixed Method (phase 1 quantitative stage, followed by phase 2 qualitative stage), or vice versa Exploratory Sequential Mixed Method, or Convergent Mixed Method (quantitative and qualitative phases are carried out simultaneously, not sequentially).

𝑁𝑍2𝑝𝑞

𝑛 = 𝑁𝑑2 + 𝑍2𝑝𝑞 (1)

Where, N= total population size; n = sample size; level of precision, e = 8%; the critical value of the standard normal variable at chosen confidence level (95%), z= 1.96; and proportion or degree of variability, p = 50%; q= 1- p. Here, the sample size (n) =220. Therefore, 220 households were selected to represent the whole farm dwellers in the study area. Combining both qualitative and quantitative techniques, a mixed research approach was employed. A well-structured interview questionnaire was used to collect relevant information from the respondents. For the present study, data collection was completed from March to June 2017. An appropriate scoring technique was followed to convert the qualitative data into quantitative forms. Respective Sub-districts’ Agricultural Extension Office (AEO) of the Department of Agricultural Extension (DAE) provided secondary

information such as lists of farmers, information on ongoing adaptation projects, current credit services, and others. Additionally, local Sub-Assistant Agricultural Officers (SAAO) assisted in data collection.

### Assessment of Livelihood Resilience Index

####  Theoretical framework

The study employed a framework combined with 3 major capacity indicators of livelihood resilience assessment developed by Béné *et al.* (2012) and GIZ (2014) to assess the livelihood resilience of flood-affected households. This framework had four dimensions, i.e., social, economic, ecological, and institutional, responding to 3 major capacities: absorptive, adaptive, and transformative. Additionally, a representative set of indicators was considered under four dimensions (Table 1). Absorptive capacity refers to the ability of a system to prepare for, mitigate, or recover from the impacts of negative events using predetermined coping responses to preserve and restore essential basic structures and functions (e.g., human life, housing, productive assets) (Cutter et al., 2008). Adaptive capacity is defined as the ability of a system to adjust, modify, or change its characteristics and actions to better respond to existing and anticipated future climatic shocks and stresses and to take advantage of opportunities (Brooks, 2003; IPCC, 2012). Lastly, the ability of a system to fundamentally change its characteristics and actions when the existing conditions become untenable in the face of climatic shocks and stresses (Béné et al., 2012; Walker et al., 2004).

**Table 1. Framework for assessing livelihood resilience**

**Capacity Dimension**

**Absorptive Adaptive Transformative Indicators**

**Social** Human Capital Social Capital Access to ICTs

**Economic** Annual family income Non-farm income

generating activities

Land productivity

**Ecological** Climate Smart Agricultural

practices & technologies

Functional and response diversity

Crop diversity

**Institutional** Access to financial institutions

*Source:* Adopted from Béné et al. (2012) and GIZ (2014)

####  Indicator selection

Infrastructure Market access

The effectiveness of the Resilience livelihood by increasing agricultural production and adopting capacities was also considered for the study. After reviewing related literature (e.g., Rasul & Thapa, 2004; FAO, 2010; Islam & Rahman, 2012; Roy et al., 2020), a primary range of indicators was identified. A methodical process combined with stakeholder participation in FGDs was used to choose the final indicators. KIIs were conducted for the validation of stakeholder responses, and a framework combining 12 indicators for 4 dimensions was established (Table 1).

####  Indicator measurement

Table 2 outlines the measurement of indicators and their scoring system. Indicators were quantified based on an established approach. This included both open and closed questions about visioning, resource mobilization, ICT use, decision-making, and social capacity (Table 2). For example, to assess climate-smart agricultural practices and technologies, the following question “Do you use resource-conserving practices and technologies e.g., integrated farming, mixed farming, floating cultivation, modern technology, etc.?” was asked. Table 3 provides descriptive statistics, showing low mean values for most indicators.

#### Table 2. Measurement procedures for the selected indicators

|  |  |  |
| --- | --- | --- |
|  | **Indicator** | **Measurement Method Scoring System** |

Human Capital Knowledge, skill, and capacity for livelihood options

Social Capital Membership and confidence in institutional benefits

Access to ICTs Extent of contact with communication media

Annual Family Income Income from agriculture in

Taka

1-5 (Definitely not to Definitely)

0-5 (No to A great deal)

**Commented [BN4]:** It is necessary to explain in more detail the factors contained in the research indicators, as well as the scientific arguments related to the scoring system in the table on page 6 of the manuscript.

