UCLouvain

UNIVERSITÉ DE NAMUR

Economics School of Louvain - ESL
Economics School of Namur - ESN

The impact of natural disasters on food security in Bangladesh

Author : Marchionne Gaia
Thesis Director : Maystadt Jean-François
Thesis Reader: Baland Jean-Marie
Academic Year 2023-2024
Master in Economics – 120 credits – Focus: *Master in Economics, General, Professional focus (ECON2MS/G)*

Université catholique de Louvain - Economics School of Louvain - Place Montesquieu 3, 1348 Louvain-La-Neuve
Université de Namur – Economics School of Namur – Rempart de la Vierge 8, 5000 Namur

Acknowledgements

I would like to express my deepest gratitude to Prof. Dr. Jean-François Maystadt for his help, feedback, and comments during my work. I thank him for pushing me always to try to improve my research.

I would like also to express my sincere thanks to Prof. Dr. Jean Marie Baland for taking the time to read my work.

I am also thankful to the Economics School of Louvain and Namur and all my professors. Although these two years were challenging at times, I will remember them with great affection, and gratitude.

I am thankful to my university friends. I am grateful for the memories and experiences we shared.

Gaia Marchionne

December 2023

Contents

List of Figures

List of Tables

Appendices

Abstract

Bangladesh is exceptionally vulnerable to natural disasters, experiencing frequent extreme floods and droughts, seriously affecting agricultural productivity. The 31.9 % of the population is experiencing moderate or severe food insecurity.

This study, based on panel data collected in two surveys known as the Bangladesh Climate Change Adaptation Survey (BCCAS) conducted between 2010 and 2012, aims to shed light on the interaction between natural disasters (such as tornadoes, droughts, cyclones, and floods) and food security.

Two indicators, namely the Food Consumption Score (FCS) and Household Food Expenditure Share (HFES), are utilized to assess food security. FCS measures food security, while HFES evaluates the vulnerability and food insecurity of households.

Additionally, the study explores the role of adaptation by estimating the adaptive impact of the community-based approach. Using household and time-fixed effects, our estimates relate changes in household food security and alterations in the frequency of natural disasters. Cyclones and tornadoes affect food security. Cyclones have a negative impact on food security (FCS), while tornadoes have a positive impact on food insecurity (HFES).

Moreover, having at least one family member participate in community groups can reduce the negative impact on food security. It increases FCS and reduces HFES.

This study emphasizes the importance of community-based adaptation for addressing vulnerabilities and ensuring future food security in Bangladesh. Community-driven decision-making, education campaigns, and disaster management training programs play a crucial role in enhancing adaptive capacity and resilience to natural disasters. Further research is needed to explore the role of local-level institutions and community organizations in building resilience for effective disaster management.

1. Introduction

In 2021, according to the Food Agriculture Organization, 2.3 billion people were food insecure (FAO, 2023). Food security is a central factor in achieving the UN Sustainable Development Goals (SDGs)[1] because insufficient nutrition poses a significant challenge to immediate survival, physical activity, and overall health (Smith et al., 2014).

An important worsening factor is climate change, its effect is heterogeneous and can be more severe in some locations, especially in low-income countries (Burke et al., 2010; IPCC 2014). Moreover, agriculture constitutes the main economic activity in LICs, contributing over 40 % of GDP. Among these countries, Bangladesh is highly vulnerable to climate change it is the seventh nation in terms of vulnerability to natural disasters (Global Climate Change Risk Index, 2021; Eckstein et al., 2021; IPCC 2014). Furthermore, it is the 81st nation for food insecurity and 31.9 % of the population is experiencing moderate or severe food insecurity (GHI, 2023; FAO, 2022). It suffers from droughts, cyclones, floods, erosion, and soil salinity, impacting public health and economic growth. The seriousness of the situation is such that the agricultural sector is one of the most affected by the shock of climate change. According to the World Bank, it represents 12.5 % of GDP and 40 % of employees work in this sector. For this reason, I decided to orient my research work to the study of the effect of natural disasters on food security at the household level in Bangladesh.

Objective of the study

The focus on the study of individual households stems from the urgency to study fair access to food by individual households. Furthermore, analyzing the literature on the subject, few researchers have empirically compared two indices, the Food Consumption Score (FCS) and the Household food share expenditure (HFES). The former measures food security and the latter measures household vulnerability and poverty. Furthermore, there is an urgent need for adaptation measures for coping with natural disasters and in this field, a few investigate the impact of them to improve food security (Burke et al., 2010).

To address this research gap, the objective of the study is to estimate the impact of climatic shocks represented by tornadoes, cyclones, droughts, and floods on household food security in Bangladesh between 2010 and 2012. Subsequently, investigate the role of community-based adaptation strategies in improving household food security status and reducing their

[1] https://sdgs.un.org/goals

vulnerability. This study relies upon the Bangladesh Climate Change Adaptation Survey of 2011 and relies upon the Bangladesh Climate Change Adaptation Survey of 2012. This is panel data, with two rounds from December 2010 to February 2011 and from September 2012 to October 2012. To do that, we rely on two regression models.

Firstly, we proceed with estimating the impact of climate shocks on two indexes of food security the FCS and HFES. For this purpose, a fixed effects model (FEM) is used to control time-varying family characteristics and time-fixed effects through clustering at the Thana level. This analysis reveals that tornadoes and cyclones have a significant negative effect on FCS and HFES respectively. Then the second analysis measures the community group participation in reducing the negative effect of climate shocks on food security. The research confirms that the education level, household size, owners' assets, being active in the labour market in a non-agriculture sector, as well as having at least one member in the household that participates in the community groups can reduce the negative impact of natural disasters on food security.

The research is structured as follows: Section 2 presents the theoretical framework and context, Section 3 reviews the literature, section 4 introduces the database, the main variables studied, the descriptive analysis and the empirical strategy. Section 5 presents the empirical results and discussion. Section 6 discusses the limitations of this work, the possible extensions, and the policy discussion. Section 7 presents the conclusions.

2. Context and theoretical framework

This section aims to elucidate the significance of the study within the specific context of Bangladesh. It provides an understanding of the theoretical framework, which encompasses key concepts and theories related to the relationship between natural disasters and food security, along with the role of coping strategies.

2.1 Context, overview of Bangladesh

Geographical and climatic context

Bangladesh, a South Asian country, is a floodplain between the delta of three rivers, Ganges, Meghna, and Brahmaputra (GMB). The country faces climate challenges making it one of the most vulnerable countries, as reported by the Global Climate Index (MoEF, 2022).

This low-lying and flat topography renders the nation susceptible to severe flooding and periodic droughts. With over 200 rivers, including 54 from India, vulnerability peaks during the monsoon period (June to September) accounting for over 80% of annual precipitation.

Bangladesh faces changing rainfall and temperature patterns, shifts in extreme event frequency and intensity causing shocks, and rising sea levels in coastal areas impacting groundwater quality for irrigation (Yu et al., 2010). By 2050 the temperature will rise by 1-3°C and the country will be more in more exposed to intensified flooding and cyclones (World Bank, 2010). In 2007 it faced the most devastating cyclone called Sidr, which caused damage of $1.67 billion, destructing houses, the agriculture sector, transportation, water resources, education infrastructure, electricity, and water sanitation (Dasgupta et al., 2010). Bangladesh identifies tropical cyclones and monsoon flooding as the primary climate hazards in the country, which hit poor and vulnerable people.

Bangladesh's economy is based on the agriculture sector (BBS, 2019). Rice is the dominant crop it covers almost 77% of the entire land area (Parven et al., 2022), but the country also produces wheat, maize, pulses, oilseeds, jute, sugar cane, tea, and tobacco, contributing to its food self-sufficiency.[2] Rice is the main source of diet, accounting for 71% of a rural household's calorie intake (WFP, 2017). According to the World Bank, 60% of Bangladesh's population

[2] There are three typologies of rice: Aus (pre-monsoon rice); Aman (during monsoon season); Boro (dry-season) (Hossain, et al., 2019).

inhabits rural areas and approximately 87% of rural households rely on agriculture for at least part of their income (World Bank, 2019; World Bank, 2022). [3]

The government recognized that climate change is an environmental and development issue challenge, in 2005 adopted the Bangladesh Climate Change Strategy Action Plan (BCCSAP), a living document that identifies six pillars point of action: *food security, social protection and health, comprehensive disaster management, infrastructure, resource and development management, mitigation and low carbon development, capacity building and institutions* (BCCSAP, 2009).