0-2 (No access to Sustained access)

1-4 (Less than Tk.50,000 to over Tk.1,50,000)

Non-farm Income Generating Activities

Involvement in non- agricultural income sources

* 1. (No involvement to Involvement)

Land Productivity Yield of rice per unit area Quantitative measurement in

kg/decimal

Climate Smart Agricultural Practices & Technologies

Practices and technologies used

0-4 (Never to Adequately)

Functional and Response Diversity

Presence of species 0-1 (No to Yes)

Crop Diversity Herfindahl Index (HI) 0-1 (Perfect specialization to perfect diversification)

Access to Financial Institutions Extent of borrowing for

production

Infrastructure Existence of buildings for resilience livelihood

Market Access Buying and selling opportunities

* 1. (No access to Sustained access)
	2. (No to Yes)
	3. (No to Yes)

*Source: Author*

####  Composite Livelihood Resilience Index (CLRI) development

* + - 1. *Data quality assessment*

To ensure data quality, careful data screening was conducted to create a reliable dataset for constructing a meaningful index. High-quality data were ensured through screening for missing values (imputed via mean substitution) and outliers (z-scores >3.3 addressed using next highest score +1 and mean +2 SDs) (Field, 2009). Skewness (~1) and near-zero kurtosis confirmed near- normality, supporting regression analysis. Multicollinearity (r >0.80) was mitigated by variable removal or averaging (Field, 2009). Following screening, correlation analysis showed 85% moderate- to-high interrelationships without problematic multicollinearity, while multivariate regression validated the dataset's structural alignment with theoretical foundations and indicator adequacy for methodological decisions (OECD, 2008). Distribution checks revealed a slight positive skew but overall normality (Table 3), critical for reliable composite index construction.

* + - 1. *Normalization of data*

Generally, the data of variables are incommensurate with each other and have different measurement units. OECD (2008) described several normalization methods such as ranking, max- min, etc. By considering the pros (e.g., simple) and cons (e.g., outlier) of various methods into consideration, this study used max-min normalization methods (Eq. 2).

𝑥 − min(𝑥)

𝑙𝑖 = max 𝑥 − min(𝑥) (2)

Where *Ii* is the normalized value of the individual indicator, *x* is the raw value of individual indicator, and *max (x)* and *min (x).*

* + - 1. *Weighting*

There is no consensus on the appropriate weighting method in decision-making, with ongoing debates about suitable methods for assigning weights to variables. A dichotomy exists between participatory (subjective) and statistical (objective) methods. Various weighting methods are available, but each has limitations. For instance, equal weighting (EW), the most widely used method, risks double counting correlated variables and lacks a statistical basis, implying equal judgment on weights (Babbie, 1995). Public opinion-based weighting is legitimate but arbitrary, requiring a well-defined policy basis (Munda, 2008). This study employed equal weighting.

#### Table 3. Descriptive statistics on salient features of the respondent households

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Selected Indicators** | **Measuring Units** | **Min** | **Observ****Max** | **ed Valu****Mean** | **e** **SD** | **Skewnes Kurtosis s** |
| Human capital | Scores | 10 | 68 | 43.73 | 15.37 | -0.214 | -0.015 |
| Social capital | Scores | 4 | 40 | 25.20 | 6.16 | -0.131 | -0.333 |
| Access to ICTs | Scores | 0 | 15 | 5.60 | 2.75 | -1.41 | 0.310 |
| Annual family income | Scores | 0 | 6 | 2.30 | 1.07 | 0.202 | -0.757 |
| Non-farm income generating activities | Scores | 0 | 5 | 1.25 | 1.12 | -1.67 | 0.612 |
| Land productivity | Kilogram | 20 | 55 | 36.84 | 4.79 | 0.404 | -0.775 |
| Climate Smart Agriculture | Scores | 1 | 34 | 18.61 | 7.90 | -0.653 | 0.546 |
| Functional and response diversity | Scores | 0 | 11 | 4.39 | 2.29 | -0.421 | -0.192 |
| Crop diversity | Hectare | 0 | 0.92 | 0.41 | 0.23 | -0.026 | -0.623 |
| Access to financial | Scores | 0 | 16 | 5.32 | 2.40 | -0.653 | 0.546 |
| institutions |  |  |  |  |  |  |  |
| Infrastructure | Scores | 0 | 20 | 10.37 | 3.65 | -0.653 | 0.546 |
| Market access | Scores | 0 | 16 | 5.32 | 3.84 | -0.653 | 0.546 |

* + - 1. *Aggregation*

Aggregation plays a crucial role in constructing composite indicators, as it influences compensation among variables (Munda, 2008). The choice of an appropriate aggregation method depends on the purpose of the composite indicator (CI) and the nature of the subject being measured. Various aggregation techniques exist, and their selection is closely tied to the normalization method used for raw data (OECD, 2008). This study employed the weighted arithmetic aggregation method (Eq. 3) to combine indicators within dimensions, aiming to minimize measurement error and capture inconsistencies.

𝐼1 ∗ 𝑤1 + 𝐼2 ∗ 𝑤2 + ⋯ 𝐼𝑛 ∗ 𝑤𝑛

𝐶𝐼 =

1

∑𝑛 𝑤

(3)

Where CI is the composite indicator, e.g., sensitivity, I is an individual indicator of a dimension and w is the weight assigned to the indicator. As equal weighting was applied, indicators were simply summed and divided by the number of indicators. Assigning a weight of 2 (or 3) to one or more indicators implies that these indicators are twice (or three times) more important than indicators that retain a weighting of 1. The percentile value of the CI, refers to the percentage of flood-affected communities demonstrating higher capability to reduce, recover from, and reorganize in response to the flood.

### Data Analysis

Data collected from the respondents were compiled, tabulated, and analyzed following the objectives of the study. Various statistical measures such as number, percentage distribution, average, and standard deviation were used in describing data. The categories and tables were used in describing data. The categories and tables were also used in presenting data for better understanding. For determining the relationship between the selected resilience indicators of the households with their use of resilience farming in increasing agricultural production, Pearson’s Product Moment Coefficient of Correlation (r) was used at 5% (0.05) level of probability. Data were analyzed by the software SPSS and MS Office Excel 2019.

## RESULTS AND DISCUSSION

### Livelihood Resilience Patterns

A comprehensive assessment of livelihood resilience is illustrated in Fig. 2, presenting the ability of communities to deal with flood shocks and stresses. The result indicates that households had more absorptive capacity than adaptive and transformative capacity. About 50% of households had absorptive capacity, whereas only one-fifth percent of households had transformative capacity. Absorptive capacity exhibited the highest contribution to livelihood resilience, accounting for 46% of the total resilience. Adaptive capacity demonstrated a 33% contribution in enhancing livelihood resilience (Fig. 2). This capacity emphasizes adjustments and modifications to cope with changing conditions. Transformative capacity focusing on long-term systemic changes to address vulnerabilities contributed the least (21%) to overall resilience (Fig. 2).

The social dimension was identified as the most (35.87%) domination in absorptive capacity building, which highlights the importance of social networks and community cohesion in mitigating flood impacts (Fig. 2). The adaptive capacity of households was found as highly influenced by human capital and social capital. The government of Bangladesh has played a crucial role in ensuring food security, even in enhancing absorptive capacity to disastrous floods. This involves giving farmers quick and all-encompassing assistance, including finance, fertilizer, seedlings, and seeds. Furthermore, flood-induced siltation has improved soil fertility, which has led to higher rice yields overall and in *Boro* rice farming specifically. Similar results were also demonstrated by Fujita et al. (2021) and Parvin et al. (2016) in their study of flood risk management in Bangladesh.

**a) Overall resilience**

**b) Absorptive**

**Absorptive**

60

50

40

30

20

10

0

**Institutional**

**Social**

50

40

30

20

10

0

**Economic**

**Transforma tive**

**Adaptive**

**Ecological**

**c) Adaptive**

**Social**

**d) Transformative capacity**

**Social**

50

40

30

20

10

**Institutional**

50

40

30

20

10

0

**Economic Institutional**

0

**Economic**

**Ecological**

**Ecological**

**Average Score= 21**

**Average Score= 33**

**Livelihood Resilience Index Score=**

**Average Score= 46**

#### Fig. 2. Overall livelihood resilience index

The economic dimension was the second contributor to influencing adaptive capacity. Insufficient financial resources restrict the variety of services and financing available to households and businesses. The impoverished people and small firms reported their inability to invest in their education and businesses due to a lack of internal resources or personal wealth restricts their opportunities and feeds the cycle of persistent inequalities and slower expansion. Ecological and institutional dimensions had a poor contribution to developing the adaptive capacity of flood-affected households. Adaptation may collapse as prevailing issues like poor governance, complexity difficulties and limited access to political power were addressed by flood affected households. Furthermore, the intervention's own unexpected effects may cause an adaptive approach to fall short in reducing risks. Therefore, building resilience capability may not be significantly impacted by an inadequate institutional structure, consistent with Roy et al. (2020).