Food security context

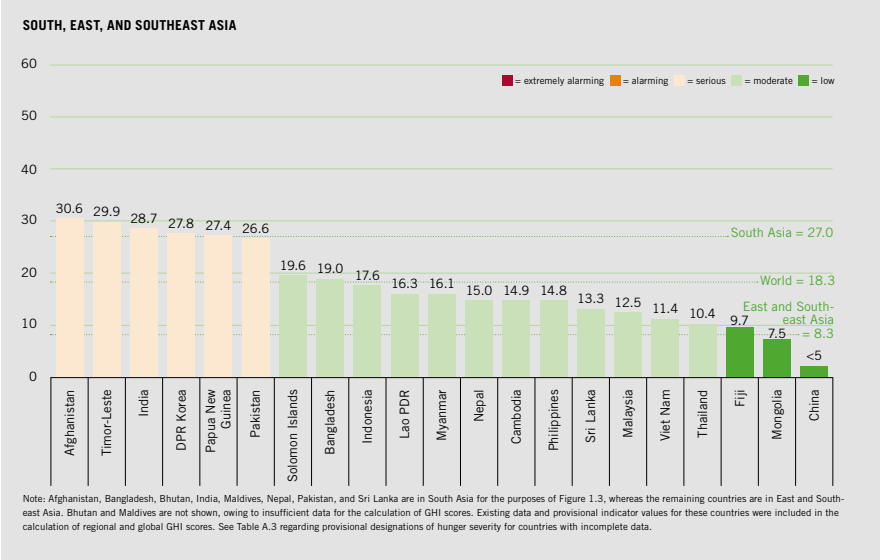

Figure 2. 1: Global Hunger Index score in South, East, and Southeast Asia (GHI, 2023)

In 2023 Bangladesh was ranked by the GHI (Global Hunger Index) in the 81st position out of 125 countries with a score of 19, such a score defines a country where the level of hunger is moderate. The figure, taken from the report made by the Global Hinger Index (GHI), shows the classification of food security for South, East, and Southeast Asia countries. As we can see in *Figure 2.1* Bangladesh is not part of the serious hunger situation, but it is still in a moderate situation.

[3] https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS

Food insecurity changes over time. The maximum level of food security is reached in March and the lowest in September. This pattern is consistent with the fact that the rice crop contributes the most to the country's food, the Aman crop, is harvested in December (Del Ninno et al., 2001; Smith et al., 2007)[4]

The challenge for Bangladesh is to boost agriculture productivity, also in response to the increase of demand for food with the increasing population. Therefore, the negative effect of climatic extreme events causes food loss and can represent a significant challenge and hurt food availability (Mirza, et al., 2011).

2.2 Theoretical Framework

Food security

Food security is the primary development goal of the UN SDGs.[5] The Food and Agriculture Organization (FAO) offers a comprehensive definition of food security, which goes beyond mere sustenance. According to the FAO, food security exists when "…all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Security, 1996). Therefore, food security is about whether people have access to enough quantity and quality of food to have a healthy life (Smith et al., 2014).

Food security is a multidimensional construct influenced by diverse and intricate factors stemming from natural and social systems.

It is essential to measure food insecurity to monitor some changes and assess the impact of intervention in food insecure countries (Maxwell, et al., 2003). There are three dimensions of food security: food availability, food access, food utilization, and food stability (Barrett et al., 2010; Moltedo et al., 2014). Availability refers to the presence or not of food through any means (production, imports). Access indicates the possibility of getting food from the market or its own production. Utilization stays for appropriate nutrition content, and stability refers to the ability to procure food over time, through production and/or food transfer (Gross et al., 2000). Stability is usually affected by a lack of production, natural disasters, crop failure, price fluctuations, and civil conflict (Reddy et al., 2019).

[4] In Bangladesh, there are two seasons Rabi, which runs from November to March is the dry season; Kharif runs from April to October and is divided into the pre-monsoon season from April to May and the monsoon season from June to September.

[5] https://sdgs.un.org/goals

While poverty remains a central determinant of food insecurity, it is essential to recognize that other significant factors also contribute to this issue. These factors encompass political instability, climate change, poor governance, group-based discrimination, low productivity levels, and high food prices, all of which collectively exacerbate the challenges faced in achieving comprehensive food security (Gustafson et al., 2016).

Natural disasters

Natural disasters are defined by the UN Office for Risk Reduction as “a natural process that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.” Natural disasters include earthquakes, floods, cyclones and droughts (UNISDR, 2019).

This natural event appears suddenly causing a shock and great damage and destruction at national and international levels. Climate change, environmental degradation and urbanization cause increasing vulnerability to natural disasters. Vulnerability is directly related to the system's susceptibility, sensitivity, or lack of resilience and ability to adapt to and cope with natural disasters (IPCC, 2007).

In the fourth IPCC report, the panel defines it as the degree to which geophysical, biological and socio-economic systems are susceptible and unable to cope with the negative impacts of climate change. Therefore, low-income countries (LIC) are more exposed, and the frequency of natural disasters is expected to increase with global warming (World Bank, 2014). The economic impact of natural disasters can be direct or indirect. The former refers to the damage to residences, productive capital, infrastructure, crops, livestock, physical and mental/health impact

The effect of natural disasters on food security

One of the sectors most impacted by natural disasters such as drought, floods, storms, crop and livestock pests, disease and infestations and wildfire is agriculture (FAO, 2021). This results in declining crop and livestock production, directly impacting the economy, increasing importations and decreasing exportations, and on entire national food systems.

The production loss can affect all components of food security, food availability, access and utilization and stability (Reddy et al., 2019). Obviously, this restriction on production would inevitably result in a reduction in farmers' income whose livelihoods depend on it. This is accompanied by a high volatility of food prices which translates into farmers having greater

difficulty in accessing food. In addition, the more vulnerable to the phenomenon are women and children because extreme events can negatively impact maternal health and childcare.
Consequently, natural disasters have extensive and complex impacts on food systems, which will vary geographically and over time. Socioeconomic conditions will profoundly influence these impacts. The drivers of food systems are divided into climate drivers and no-climate drivers such as demography, socioeconomic, irrigation, and soil fertility. These drivers impact production aspects such as livestock, fish and crops and no production aspects income, transport, storage, and retailing (IPCC, 2014). Therefore, LICs due to their higher exposure to natural disasters and their higher dependency on crop activities are affected by compromised food availability and poor nutritional results (Adedeji et al., 2016).

Coping strategy

Humans can adapt their behaviour to natural disasters (Burke et al., 2010). Coping capacity is defined by the IPCC as the ability "of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance by responding or reorganising themselves in ways that maintain their essential function, identity and structure." (IPCC, 2019).
Adaptation, therefore, concerns measures introduced in a system already impacted by climate, that help to reduce negative outcomes (Disaster Risk Reduction DRR) or foster positive outcomes (Burke et al., 2010). The ability to adapt, learn and transform increases resilience to natural hazards (IPCC, 2019).
Adaptation measures are divided into ex-ante and ex-post. The former refers to those actions taken in anticipation, and the latter, to responses which are undertaken after the natural hazard manifestation.
Examples of ex-ante strategies can be diversifying farm plot locations, changing the timing of crop production, irrigating the crop area, and switching crop varieties depending on their climate sensitivity (Hossain., 2019; Burke et al., 2010; Di Falco, et al., 2011).
Adaptations to agriculture are not the only solutions for enhancing food security; non-agricultural, less climate-sensitive sources of income are also an adaptation strategy (Uddin et al., 2014; Burke et al., 2010).
Ex-post strategies involve using cash reserves, seeking financial support from credit markets or family, selling assets, or relocating for work in unaffected areas (Barua et al., 2020).
Furthermore, some adjustments to agricultural management may involve replanting more resistant types of crops that are less valuable or productive. However, sometimes ex-ante

strategies are insufficient, or the ex-post is not available due to the lack of a social safety network and access to credit (Burke et al., 2010).

Especially in LIC countries poor people are rarely insured to cover a loss due to natural disasters such as storms or cyclones (Reid et al.,2009).

Therefore, is necessary that poor communities adopt strategies to adapt for improving their resilience which is a critical means to eradicate extreme poverty, end hunger and ensure food security and nutrition (FAO, 2021).

Formal and informal institutions

Institutions are often referred to as "rules of the game of a society" and help structure human interactions in political, economic, and social spheres (North, 1991).

Institutions play a crucial role in reducing uncertainty and shaping the way people interact with each other (Acemoglu & Johnson, 2005; North, 1991).

Formal institutions are those that have a clear structure and follow rules, laws, and regulations. On the other hand, informal institutions are not well-structured, and they may not have clear organizations. They include traditions, taboos, and codes of conduct. Political parties, political assemblies, and private companies are examples of formal institutions, while informal ones can be rules that result from generally accepted practices. (Messer et al., 2003; North 1991). Institutions have the power to modify the assets that people use, improving their livelihood and reducing their vulnerability. Livelihood assets are different kinds of assets that play a role in household livelihoods, such as physical capital, financial capital, and human capital. In developing countries, households often find informal ways to reduce risks from or cope with ex-post shocks (De Vreyer et al., 2013; Casson et al., 2010).

One such way is through a community-based approach, where members work together to improve their livelihoods through collective actions (Schipper, et al., 2014). Generally, individuals cooperate with other players to maximize their output, especially when the play is repeated and they have complete information about the others and their past performance (North, 1991). The fundamental element that helps community-based groups resolve problems in systems of collective action is social capital (Casson et al., 2010). Social capital includes trust, reciprocity, sanctions, networks, and cooperation at individual, village, and group levels. A greater equality in social capital can reduce the transaction costs in organizing certain activities (Adhikari et al., 2010).