The ecological dimension accounts for 17.85% of limiting transformative capacity, reflecting that ecological transformative capacity is less emphasized compared to social and economic aspects. Potential gaps in governance and institutional support for strengthening transformative capacity are depicted as the lowest contribution (13.10%) of the institutional dimension depicted in Fig. 2. The majority of the current development approaches dealt with the obvious or direct sources of risks and vulnerabilities, but they neglected to address the underlying issues that occasionally enabled transformation processes.

Table 4 illustrates significant relationships between indicators and dimensions responding to the overall livelihood resilience index. Human capital showed highly significant (p < 0.05) relationships (r= 0.478) with the social dimension, indicating the critical role of this indicator in enhancing the resilience capacity of flood-affected households. Additionally, social capital is positively related to livelihood resilience, with a coefficient of r = 0.402, which is significant at p < .05. Flood-affected community people showed their economic stability by adopting non-farming income-generating activities. Pearson correlation analysis (p < 0.05) demonstrated a highly positive association (r= 0.223) between farming income-generating activities and economic dimension (Table 4).

#### Table 4. Pearson’s correlation coefficients between the selected indicators and livelihood

**resilience index as well as their underlying dimensions**

|  |  |  |
| --- | --- | --- |
| **Dimension** | **Indicators** |  **Correlation coefficient Resilience Dimensions****Index** |
| **Social****Economic** | Human capital Social capital Access to ICTsAnnual family incomeNon-farm income generating activities | 0.478\*\*0.402\*\*0.101\*0.212\*\*0.238\*\* | 0.432\*\*0.398\*\*0.143\*0.201\*\*0.223\*\* |
| **Ecological** | Land productivityClimate Smart Agricultural practices & technologiesFunctional and response diversity | 0.140\*0.213\*\*0.207\*\* | 0.113\*0.210\*\*0.109\* |
|  | Crop diversity | 0.010 | 0.014 |
| **Institutional** | Access to financial institutions InfrastructureMarket access | 0.103\*0.290\*\*0.011 | 0.1000.123\*0.015 |

*R2 = 0.781 (Adjusted value 0.779), \*\* 5% level of significant and \* 1% level of significant*

Non-farming income-generating activities (r= 0.238) and annual family income (r= 0.212) were identified as strengthening the economic dimension with a view to overall livelihood resilience building. Crop diversity (r= 0.010) showed an insignificant association (p > 0.05) with the ecological dimension, indicating the limited opportunities for the community to practice diversified crop production due to environmental challenges prevailing in this region. Moreover, access to financial institutions (r= 0.100) and market access (r= 0.015) revealed an insignificant (p > 0.05) relationship to the institutional dimension. This weak association with the institutional dimension signifies the limited capacity of flood-affected households in this dimension. Due to a lack of market opportunities and flexible financial institutions agriculture-reliant marginalized communities reflected a lower resilience against flood or associated vulnerabilities.

FAO (2013) defines climate-smart agriculture (CSA) as an approach to transform agricultural systems for sustainable development and food security under climate change. CSA integrates strategies across local to global levels to address climate risks while balancing synergies and trade- offs between productivity, adaptation, and mitigation. Community people demonstrated the potential contribution of climate smart agricultural practices & technologies (e.g., cropping pattern change, flood tolerant crop cultivation) in enhancing livelihood resilience in flood affected areas. However, this study demonstrated weak institutional capacity and malfunctioning political exercise by local community people contributing the least resilience to flood vulnerabilities.

### Key Factors Contributing to Livelihood Resilience

The results of regression analysis (R² = 0.781) indicate that twelve variables explain 78.1% of livelihood resilience variation, leaving 21.9% unexplained by these factors (Table 5). Standard errors assess whether regression coefficients (*B*-values) significantly differ from zero. Table 5 highlights influential factors (p < 0.05) involving human capital, social capital, ICT access, income, climate- smart agriculture, nonfarm activities, and infrastructure. While b-values are critical, standardized β values measured in standard deviations—are more interpretable, enabling direct comparisons of variables’ relative importance in this statistical analysis.

####  Human capital

The human capital (standardized β = 0.278) value indicates that as human capital increases by one standard deviation, livelihood resilience increases by 0.278 standard deviations (Table 5). FAO (2013) identifies human capital as a cornerstone of social sustainability, encompassing an individual’s knowledge, skills, experience, health, and nutrition. Thus, identifying moderate education levels and skills among community people may enable them to adopt innovative agricultural practices and modern technologies to ensure food security, environmental stewardship, and improved livelihoods. NGOs and GOs were identified to expand access to education, training programs, and services like field schools and extension activities for enhancing human capital.

MacGillivary (2004) emphasized human capital’s role in addressing emerging social challenges by building the capacity to address root causes of problems, enabling households to contribute meaningfully as growers, leaders, and practitioners. Nelson (2013) highlights institutional, market, and societal human capital as catalysts for managing and promoting individual and collective well- being through capacity development. Training programs in flood preparedness and livelihood diversification could bridge this gap, enabling communities to adopt resilient practices like water purification and shelter reinforcement. However, current initiatives remain insufficient, highlighting the need for targeted educational interventions to build adaptive capacity.

#### Table 5. Summary of regression analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variables** | **B** | **SEB** | **β** |  |
| Human capital | 0.082 | 0.010 | 0.278\*\* |  |
| Social capital | 0.199 | 0.0321 | 0.224\*\* |  |
| Access to ICTs | 0.1760 | 0.0420 | 0.117\* |  |
| Annual family Income | 0.120 | 0.0101 | 0.123\* |  |
| Non-farm income generating activities | 0.170 | 0.0092 | 0.251\*\* |  |
| Land productivity | 0.127 | 0.045 | 0.106 |  |
| Climate smart agriculture | 0.120 | 0.0101 | 0.123\* |  |
| Functional & response diversity | 0.170 | 0.021 | 0.105 |  |
| Crop diversity | 0.111 | 0.010 | 0.109 |  |
| Access to financial institution | 0.170 | 0.021 | 0.115 |  |
| Infrastructure | 0.150 | 0.012 | 0.220\*\* |  |
| Market access | 0.190 | 0.031 | 0.091 |  |
| *\*\* 5% level of significant and \* 1% level of significant* |  |  |  |  |

* + 1. **Social capital**

Social capital (standardized β = 0.224) refers probability of to rise in livelihood resilience by 0.224 standard deviations with an increase in the number of social capital by 1 (Table 5). Social capital was regarded as critical for sustainable communities, comprising mutual interest, collaborations, and partnerships rooted in shared purposes and trust. It includes structural (organizational networks) and cognitive (norms, values, attitudes) components (FAO, 2013). Household discussions highlighted social capital’s role in enhancing growers’ physical/human capital. In alignment with the findings of

this study, Trewevas (2002) linked social capital to livelihoods, emphasizing education, training, and field schools/IPM clubs for human capital development.

Flood-affected households often lack access to funds for rehabilitation, with only a limited number of individuals reporting active savings. As Tibbs (2011) noted that trust-based reciprocity strengthens household relationships and may allow for giving loans in necessities. UNDP (2011) underscores leadership, motivational, and organizational skills as key to resource accessibility, correlating higher social capital with resilience knowledge. However, traditional mentalities and inadequate awareness hinder effective social coordination, underscoring the need for initiatives that promote trust and participatory decision-making.

####  Non-farm income-generating activities

Standardized β =.251 for non-firm income generating activities demonstrates that livelihood resilience rises by 0.251 standard deviations for every standard deviation increase in non-firm income generating activities (Table 5). Thomas et al. (2013) defined the rural non-farm economy (RNFE) as income-generating activities (including remittances) in rural areas that are non- agricultural, contributing to local economic growth. These activities are critical for poverty alleviation, food security, and farm competitiveness, particularly for rural poor households. International interest in sharing methodological approaches for RNFE analysis and policy interventions highlights its growing significance in development discourse. Non-farming income practices, including fishing, home gardening, tailoring, small trade, and short-term migration to urban areas for work, were identified to cope with economic hardships posed by flood hazards in this area.

Trewevas (2002) emphasized non-farm income generation as a solution to food insecurity caused by economic constraints, particularly when food availability is not the primary issue. This study identified women’s income-generating activities (IGAs) near home as a key development objective, supported through self-help groups, which may strengthen their livelihood resilience at a greater proportion. In the line of the present findings, Leeuwis (2004) stresses women’s control over financial resources (e.g., savings, loans) as essential for IGA implementation, cautioning against raising unrealistic expectations. Scaling up vocational training and microfinance access could enhance diversification, though systemic barriers like infrastructure gaps persist.