Community-based approach

The community-based approach (CBA) is a bottom-up adaptation strategy, based on a process of learning, knowledge and needs at the community level, which enables people to be more resilient in coping with natural disasters (Smith, et al., 2007). Communities that adopt a CBA make efficient use of small resources through frequent interactions (Baland and Platteau, 1996; Libois, 2022). CBAs make it possible to counteract the *tragedy of the commons,* a concept by Elinor Ostrom that indicates mismanagement and inefficiency in the use of resources (Ostrom, 1990). Proper management of local or village-level natural resources can enhance their ability to adapt to natural disasters. These collective arrangements are guided by formal and informal mechanisms to enforce them Community members have local knowledge and networks of support, trust, and leadership. These elements enable them to withstand external disruptions to their social infrastructure, to cope with various challenges that include environmental problems and socio-economic upheavals (Adger, et al., 2000).

The challenges faced by impoverished communities extend beyond climate change impacts to encompass health, employment, food prices, and community conflicts (Reid et al., 2009).

For instance, communities adopt strategies against flood risks like constructing elevated houses, diversifying livelihoods, and activating community-based networks for shelter and sustenance. To further support these communities, scientists emphasize the importance of mitigation efforts, particularly the reduction of greenhouse gas emissions. While mitigation is generally more effective, it requires a longer timeframe to make a substantial impact (Rawlani et al., 2011).

3. Literature review

The literature review encompasses two principal research strands. The first field concerns the negative impact of natural disasters on food security and on agriculture production that constrain the access and availability of food items. The second strand is about the coping strategies that can be adopted to overcome and mitigate this negative effect.

Relation between natural disasters and food security

First, this research contributes to the literature attempting to identify the impact of climate change on food security. At the global level, climate change has a negative impact on all four dimensions of food security, which are food availability, food access, food utilisation, and food stability (FAO, 2023; IPCC, 2019). However, the impact of climate change is not the same for all countries, as it varies based on their socioeconomic status (FAO, 2021).

Higher-income countries (HIC) are less affected by natural disasters than lower-income countries (LIC), due to higher education levels, greater openness to foreign markets, and a more complete financial system (Skidmore et al., 2005).

LICs, on the other hand, are more vulnerable to natural disasters and are at risk of food insecurity (Adedeji et al., 2016; FA0, 2021). For instance, according to Reed et al. (2022), floods have affected nearly 12% of people experiencing food insecurity in Africa from 2009 to 2020. Moreover, one-quarter of all damage caused by natural disasters affects the agriculture sector in LICS, which has significant impacts on employment opportunities, household income, and exports (Shah et al., 2022; FAO, 2015). Consequently, developing countries are increasingly reliant on imports, which can exacerbate poverty, and vulnerability, and cause food price fluctuations, affecting low-income households (Schmidhuber, 2007; FAO, 2023; Alamgir et al., 2018).

An extensive literature investigates the effect of natural disasters on household-level food security and general household consumption or expenditure (De Vreyer et al., 2013; Mafuru, 2003; Shariff et al., 2008). In this regard, Israel, and Briones (2012) analyze the impact of typhoons, floods, and droughts on food security in the Philippines and they find a negatively significant effect on rice production that decreases food availability.

A study conducted in Cambodia has revealed a significant negative impact on household consumption due to covariate shocks (Nguyen et al., 2020). Similarly, a study conducted on a sample Indian household between 1988 and 2012 has shown that the poorest ones experience a decline in consumption due to rising temperatures (Aggarwal, 2021). Oskorouchi et al. (2021)

examine the impact of exposure to flooding during the 12 months of 2011 and 2012 in Afghanistan. Floods are bound to decrease consumption and nutrients in the diet and negatively affect household income, raising the likelihood of being poor by 3%. However, there is a lack of research comparing food security indicators such as the Food Consumption Score (FCS) and the Household Food Expenditure Share (HFES). It is essential to take a comprehensive approach that examines the quality of the diet and its relationship with the vulnerability of impoverished households. This study provides a more comprehensive look and can capture the various factors of this multidimensional indicator.

Indeed, as confirmed by the literature, several factors impact households' exposure to food insecurity, such as asset ownership, education, income, skill, experience, and access to insurance (Barua et al., 2020). Additionally, geographical position is also important, as it can influence the distance from the market and the availability of transportation, as highlighted by Mafuru et al. (2003).

Strategies adopted to cope with natural disasters

Second, this study aims to contribute to the literature seeking to identify the coping strategies crucial to adapting to natural disasters for improving food security at the household level.

Adaptation is a key strategy in the context of coping and is fundamental to linking the short-term impacts with the long-term effects (Dell, et al. 2014). Compensating for food shortages requires adopting adaptive measures, farming technologies, and openness to trade, as they increase agricultural productivity (Pawlak et al., 2020).

A limited amount of literature uses micro-level, household-level data to examine the change in household behaviours before and after being affected by natural disasters (Di Falco et al., 2011; Jiliang et al., 2016). Literature investigates the role of coping strategies such as crop diversification, irrigation, adapting crop varieties to specific climate patterns, crop rotation, finding off-farm jobs, moving to non-farm activities, and using crop insurance or migration.

One of the possible coping strategies is selling assets to maintain a household's consumption level constant, as evidenced by a study in Cambodia (Nguyen et al., 2020). Others move away from agricultural work because of reduced income due to the negative impact of environmental disasters that reduce agricultural production (Eskander et al., 2016). In general, labour supply increases in the non-agricultural sector (Rose, 2001). Uddin et al. (2014) examine the adaptation strategies adopted by farmers in Bangladesh and conclude that irrigation is the most used while crop insurance is the least used, this underlines the lack of good management in finance institutions underwriting agriculture. Indeed, according to Delaporte et al. (2018), households

in poor rural areas face difficulty in accessing coping strategies, and their ability to adapt increases with access to education and electricity. This lack of coping strategies can also affect the mobility of the population due to the impact of climate change. Natural disasters in Bangladesh do not have a positive impact on rural mobility as households lack the resources to migrate, as reported by Mueller et al. (2011). Furthermore, the impact of natural disasters on agricultural production and food security varies across regions and periods. Thomas et al., (2013) analyze the effect of climate change on crop yields in Bangladesh, concluding that while some crops may benefit, the effects are not evenly distributed. This finding was also supported by Houssain et al. (2018), who use a Ricardian model to examine the effect of climate change on crop farming in Bangladesh. They examine the period of the average monthly temperature during the period 1946-2016 and they find that an increase in temperature has a positive impact on crops with irrigation, but its effects are not uniform.

Despite these findings, there is a notable research gap in understanding the role of communities and local knowledge in responding to climate change. The Community-based approach empowers vulnerable communities to identify and implement appropriate responses to climate change locally (Schipper et al., 2014). Their role is essential for collective action that can improve their access to the market. This highlights the need for further exploration in this area.

The role of community-based approach

The community-based approach has been studied across various regions, revealing its positive impact on increased resilience to natural hazards. In Nepal, community-based organizations have been extensively studied (IPCC, 2014). Libois et al., (2022) study the role of Community Forest User Groups (CFUGs), which are responsible for 50% of the forests in the country. Their study finds that CFUGs have a positive impact on community forestry, increasing the forest size. Additionally, community forestry in Nepal positively influenced forest collection practices (Adhikari et al., 2010).

In Indonesia, studies in Jakarta and Palu City underscored the pivotal role of communities and coordination in reducing vulnerability. Collective action, defined as social capital, was highlighted as a key factor for adaptation in flood-prone Jakarta (Marfai, et al., 2015). Similarly, community adaptation in Palu City to a tsunami and earthquake was strongly shaped by local experiences and knowledge of these phenomena (Yulianto, 2021).

In Malawi, a study explores the impact of forests on food security, assessed through the Food Consumption Score (FCS) for general well-being (Meyer, et al., 2023). Moreover, in 2009

Bangladesh implemented the “Community-Based Adaptation to Climate Change through Coastal Afforestation” (CBACC-CA) program, executed by the Ministry of Environment and Forestry. This program is focused on sustainable practices, including cyclone and tidal protection through mangrove plantations. Within this initiative, the “Forest, Fish, and Fruit” (FFF) model aims to enhance community resilience via diversification, reforestation, and early warning measures (MoEF, 2008; Rijai et al., 2019). Rawlani et al. (2011) underscore the “FFF” model's effectiveness, emphasizing the community's role in infrastructure adaptation while highlighting the need for interdepartmental coordination. Bangladesh has transitioned to a holistic strategy, emphasizing risk identification, mitigation, and integrated response to strengthen both preparedness and community resilience. Social capital proves crucial for effective disaster management, with socially and economically marginalized communities facing increased vulnerability, in contrast to reduced vulnerability in developed communities (Ahamed, 2013).

The urgency to gather quantitative evidence on the community's role in Bangladesh, particularly in enhancing food security for impoverished communities, underscores the need for further research to comprehensively understand and leverage their pivotal role in climate adaptation and resilience-building efforts.

4 Data and Methodology

In this section I first describe the data used in section 4.1, then I define the variables and how the food security indicators have been constructed in section 4.2, in section 4.3 I present the descriptive analysis and finally in 4.4 the empirical strategy adopted.

4.1 Data

The research study's purpose is to analyze the consequences of food security due to natural disasters and to analyze the role of group communities as adaptation measures. The BCCAS comprises two rounds of data collection, referred to as BCCAS I and BCCAS II. This survey was conducted under the supervision of the United States Agency for International Development (USAID) and designed by the International Food Policy Research Institute (IFPRI). The actual administration of the survey was carried out by the Bangladesh Centre for Advanced Studies in Dhaka, Bangladesh. The survey's sampling approach was designed to provide a representative sample from different regions across Bangladesh. It included 40 randomly selected unions, *Figure 4.1* highlights the selected unions in different colours. The unions aim to represent the seven distinct agroecological zones: Barind Tract, Bill & Haor Basin, Flood Plain, Himalayan Plain, Madhupur Tract, North-Eastern Hill, and Tidal Flood Plain, identified by the Bangladesh Centre for Advanced Studies. These zones exhibit diverse climate patterns, making it essential to collect data from various parts of Bangladesh when studying how households cope with climatic adversities in a comprehensive and representative manner.[6] In each of the unions, twenty agricultural households were randomly chosen from a single village, resulting in a total sample size of 800 households. *Table 4.1* on household location demonstrates that the survey is quite representative of Bangladesh, thus generalizing the results to a national level. BCCAS I was conducted during the period from December 2010 to February 2011, while BCCAS II was carried out between September and October 2012. Importantly, each survey round collected data related to the preceding production year, covering 2010 and 2012, respectively. A remarkable feature of the survey is the high rate of follow-up interviews. Over 97% of the households that participated in BCCAS I were successfully reinterviewed in BCCAS II, ensuring data continuity and allowing for the observation of changes over time. The BCCAS dataset is rich in its collection of various information. It

[6] Bangladesh is divided into 64 districts, which are further subdivided into administrative divisions called Upazilas/Thana, within Upazila another administrative division exists called Union.

encompasses demographic characteristics, data on social capital, land tenure, crop and livestock management, input utilization, access to extension services, the incidence of climatic shocks within the past five years, and the adaptation strategies adopted by households (Thomas et al., 2013).[7]

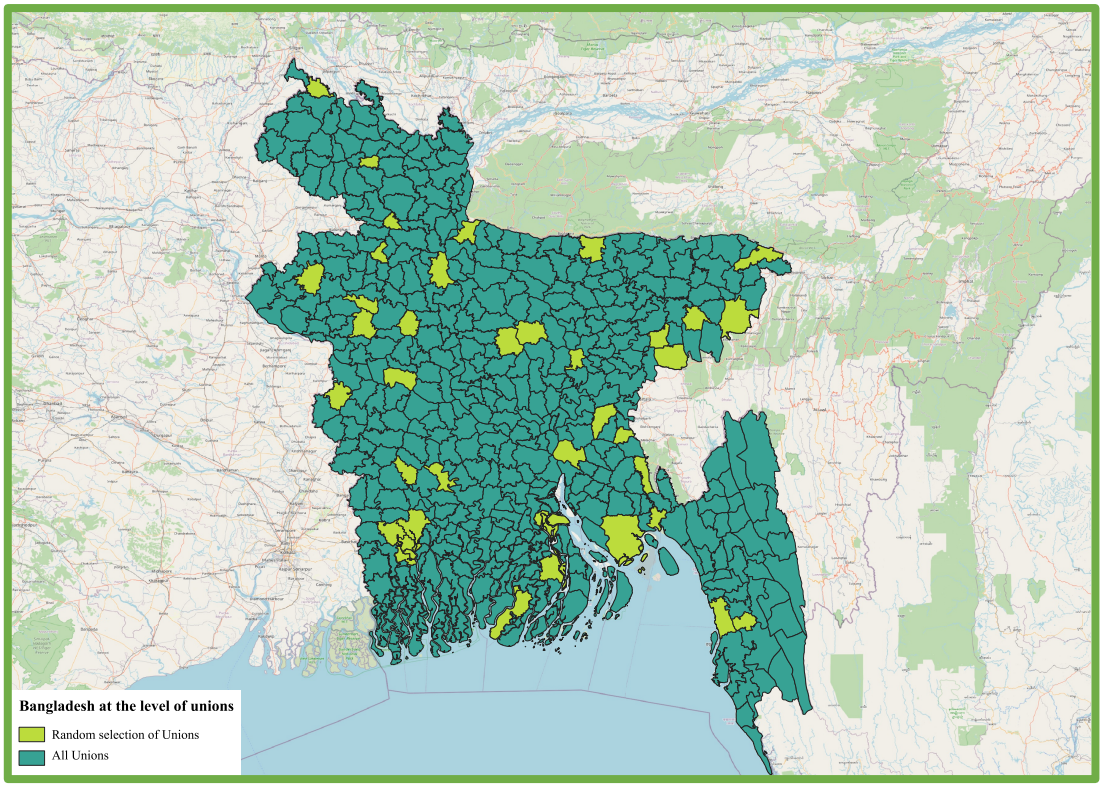

Figure 4. 1: This map illustrates the 40 unions randomly selected for the BCCAS survey

Household Location Round I				**Household Location Round II**			
Variables	Min	Max	N	Variables	Min	Max	N
Union	1	40	800	Union	1	40	800
Upazila	1	39	800	Upazila	1	39	800
District	1	31	800	District	1	31	800
Agroecological zone	1	7	800	Agroecological zone	1	7	800
Household	1	800	800	Household	1	800	800

Table 4. 1: BCCASI BCCASII

[7] https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/27704
https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/27883

4.2 Definition of the variables

In this section, I present which type of variables I considered for the analysis and how they are constructed.

Food security is impacted by different factors, such as family size, sex, literacy level, the level of education as presented in *Table 4.2*.

Variables	Definition
Family size	Total number of members in the family
Gender	1=yes household head is male, 0= female
Active member	Household heads aged between 14 and 65, considered active working members
Age	Household head's age in years
Married	1= yes if the household head is married, 0= otherwise
Literacy	1= the household head can read and write
Education level years of schooling	Years of schooling
Electricity access	1= household have electricity connection, 0= otherwise
Group member	1= a member of the household is a group member, 0= otherwise

Table 4. 2: Variables in the dataset

4.2.1 Definition of food security

The literature presents different indicators to measure food security, Gustafson et al. (2016) and Maxwell et al. (2013) present seven metrics to measure food security in their articles.

In their comparative analysis of food security indicators, Maxwell et al. (2013) argue that the different measures of access to food are important for early warning systems, for assessing the present and future conditions of vulnerable populations, and for the continuous monitoring and evaluation of specific programs and policies. Specifically, the seven separate measures comprise the Coping Strategies Index (CSI), the Reduced Coping Strategies Index (rCSI), the Household Food Insecurity and Access Scale (HFIAS), the Household Hunger Scale (HHS), the Food Consumption Score (FCS), the Household Dietary Diversity Scale (HDDS) and a self-assessed measure of food security (SAFS). All of them are proxy indicators that try to measure the multidimensional nature of food security, none of them is perfect and persistent over time. *Table 4.3* shows the different food security indicators; the factors they measure and the weaknesses and strengths points.

Food security indicators	What is it	Strength	Weaknesses
CSI (Coping Strategy Index)	A measure of consumption, indirect food security. (WFP/VAM)[8] Frequency and severity of behaviours to cope with limited access to food (ex. limit consumption by adults and leave it to children). It captures elements of quantity or sufficiency.	Universal validity (Maxwell, 2003). It provides a status of food insecurity. Instrument for an early warning[9]	Answer to general question
rCSI (Reduced Coping Strategy index)	Consumption measure, indirect food security. It captures elements of quantity or sufficiency.	Universal validity Allows comparison between countries.	Measures the less severe coping behaviors
HFIAS (Household Food In- In-security and Access Scale)	It captures sufficiency and psychological factors.	It can detect food insecurity with the psychosocial manifestation	It cannot be compared between countries It cannot be used for assessing eligibility (Coates et al.,2007)
HHS (Household Hunger Scale)	Psychological/behavior measure. It captures the extreme behaviors of insufficiency	Captures the most severe level of food security It can be used to compare countries over time and across regions.	It can overestimate the level of food insecurity within the household. The selection of one respondent does not represent the entire household (Coates, et al.,2007)
FCS (Food Consumption Score)	Dietary diversity, Food frequency measure (WFP, 1996) Food groups consumed by the 7 days.	Caloric intake proxy indicator at the household level. Composite score Food groups are weighted	Underestimates the prevalence of food insecurity. It does not capture season changes, the intra-HH food consumption. It is not valid everywhere It does not consider the quantity.
HDDS (Household Dietary Diversity Scale)	Dietary diversity, Food frequency measure 24h	A more accurate reflection of the calorie content of the diet, a proxy of the HH food access Standardized questions simple.	At household level. It does not provide information on individual diet, quantities used and the weights of food groups.[10]
SAFS (self-assessed measure of food security)	Self-assessment measure	It captures the change in livelihood status over a longer period.	Too easily to manipulate
HFES (Household Food Expenditure Share)	Household expenditure information Used by governments and NGO	It is sensitive to food price fluctuation.	It may underestimate the food expenditure share. Does not consider food from its own production and items received through gifts and assistance It can depend on price shocks (Akerele, 2015)

Table 4. 3: Seven different food security measures)[11]

After evaluating the literature and available data, I opted for the use of two indicators, which WFP usually uses together (Rose et al., 2013): The Food Consumption Score and the Household

[8] VAM, Vulnerability analysis Mapping unit
[9] https://www.spring-nutrition.coping-strategies-index
[10] https://www.fao.org/WFP_IndicatorsFSandNutIntegration.pdf
[11] https://inddex.nutrition.tufts.edu

Food Expenditure Share. These two indices are used together to assess the vulnerability and food security status of a household; they are not good enough on their own, but together they can provide a more reliable and broader perspective.