####  Infrastructure

According to infrastructure (standardized β = 0.220), livelihood resilience rises by 0.220 standard deviations for every standard deviation increase in infrastructure (Table 5). Thomas et al. (2013) referred to infrastructure as the essential facilities and systems that serve a territory, as well as provide the services and facilities required to run its economy. It typically features technical structures such as established markets, deep tube wells, concrete roads, schools, health centers, cyclone shelters, embankments, roads, bridges, water management systems, modern telecommunications facilities, and so on. Flood-resistant shelters and water management system building were seen to be enhanced to reduce displacement risks by getting incentives from NGOs or their own interests.

According to Roy et al. (2020), the physical infrastructure in flood-affected areas is mostly fragmented and poorly constructed. The primary causes of the physical dimension's inadequate contribution to enhancing families' ability to sustain themselves were recurrent floods in 2007, 2014, and 2017. However, the present study identified government initiatives in building river embankments, rehabilitating roads, and water management structures. Those physical components of interrelated systems are essential to enable, sustain, or enhance lives and livelihoods in flood-affected areas of Bangladesh.

## CONCLUSION

The findings of the present study conclude that absorptive capacity contributes the most to overall livelihood resilience in flood-affected regions of Bangladesh, followed by adaptive capacity and transformative capacity. Absorptive capacity was identified as strongly influenced by social and economic factors, while ecological and institutional dimensions play a lesser role. Community dwellers demonstrated their least transformative capacity, representing the ability for structural changes to address root causes of vulnerability. The minimal contribution of ecological and institutional dimensions diminished the transformative capacity of marginalized households. The low institutional contribution across all capacities underscores a need for stronger governance and policy support.

Human capital of the flood hazard vulnerable households had the highest contribution to building livelihood resilience, indicating skills, health, mindset, and adaptability are critical for enhancing livelihood resilience. Involving in non-farm income-generating activities influenced the strengthening of their economic dimension. On the contrary, regression analysis results indicate that crop diversity, market access, and land productivity showed less contribution to improving household livelihood resilience. In conclusion, enhancing livelihood resilience requires prioritizing social cohesion and economic stability while addressing gaps in ecological sustainability and institutional frameworks. A balanced approach to strengthening all three capacities is essential for communities to effectively manage flood-related risks over both short- and long-term horizons.

Based on the conclusion of this study, five recommendations could be placed to improve overall livelihood resilience, especially in the face of flood shocks and stresses:

1. **Enhance institutional support:** The institutional aspect consistently scored the lowest across all capacities in this study. Focusing on strengthening local governance and improving access to resources and information could make institutions responsive to the needs of the flood-affected community.
2. **Boost ecologically smart strategies adoption:** Ecological resilience is relatively low, indicating vulnerability to environmental changes. Promoting sustainable land management practices, reforestation efforts, and conservation of natural resources might potentially enhance the ecosystem's ability to withstand floods.
3. **Strengthen transformative capacity:** Given that transformative capacity is the lowest (21%), prioritize interventions that foster systemic changes. This could involve policy reforms, infrastructure development (e.g., improved drainage systems, flood-resistant housing), and diversification of livelihood options to reduce reliance on flood-vulnerable activities.
4. **Improve economic institution functionalities:** Economic factors were found as consistently moderate. Implementing programs that diversify income sources, promote skill development, and provide access to financial services (e.g., microloans, insurance) would help households recover from economic losses due to floods.
5. **Foster social network:** Social capital is the strongest element, but there is still room for improvement. Support community-based organizations, promote social networks, and encourage collective action to enhance the ability of communities to cope with and recover from

floods. This may include initiatives that build trust and cooperation among community members. **Commented [BN5]:** It is quite good and easy to

understand, but it would be better if there was a glossary for standard terms so that lay readers could understand them.

## REFERENCES

**Commented [BN6]:** References from research in the last 5 years c**ould** be added to enrich the bibliography.

Amin, M. N., Solayman, H. M., Snigdha, S. S., & Sultana, J. (2018). Climate resilient livelihood activity in the south central coastal region of Bangladesh. Journal of Science, Technology and Environment Informatics, 6(01), 421-430.