In fact, the HFES may be sensitive to fluctuations in food prices and considers quantity, the other, the FCS, considers caloric intake, and own production, but on the other hand, does not consider seasonal changes. Both consider consumption within the household and underestimate the prevalence of food insecurity.

Food consumption score

The Food Consumption Score was used for the first time by WFP in 1996. This index is a proxy for household caloric availability, and it collects data on the frequency and diversity of food groups over the last 7 days, therefore it captures information on the usual household diet.

FCS puts different weights for the different types of food groups as *Appendix 1* shows. To obtain the FCS it is needed to sum the weighted food groups[12] within the household. It is then possible to determine the Household Status: poor if FCS is in the range of 0-21, borderline if FCS is within 21.5-35 and acceptable if FCS is more than 35.

Regarding the index construction using BCCASI and BCCAS II data, the question regarding each food group was the following: “Did you consume it in the last 14 days?”. Therefore, the household diet refers to the last 14 days and not 7 days as recommended by the WFP. A 14-day period may provide a broader picture of families' diets. This can be useful for identifying long-term dietary trends, assessing dietary variety, and detecting changes in family dietary patterns over time. Additionally, it may be more representative of actual food consumption, accounting for weekly or seasonal variations in eating habits.

However, it can be challenging for individuals to accurately recall what they have eaten over the past two weeks. This could lead to errors in data collection and potentially affect the reliability of the gathered information (De Weerdt et al., 2016).

[12] The food items considered are present in Appendix 2.

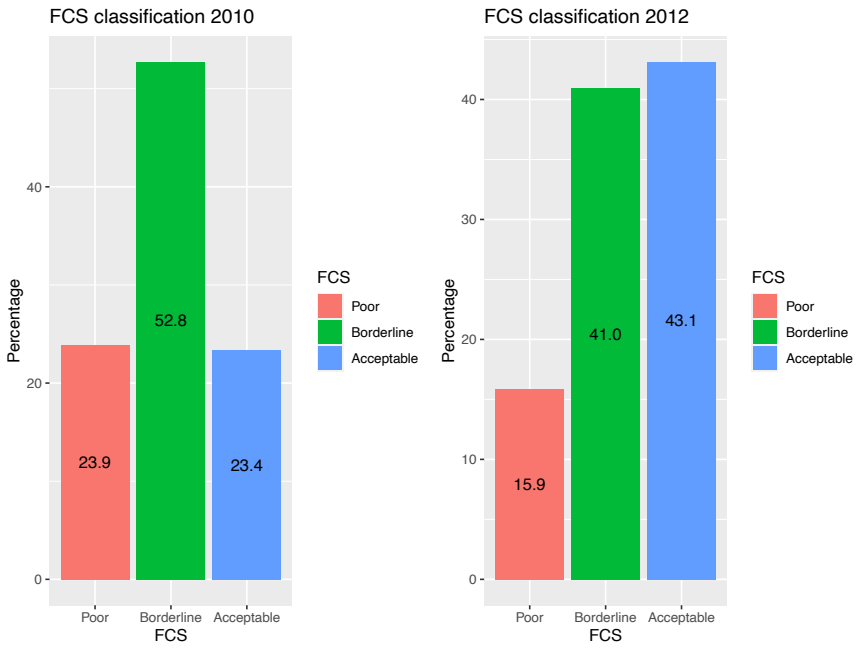

Figure 4. 2: Barplot Household Classification based on FCS 2010 and 2012

Figure 4.2 illustrates the bar chart of the status of the households in 2010 and 2012. As shown in the bar chart the households classified as poor have decreased by 8 percentage points, those labelled as borderline have decreased by 11 percentage points and the ones who are defined as acceptable have increased by 19.7 percentage points.

Household food expenditure share

Household Food Expenditure Share is an indicator of food security, poorer and vulnerable households spend a larger proportion of food items instead of other goods (Lele, et al., 2016). According to the Engel law, the share of income spent on food decreases as household income increases. IFPRI has used Engel's law, to develop a proxy measure of a household's food insecurity (Rose, 2013).

The indicator is constructed as follows:

$$\frac{Food\ expenditure}{No food expenditure} \times 100 \qquad (4.1)$$

Smith and Subandoro (2007) indicate three different groups of households concerning the value of the HFE index, if more than 75% is spent on food items, the household food security is classified as very high vulnerability, between 65% - 75% high vulnerability, 50% - 65%

medium vulnerability and less than 50% low vulnerability.[13] *Figure 4.3* presents the score of households between 2010 and 2012. As can be seen, these families classified as very high, high and medium insecure and vulnerable have decreased by 8, 6.9, and 3.8 percentage points respectively in accordance with *Figure 4.2* concerning households defined as poor and borderline by the FCS. Those families classified as low food insecure have increased by 18.8 percentage points.

Figure 4. 3: Household Classification based on HFES 2010 and 2012

4.2.2 Definition of natural disasters

The main explanatory variables are the natural disaster variables.

In most cases, researchers have used climate variables or weather variables, where climate variables are the distribution of the outcomes, and weather refers to a particular distribution. The difference depends on the period considered: the former refers to atmospheric conditions over a long period, and the latter to a short one (Auffhammer et al. 2013). Generally, climate variables are studied as the annual deviation from the mean of climate variables (Dell, Jones Olken 2014). It is necessary to detect the signal of climate change in the noise of climate variability (Burke, 2014). As defined by Hsiang (2016), climate variables are a vector (Ciτ) of

[13] The non-food consumption was collected over the last one month and food consumption in the last 14 days, so I multiplied the food expenditure by 30/14.

random variables for any position in space *i* and during time *t,* so in principle, the climate is based on a theoretical model of climate.

Consequently, most of the research in the literature generally considers the climate variable to be present in the theoretical model of climate from an external source.

In our case, we rely on self-reported data on natural disasters collected in the household and community level survey. The question asked the households in the first round is: "In the last five years, have the household's property and productivity been affected by natural disasters and how many times". In the second round, a similar question is asked referring to the period since the last interview. *Table 4.4* shows all the natural disasters collected in the survey at the household and community level. I selected those with the likely greatest impact such as tornadoes, droughts, floods, and cyclones. Therefore, in this case, the weather variable relies on natural hazards that indicate the frequency registered by the households. This can provide valuable information directly from individuals about their perceptions, attitudes and actions related to climate change and its impact. On the other hand, it can distort the data due to their perceptions. As seen in *Table 4.4*, standard errors are high. This means that the distribution is not normal, and the dispersion is high. Indeed, many factors could challenge the reliability of self-reported data that depends on the livelihood characteristics of the households. There is the possibility that those households with a better house infrastructure under-report the weather shocks and those with labour losses, and health problems can lead to biased over-report (Nguyen et al., 2020).

Weather shock according to household report			**Severe weather and diseases according to community reports**		
Variables	Mean	Std. Dev.	Variables	Mean	Std. Dev.
Tornado	0.153	0.579	Tornado	0.388	0.49
Drought	0.47	0.937	Drought	0.65	0.48
Cyclone	0.161	0.519	Cyclone	0.225	0.42
Floods	0.3	0.829	Flood	0.55	0.501
Sea level	0.013	0.215	Livestock epidemic	0.362	0.484
Rainfall	0.069	0.471	River erosion	0.113	0.318
Temp rising	0.101	0.533	Poultry plague	0.65	0.48
Temp variation	0.018	0.264	Tidal wave	0.05	0.219
Soil erosion	0.075	0.526	Pestilence stricken	0.375	0.487
Flashfloods	0.22	0.614			
Salinity	0.161	0.75			
Sea change	0.119	0.628			

Table 4. 4: Summary statistics of natural hazards at the household and community level

4.3 Descriptive Analysis

Table 4.5 represents the characteristics of the households for the first and second rounds of the survey. Almost 94% of the household heads are male, and the average age of them is almost 45 years old. The household size is almost 5 members per household and the average year of education is almost 4 years. The marital status is 86% married. In addition, 20% of our respondents cannot write and read, 76% are farmers or work in the agriculture sector and almost 90% are Muslim. It is important to note that the percentage of agricultural workers in 2012 decreased by 18% compared to 2011.

	Descriptive Statistics of the Households 2010					**Descriptive Statistics of the Households 2012**				
Variables	**Mean**	**SD**	**Min**	**Max**	**N**	**Mean**	**SD**	**Min**	**Max**	**N**
Sex	0.94	0.235	0	1	800	0.943	0.231	0	1	800
Size of the Household	4.99	2.198	1	22	800	6.257	6.072	1	15	800
Age of the Household head	45.523	13.699	17	95	800	44.252	18.968	0	97	800
Years of Education	3.53	4.18	0	17	800	3.149	4.125	0	17	800
Marital status										
Never married	0.02	0.140	0	1	800	0.02	0.14	0	1	800
Married	0.86	0.347	0	1	800	0.861	0.346	0	0	800
Widow	0.03	0.164	0	1	800	0.03	0.171	0	1	800
Separated	0.01	0.035	0	1	800	0.01	0.035	0	1	800
Literacy level										
Cannot read and write	0.19	0.389	0	1	800	0.185	0.389	0	1	800
Can only sign	0.3	0.459	0	1	800	0.299	0.458	0	1	800
Can only read	0.05	0.071	0	1	800	0.005	0.071	0	1	800
Can read and write	0.42	0.494	0	1	800	0.423	0.494	0	1	800
Occupation										
Farm work	0.767	0.423	0	0	800	0.626	0.484	0	1	800
No farm work	0.186	0.39	0	0	800	0.243	0.417	0	1	800
No paid work	0.046	0.21	0	1	800	0.061	0.24	0	1	800
Assets	22.720	50.884	1	1232	800	26.757	26.395	1	473	800
Religion										
Muslim	0.89	0.315	0	1	800	0.889	0.315	0	1	800
Hindu	0.11	0.312	0	1	800	0.109	0.312	0	1	800

Table 4. 5: Characteristics of Households 2010-2012

Table 4.6 indicates the summary statistics for household assets. They are divided into consumable durables, means of transport, livestock, and agriculture equipment. The summary statistics include also data related to housing construction and water sanitation, such as whether the households have electricity connections, what material the house is made of, and which facilities are available for water purification and sanitation. This information can be used to construct two indexes, the asset index, and the Socioeconomic status (SES) (Filmer & Pritchett, 2001; Deaton 2003). The SES considers different variables such as literacy and education level and the type of occupation of the household head, ownership of land and living standards as the ownership of durable assets (e.g., Radio, TV, electric iron). To construct the SES index, researchers have applied the Principal Component Analysis (PCA), which is a multivariate statistical technique that reduces the number of variables and combines them into different components. Each component explains a different percentage of the variation of the original

data, generally a positive factor is associated with higher SES and negative ones with lower SES (Vyas et al., 2006). The measurement of the SES index is important as it is a multivariate score, which considers multidimensional variables, resulting in the household socio-economic status. In a similar way to the previous score, the asset index is an indicator that represents a proxy for the economic well-being of a household. It can be used in cases when the consumption and expenditure data at the household level are not available (Carter, 2006). Similarly, also in this case it applies the PCA, by considering only those assets, owned by less than 95% of the household and more than 2% [14] (Rakib et al., 2014). *Appendix 3* illustrates the simple OLS regression that estimates the natural disasters (tornado, cyclone, flood, drought) impact on SES score estimates for the 800 households in 2010. It shows a negative impact on the SES score, the household socioeconomic score is significantly negatively impacted by floods.

[14] https://sitoolkit.com/the-five-domains/economic/poverty/asset-index

	Assets 2010			Assets 2012		
Variables	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Consumable durables						
Radio	0.130	0.337	800	0.101	0.301	800
Watch	0.511	0.500	800	0.504	0.500	800
Mobile phone	0.646	0.478	800	0.759	0.428	800
Electric iron	0.058	0.233	800	0.088	0.283	800
Electric fans	0.305	0.461	800	0.437	0.496	800
Cd player	0.054	0.226	800	0.073	0.261	800
TV	0.269	0.444	800	0.307	0.461	800
Refrigerator	0.024	0.171	800	0.041	0.198	800
Sewing machine	0.009	0.196	800	0.057	0.232	800
Jewelry	0.489	0.466	800	0.902	0.298	800
Hand well	0.225	0.500	800	0.589	0.492	800
Transport						
Bicycle	0.005	0.455	800	0.334	0.472	800
Van	0.743	0.218	800	0.060	0.239	800
Motorcycle	0.234	0.152	800	0.045	0.207	800
Motor vehicle	0.088	0.093	800	0.017	0.131	800
Livestock						
Buffalo	0.489	0.500	800	0.539	0.499	800
Goat	0.225	0.418	800	0.298	0.458	800
Pigs	0.072	0.071	800	0.004	0.061	800
Chicken	0.743	0.438	800	0.786	0.410	800
Agriculture equipment						
Fishing net	0.024	0.423	800	0.343	0.475	800
Boat	0.018	0.136	800	0.032	0.179	800
Plough	0.231	0.422	800	0.194	0.395	800
Tractor	0.018	0.136	800	0.020	0.140	800
Pump	0.725	0.264	800	0.107	0.317	800
Well	0.001	0.100	800	0.012	0.111	800
Thresher	0.238	0.152	800	0.019	0.135	800
Electricity	0.463	0.499	800	0.555	0.497	800
Type of materials						
Brick	0.874	0.148	800	0.884	0.320	800
Water drinkable/ Source of water supply						
Piped water	0.013	0.035	800	0.013	0.116	800
Tube well	0.899	0.302	800	0.884	0.320	800
STW[15]	0.538	0.225	800	0.066	0.248	800
Ring well	0.125	0.111	800	0.007	0.086	800
Pond river	0.028	0.163	800	0.019	0.135	800
Sanitation						
Flush water	0.001	0.035	800	0.009	0.093	800
Without flush water	0.584	0.493	800	0.620	0.486	800
Latrine	0.009	0.093	800	0.011	0.105	800
Hanging toilet	0.018	0.131	800	0.007	0.086	800
No toilet	0.385	0.487	800	0.352	0.478	800

Table 4. 6: Summary of Asset Ownership

[15] Shallow Tube Well

4.4 Empirical Strategy

To estimate the impact of climate hazards (drought, cyclones, tornadoes, and floods) on food security at the household level, I used a fixed-effect model. This section explains the regression method used, from the basic framework to the fixed effect model.

The baseline model:

$$FS_{hut} = \beta_0 + \beta_1 C_{hut} + \beta_2 X_{hut} + \mathcal{E}_{hut} \qquad (4.2)$$

Where *h* stands for households, *u* stands for Thana/Upazila, *t* denotes the time.

FS_{hut} denotes food security in this case measured by the Food Consumption Score or the Household Food Expenditure Share. The first one measures the food security at the household level, by constructing an index that looks at the quality and frequency of the food item. The second one looks at the proportion of food expenditure on the total expenditure at the household level. The outcome of food security is measured in the household *h* living in Thana/Upazila *u* at the time *t;* β_0 is a constant; C_{hut} is the vector of natural disasters (drought, cyclones, tornadoes, floods)[16].; X_{hut} is the vector of control variables; ε_{hut} denote the error term.; β_1 and β_2 are the coefficient parameters.

The coefficient of interest, β_1 describes the marginal effect of the occurrence of a natural disaster.

For the OLS model, the central assumption is the unit homogeneity: two identical sample populations are influenced and exposed to climate variables in the same way and the effect on the outcome is the same (Hsiang, et al., 2016). However, this type of model may create a problem of endogeneity, climate variables might not be orthogonal to socioeconomic factors thus, there may be some unobserved factors, called unobserved heterogeneity that may have an impact on the dependent variables, FCS and HFES, such as the religion of the household, geographical location, socioeconomics factor or government policies.

Therefore, it is useful to adopt some strategies, that can control for these unobserved time-invariant factors, as household-specific characteristics. Such as household size, cultural factors, endowment effects, tradition and norms, and geographical location. This allows us to focus on the within-entity variation that mitigates the endogeneity problem due to unobservable elements (Dell et al., 2014).

[16] Regarding the weather shocks, households were asked whether the household's productivities or property had been impacted by natural disasters and how many times these occur in the last five years. (BCCAS I, BCCAS II)

The fixed effect model has different advantages: as explained previously, it controls the unobservable factors. Therefore, it considers those variables that are constant on time, that otherwise as in the model of *equation 4.2* are omitted. In addition, it considers the dynamic, causes the effect of natural disasters can have an effect after some time. [17]

Since the data cover two periods, 2010 and 2012, with two cycles BCCAS I and BCCAS II, and 97% of the households were re-interviewed, it is possible to construct a panel data model. Therefore, I exploit the panel nature of the dataset by measuring the effect of cyclones droughts tornadoes and floods on food security using a fixed-effect regression.