Bhattacharjee, K., & Behera, B. (2018). Determinants of household vulnerability and adaptation to floods: Empirical evidence from the Indian State of West Bengal. International journal of disaster risk reduction, 31, 758-769.

Babbie, E. (1995). The practice of social research. Wadsworth, Washington, pp. 161–175.

Béné, C., Wood, R. G., Newsham, A., & Davies, M. (2012). Resilience: New utopia or new tyranny? Reflection about the potentials and limits of the concept of resilience in relation to

vulnerability reduction programmes. IDS working papers, no. 405.

Billah, M., & Ansary, M. A. (2018). Assessment of flood risk in the eastern part of Jamuna Floodplain.

Journal of the Asiatic Society of Bangladesh, Science, 44(2), 211-224.

Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework. Tyndall Centre for

climate change research working paper, 38(38), 1-16.

Clay, N. (2018). Integrating livelihoods approaches with research on development and climate

change adaptation. Progress in Development Studies, 18(1), 1-17.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. Global environmental change, 18(4), 598-606.

Dinh, N. C., Tan, N. Q., Tinh, B. D., Ha, V. H., Kien, N. D., Hung, P. X., ... & Phuong, H. T. (2023).

Decoding the livelihood vulnerability of flood-prone communities in Vietnam: Implications for disaster risk reduction and sustainable rural development. Journal of Agriculture and

Environment for International Development (JAEID), 117(2), 99-122.

FAO (Food and Agriculture Organization). (2010). Measuring Resilience—A Concept Note. Food

And Agriculture Organization, Rome, Italy.

FAO (Food and Agriculture Organization). (2013). Resilience Livelihood. Disaster Risk Education for

Food and Neutrition Security (Third Edition).

Field, A. (2009). Discovering statistics using SPSS. Third Edition SAGE Publications Ltd, London. Fujita, K., Shaw, R., & Parvin, G. A. (2021). After the 2004 Bangladesh Flood: Integrated

Management for Flood Disaster Risk Reduction in Four Different Areas. Climate Change,

Disaster Risks, and Human Security: Asian Experience and Perspectives, 291-316.

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit). (2014). Assessing and monitoring

climate resilience. Bonn: GIZ, GmbH.

Hoq, M. S., Raha, S. K., & Hossain, M. I. (2021). Livelihood vulnerability to flood hazard: understanding from the flood-prone haor ecosystem of Bangladesh. *Environmental*

*management,* 67(3), 532-552.

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.

Hossain, M. A., Reza, M. I., Rahman, S., & Kayes, I. (2011). Climate Change and its Impacts on the Livelihoods of the Vulnerable People in the Southwestern Coastal Zone in Bangladesh. *Climate Change Management,* 237–259.

IPCC (Intergovernmental Panel on Climate Change). (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.

IPCC (Intergovernmental Panel on Climate Change). (2012). Managing The Risks of Extreme Events And Disasters To Advance Climate Change Adaptation. Field, C.B., V. Barros, T.F. Stocker Et Al. (Eds.). Cambridge University Press.

Islam, N., & Rahman, M. (2012). An assessment of crop diversification in Bangladesh: a spatial analysis. Applied Economics Letters, 19(1), 29-33.

Liu, H., Pan, W., Su, F., Huang, J., Luo, J., Tong, L., ... & Fu, J. (2022). Livelihood resilience of rural residents under natural disasters in China. Sustainability, 14(14), 8540.

Leeuwis, C., Leeuwis, C., & Ban, A. (2004). Communication for rural innovation (Vol. 231). Blackwell publishers.

Lu, H., Zheng, J., Ou, H., Liu, Y., & Li, X. (2022). Impact of natural disaster shocks on farm household poverty vulnerability—A threshold effect based on livelihood resilience. Frontiers in Ecology and Evolution, 10, 860745.

MacGillivary, A. (2004). The Triple Bottom Line: Does It All Add Up, edited by Adrian Henriques and Julie Richardson. London: EarthScan, 121-130.

Munda, G. (2008). Social multi-criteria evaluation for a sustainable economy (Vol. 17). Berlin: Springer.

Nasrnia, F., & Ashktorab, N. (2021). Sustainable livelihood framework-based assessment of drought resilience patterns of rural households of Bakhtegan basin, Iran. Ecological Indicators, 128, 107817.

Nayem, Z., Hossain, M. S., Al Nayeem, A., & Rahaman, M. A. (2021). Analyzing influential factors to flood resilience in the northern flood-prone rural areas of Bangladesh. Climate Vulnerability and Resilience in the Global South: Human Adaptations for Sustainable Futures, 327-339.

Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to environmental change: contributions

of a resilience framework. Annu. Rev. Environ. Resour., 32(1), 395-419.

OECD (Organisation for Economic Co-operation and Development). (2008). Handbook on Constructing Composite Indicators: Methodology and User Guide, OECD Publishing, Paris.

Pain, A., & Levine, S. (2012). A conceptual analysis of livelihoods and resilience: Addressing the 'insecurity of agency'. ODI.

Parvin, G. A., Shimi, A. C., Shaw, R., & Biswas, C. (2016). Flood in a changing climate: The impact

on livelihood and how the rural poor cope in Bangladesh. *Climate,* 4(4), 60.

Paul, B. K. (1997). Flood research in Bangladesh in retrospect and prospect: a review. Geoforum, 28(2), 121-131.

Rahman, R., & Salehin, M. (2013). Flood risks and reduction approaches in Bangladesh. *Disaster*

*risk reduction approaches in Bangladesh*, 65-90.

Rakib, M. A., Islam, S., Nikolaos, I., Bodrud-Doza, M., & Bhuiyan, M. A. (2017). Flood vulnerability, local perception and gender role judgment using multivariate analysis: A problem-based “participatory action to Future Skill Management” to cope with flood impacts. *Weather and*

*climate extremes,* 18, 29-43.

Rasul, G., & Thapa, G. B. (2004). Sustainability of ecological and conventional agricultural systems in Bangladesh: an assessment based on environmental, economic and social perspectives.

Agricultural systems, 79(3), 327-351.

Roy, R., Gain, A. K., Hurlbert, M. A., Samat, N., Tan, M. L., & Chan, N. W. (2020). Designing adaptation pathways for flood-affected households in Bangladesh. *Environment,*

*Development and Sustainability,* 23, 5386-5410.

Roy, S. (2018). Livelihood resilience of the indigenous Munda community in the Bangladesh

Sundarbans forest. Handbook of climate change resilience, 1-22.

Smith, L. C., & Frankenberger, T. R. (2018). Does resilience capacity reduce the negative impact of shocks on household food security? Evidence from the 2014 floods in Northern Bangladesh. World Development, 102, 358-376.

Speranza, C. I., Wiesmann, U., & Rist, S. (2014). An indicator framework for assessing livelihood resilience in the context of social–ecological dynamics. Global Environmental Change, 28, 109-119.

Tibbs, H. (2011). Changing cultural values and the transition to sustainability. Journal of Futures Studies, 15(3), 13-32.

Thomas, T. S., Mainuddin, K., Chiang, C., Rahman, A., Haque, A., Islam, N., ... & Sun, Y. (2013). Agriculture and adaptation in Bangladesh: Current and projected impacts of climate change (Vol. 1281). Intl Food Policy Res Inst.

Tompkins, E. L., & Adger, W. N. (2004). Does adaptive management of natural resources enhance resilience to climate change?. Ecology and society, 9(2).

Trewavas, A. (2002). Malthus foiled again and again. Nature, 418(6898), 668-670.

Uddin, K., & Matin, M. A. (2021). Potential flood hazard zonation and flood shelter suitability mapping for disaster risk mitigation in Bangladesh using geospatial technology. *Progress in disaster science,* 11, 100185.

UNDP (United Nations Development Programme). (2011). Human Development Report 2011- Sustainability and Equity: A Better Future for All, UN Plaza, New York.

Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. Ecology and society, 9(2).

Walter, K. M., Zimov, S. A., Chanton, J. P., Verbyla, D., & Chapin III, F. S. (2006). Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming. nature, 443(7107), 71- 75.

Weldegebriel, Z. B., & Amphune, B. E. (2017). Livelihood resilience in the face of recurring floods: an empirical evidence from Northwest Ethiopia. Geoenvironmental Disasters, 4, 1-19.

Welle, T., & Birkmann, J. (2015). The world risk index–an approach to assess risk and vulnerability on a global scale. Journal of Extreme Events, 2(01), 1550003.

Yamane, Taro. (1967). Statistics: An Introductory Analysis, 2nd Ed., New York: Harper and Row.

Zhou, W., Ma, Z., Guo, S., Deng, X., & Xu, D. (2021). Livelihood capital, evacuation and relocation willingness of residents in earthquake-stricken areas of rural China. Safety science, 141, 105350.