Fixed effect model:

$$FS_{hut} = \beta_1 C_{hut} + \beta_2 X_{hut} + \delta_h + \delta_t + \varepsilon_{hut} \qquad (4.3)$$

δ_h and δ_h stand for time fixed effect and household fixed effect, such as characteristics within the household constant in time as sex, religion, and literacy level. The unobserved household-specific effects are supposed to be fixed over time across households *h.*

β_1 and β_2 are the parameters of the coefficients.

X_{ht} is the vector of time-varying observables explanatory, including the age of the household head, size of household, education level (years of schooling), and number of assets. (Angrist, et al., 2009; Dell et al. 2014) and ε_{hut} is the error term.

To deal with the possible correlation and heteroskedasticity among households within the district (Thana) due to the arbitrary spatial correlation of the natural disasters impact (cyclone, drought, tornado, floods) standard errors are clustered at the Thana/Upazila level (39) (Wooldridge 2003).

Using fixed effects may ensure that any impact of natural disasters is independent of the type of sites or the time. A simple OLS method may induce a downward bias in the impact on food security due to the literacy level, and the severity of the natural disaster estimating. So, the panel data can control for the heterogeneity between households that may have an impact on food security. The time variables capture changes in food security status at the household level that may be due to common shocks (Jiliang & Maystadt, 2016).

[17] The introduction of fixed effects is not without limits when applied to a short period of investigation (Hurwicz bias) when the rounds are only 2. The unobserved heterogeneity depends on the length of the panel, multiple linear panel data would get a more comprehensive understanding of the causal effect (Millinet and Bellemare, 2023)

In the second round of the dataset, a section includes information on groups, such as farmers groups, women groups, credit savings groups, religious groups, community-based groups etc. including their activities such as helping education development, political and public awareness, and helping agriculture development. Since this division is not included in the first round, I will assume that these informal groups are constant over time and can have a positive effect on mitigating the negative effects of floods, cyclones and tornados.

The hypothesis of the work is how the informal groups can mitigate adverse weather conditions and as a consequence improve food security at the household level. I assume that the households belonging to the same group have some characteristics in common. After controlling for those characteristics, I study the effect of the within-location variations in weather variables on the outcome.

Coping strategy model:

$$FS_{hut} = \beta_0 + \beta_1 C_{hut} + \beta_2 (C_{hut} * group_{2012}) + \beta_3 X_{hut} + \delta_h + \delta_t + \varepsilon_{hut} \qquad (4.4)$$

$group_{2012}$ is a dichotomous variable indicating whether or not a household member belongs to the activity of a group in 2012, such as farmers' groups, women's groups, credit-saving groups, religious groups, community-based groups. I hypothesize that the variation of the intensity of floods, tornadoes and cyclones with the interaction with groups improves the food security so it increases the FCS and decreases the share of expenditure on food.

5. Empirical Results

In this section, I will present the empirical results of the OLS model and Fixed effect model and the effect of the community-based approach as an adaptation measure to cope with natural disasters.

5.1 OLS and Fixed effect model

	Impact of natural disasters (tornado, drought cyclone, floods) on Food Consumption Score				**Impact of natural disasters (tornado, drought cyclone, floods) on Household Food Expenditure Share**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	FCS	FCS	FCS	FCS	HFES	HFES	HFES	HFES
	Food security				**Food insecurity**			
Tornado	-1.96***	-1.955***	-2.716**	-3.213***	2.571***	2.282	1.68	0.881
	(0.617)	(0.635)	(1.106)	(1.057)	(0.983)	(1.686)	(1.986)	(1.988)
Drought	1.471***	0.817	0.806	0.697	-0.325	0.08	-0.328	-0.455
	(0.557)	(0.506)	(0.754)	(0.605)	(0.593)	(0.575)	(1.219)	(1.188)
Cyclone	-0.267	-0.206	-0.542	-0.437	3.218***	3.078***	6.049***	4.489***
	(0.455)	(0.585)	(0.785)	(0.746)	(0.875)	(0.869)	(1.405)	(1.349)
Floods	-0.115	0.197	0.032	0.192	1.27*	0.585	2.214**	1.417
	(0.42)	(0.375)	(0.53)	(0.492)	(0.674)	(0.678)	(0.893)	(1.001)
Size		0.132***		0.154***		-0.099***		-0.174***
		(0.016)		(0.026)		(0.014)		(0.031)
Age		0.012		-0.028		0.086**		-0.023
		(0.028)		(0.059)		(0.037)		(0.083)
Education		0.524***		-0.362		-0.417***		-0.747
		(0.091)		(0.335)		(0.107)		(0.497)
Electricity		4.384***		2.449*		-4.143***		-4.2
		(0.822)		(1.261)		(1.243)		(2.541)
No farm work		0.822		0.131		3.403**		0.326
		(0.813)		(1.129)		(1.281)		(1.765)
Assets		0.028		0.009		-0.022		-0.014
		(0.017)		(0.014)		(0.014)		(0.012)
Active member		0.056		5.456**		4.76***		20.531***
		(1.16)		(2.308)		(1.629)		(3.494)
Gender		3.089*				7.567***		
		(1.753)				(2.498)		
Muslim		8.56***				1.638*		
		(0.709)				(0.94)		
Hindu		9.928***				1.762		
		(1.496)				(3.533)		
Married		-0.203				-1.795		
		(0.929)				(1.556)		
Constant	36.921***	17.735***	37.22***	30.531***	50.881***	41.181***	50.41***	42.71***
	(0.433)	(2.486)	(0.282)	(2.415)	(0.578)	(3.271)	(0.463)	(3.687)
Observations	1600	1600	1600	1600	1600	1600	1600	1600
R-squared	0.011	0.209	0.016	0.111	0.017	0.087	0.039	0.131
FE	NO	NO	YES	YES	NO	NO	YES	YES
Clusters	NO	YES	YES	YES	NO	YES	YES	YES

Note: Standard Errors are clustered at Thana/Upazila level in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

Table 5. 1: Impact of natural hazards on FCS and HFES OLS and Fixed effect model

Table 5.1 presents the results of estimating *equation 4.2,* the impact of weather shocks on two dependent variables, that we estimated before, the Food Consumption Score and Household Food Expenditure Share.

Columns (1,2) and (5,6) present the results of the Ordinary Least square model shown in *equation 4.2* considering the two cycles (2010-2012) with 1600 observations, for FCS and HFSE. The R-squared, explained variance is 1.1% and 1.7% for the OLS model which does not control for household characteristics, standard errors are clustered at the household level. [18]Surprisingly, experiencing drought is associated with a significant positive impact on FCS and being affected by floods or cyclones is not associated with a statistically significant overall decrease in FCS, only tornadoes have a statistically significant negative impact on FCS. When looking at the HFES, tornadoes, cyclones and floods have a significant positive impact, while drought has a negative, non-significant impact on the FCS. Since the two indices are inversely correlated: a higher score on the FCS indicates greater dietary diversity and food frequency and, therefore, less food insecurity, while higher values on the HFES indicate greater food insecurity.

Columns (2) and (6) consider the age of the household head, the size of the households, the education level in years, the literacy level of the household head and the gender, having access to electricity, the number of assets ownership, the religion (Muslim and Hindu) and the active members in the labour market. The R-squared is 20% and 8.7% respectively. The standard errors are clustered at the Thana/ Upazila level. In this case, only having experienced a higher frequency of tornadoes has significantly decreased the FCS by 1.955 units. This means that, for a one-unit increase in the frequency of tornadoes, the FCS (Food Consumption Score) decreases by an average of 1.995 units. About *column (6)*, cyclones are the only natural shock that significantly impacts household food expenditure shares. Cyclone exposure increases the HFES on average by 3.078 percentage points of their food expenditure. This suggests that an elevated frequency of cyclones by one unit is linked to a higher proportion of household expenditure allocated to food, potentially reflecting increased economic challenges or disruptions caused by these disasters. This result compared to the literature is higher, usually the coefficients are between 0 and 1. A possible explanation may lie in using a questionnaire, made to households as climate variables, which may lead to overestimating environmental disasters. In addition, controlling for the explanatory variables reduces the negative impact of natural disasters. For example, households with higher education levels may offer greater knowledge regarding

[18] The R squared are quite small, the natural disaster variables explain about 1% of the food security.

production practices and households more educated are wealthier families with more adaptability to natural hazards as confirmed by Kuku-Shittu, et al. (2013) and Islam et al., (2022). Therefore, the FCS, measure of food security, increases and HFES, measure of food insecurity, decreases when controlling for these factors.

Columns (3,4) and (7,8) present the results of the fixed effect model illustrated in *equation 4.3*. In our case, due to the endogenous nature of some of the explanatory variables (individual household-specific characteristics such as household size, cultural factors, endowment effects, tradition and norms, and geographical location), we apply fixed effects. These include household fixed effects to account for household-specific characteristics that remain constant over time. Additionally, time-fixed effects are incorporated to control for period-specific influences. By looking at *columns (3)* and *(7)* we can immediately notice that the R-squared has increased and it is 1.6% and 3.9% for the FCS and HFES. In *column (3),* the only variable with a statistically significant negative effect on the Food Consumption Score (FCS) is the tornado variable. Households affected by tornadoes between 2010 and 2012, on average, experienced a decrease in their FCS by 2.716 units. This implies that the impact of tornadoes during this period is associated with a reduction in the food consumption scores of affected households, indicating a negative influence on their overall food security. In *column (7*) households affected by cyclones and floods have shown notable changes in their food expenditure share (HFES). Specifically, those impacted by cyclones have significantly increased their food expenditure share by 6.049 units, while households affected by floods have increased it by 2.214 units. This suggests that the occurrence of cyclones and floods between 2010 and 2012 is linked to a considerable rise in the proportion of household expenditure allocated to food. Low-income households substitute their consumption with food items (Dorband et al. 2019).

In *columns (4) and (8)* the R-squared increases, reaching 11% and 13% respectively. In those columns are included other control variables that vary over time as age, size, education, active member, assets, electricity connection and no farm work. household size is significant and positive for FCS, as suggested by the literature. Larger household sizes may diversify income sources and benefit from economies of scale, reflecting that multi-member households have an advantage in improving food security (Demeke et al., 2011). Consistent with a study conducted in Cambodia about the impact of shocks on household choices, household size has a negative effect on food consumption expenditure (Demeke et al., 2011). Furthermore, if the asset ownership increases their food security status would increase, having a positive effect on food

security and a negative on vulnerability because they can cope with shocks of natural disasters by selling durable assets (Nguyen et al. 2020).

In summary, the fixed effect regression result shows a strong association between persistent food insecurity and vulnerability when affected by a tornado for FCS and cyclone for HFES. The household size, the education level of household heads, the ownership of livestock, the physical and land assets and having an active member not in the agriculture sector improve their economic well-being and food security. In addition, it is important to stress that drought and floods do not significantly impact FCS or HFES. The possible explanation lies on the one hand, in the Bengali government's efforts to reduce flood disasters and increase the resilience of communities and, on the other hand, in the difficulty of identifying the effects of a disaster such as drought that has medium- and long-term effects. Bangladesh has initiated several governmental and non-governmental activities, such as the Ministry of Environment and Forestry (MoEF) between 2009 and 2015 and community-based climate change adaptation (CBACC) (MoEF, 2008; NAPA, 2005). Both aimed at reducing vulnerability, one by building flood protection infrastructure and the other by strengthening the resilience of coastal communities. Moreover, the impacts of natural disasters are not all the same, in terms of duration, size and area affected. For example, floods have short-term and long-term effects but are confined to a small area, as are cyclones and tornadoes. Droughts have medium and long-term effects on land subsidence, seawater intrusion along river systems with reduced water flow and damage to ecosystems (FAO, 2023).

5.2 Community-based approach

	The impact of group membership on Food Consumption Scores during natural disasters (such as tornadoes, droughts, cyclones, and floods).		The impact of group membership on Food share expenditure during natural disasters (such as tornadoes, droughts, cyclones, and floods).	
	(1)	(2)	(3)	(4)
Variables	FCS	FCS	HFES	HFES
	Food security		**Food insecurity**	
Tornado	-2.716**	-2.292**	1.68	-1.098
	(1.106)	(1.077)	(1.986)	(2.139)
Drought	0.806	-0.075	-0.328	0.47
	(0.754)	(0.604)	(1.219)	(1.592)
Cyclone	-0.542	0.517	6.049***	3.086**
	(0.785)	(0.733)	(1.405)	(1.185)
Floods	0.032	0.581	2.214**	0.721
	(0.53)	(0.512)	(0.893)	(1.031)
Tornado x group member		3.369		10.374
		(5.322)		(6.263)
Drought x group member		1.326		-1.105
		(1.07)		(1.986)
Cyclone x group member		0.077		-1.601
		(4.087)		(8.491)
Floods x group member		3.486*		-2.037
		(1.99)		(4.344)
Size		0.141***		-0.159***
		(0.023)		(0.03)
Ages		-0.065		0.052
		(0.055)		(0.08)
Education		-0.262		-0.955*
		(0.335)		(0.486)
Electricity		0.708		-1.527
		(1.192)		(2.502)
No farm work		0.369		0.062
		(1.098)		(1.717)
Assets		0.007		-0.011
		(0.01)		(0.009)
Active member		8.243***		15.723***
		(2.163)		(4.071)
Constant	37.22***	28.756***	50.41***	45.884***
	(0.282)	(2.495)	(0.463)	(4.283)
Observations	1600	1600	1600	1600
R-squared	0.016	0.152	0.039	0.17
Clusters	YES	YES	YES	YES
FE	YES	YES	YES	YES

Note: Standard Errors are clustered at Thana/Upazila level in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

Table 5. 2: Impact of shocks on FCS and HFES OLS and Fixed effect inserting the group adaptation strategy

Table 5.2 presents the results of the fixed effect model, by introducing the interaction with the group variables *equation 4.4.* The group variable is a dichotomous variable that indicates if someone in the household is a member of a community/ village association (BCCAS II, 2012). This data is collected only for the second round of 2012, so we cannot exploit time variation and draw causal inferences. In addition, group membership is likely to be a response to natural disasters and a selection bias may exist. The types of groups are NGO/credit/savings group, Traders/ Business, Religious group, Women group, Neighborhood/ village committee, Festival/ burial group, Political and Cultural group, NGO Health Water, soil and waste management group Sports group and other (specify NGO/ Civic group Youth group Community-based group.

As in *Table 5.1,* tornadoes and cyclones are the types of natural disasters that have a significant effect on FCS and HFES. In *Columns (2) and (4),* households affected by tornadoes experience a significant decrease in FCS by 2.292 units while regarding the effect of cyclones, it increases the household's food expenditure share by 3.086 percentage points.

Columns (2) and (4) indicate the results of *equation 4.4.* As previously, the tornado variable and cyclone represent the main natural hazards that significantly impact FCS and HFES. Furthermore, some explicative time-variant variables are added as household size, household head age, no farm work, electricity connection, number of assets owners and active members. As mentioned before, all of them mitigate the effects of the tornado and cyclone effects. The interaction term between natural disasters (tornadoes, cyclones, droughts and floods) and group members positively influences food security. The positive impact is significant only for the interaction with floods.

Those households impacted by floods and having at the same time a member that belongs to one of the groups experienced a positive effect by 3.486 units and the effect is statistically significant at a 90% confidence level.

These findings are consistent with the literature even if most of the work is qualitative research. (Burke and Lobell 2010). Moreno et al., (2018), show that in Chile when there was the sixth largest earthquake in 2010, capacities such as organization, local knowledge, cooperation, social networks, trust, and participation are crucial in coping with the disaster.

Another study conducted by Marfai et al., (2015) investigates the role of local communities in response to a flood in Jakarta in 2007 and concludes stating that local communities in Jakarta can adapt to flooding based on their experiences. However, challenges such as a lack of concern and passivity within the community need to be addressed.

As mentioned before community-based adaptation is a strategy carried on by the government in Bangladesh and NGOs the strategies adopted to improve food security and social and health protection are livelihood diversification, developing crop varieties which are tolerant to floods, drought, and salinity, and implementing drinking water and sanitation programmes (UNDP, 2021).

6. Discussion

6.1 Limitations and possible extensions

Limitations of this work

My research may have several limitations.
The first limitation of this research is related to the short period. The period spans only two years, potentially introducing bias and limiting the ability to capture long-term trends. The fixed effects are biased if they are characterized by a small number of panels and this error is called Hurwicz (Nickell, 1981).
Although researchers Burke and Hsiang argue that even a short period can have an economic impact (Hsiang, et al., 2014; Kalkuhl et al., 2020).

The second limitation regards the low R-squared. A low R-squared indicates that the model, which includes natural disasters as explanatory variables, does not explain a large proportion of the variation observed in food security. This suggests that other socio-economic factors, such as demography, socioeconomic conditions, irrigation, and soil fertility, also contribute significantly to explaining variations in food security. Additionally, using self-reported data in surveys can introduce variability and high standard errors, further impacting the model's explanatory power.

Thirdly, short-term fluctuations differ significantly from long-term trends (Dell et al., 2014). The impact of a one-year temperature rise in a specific country contrasts with the overall temperature increase in that country, drought causes a medium-long impact.
Dell et al., (2014) summarise panel model issues in a short period in three main factors: adaptation, intensification, and extrapolation beyond historical experiences.
Adaptation implies that short-term estimates of weather shocks in panels may not align in magnitude with long-term impacts, as technological advancements and government interventions can drive adaptation (Kalkuhl et al., 2020).
Intensification of climate change poses another challenge. Some damages, like those from droughts, may go unnoticed in the short term but accumulate over time, for this reason, the panel estimates may be an upper bound or lowe-bound of the effect of climate changes.
The last factor is the extrapolation beyond historical experience, and it is the connection between short-term shocks and future changes that hinges on the dominance of adaptation.
If adaptation prevails, weather shocks may surpass climate shocks.

This may have led to different results if the time investigation had been longer and if I had more information about the adaptation strategies used. Such as flood protection and solutions to improve the resilience of coastal communities as carried on by various governmental and non-governmental initiatives the Ministry of Environment and Forestry (MoEF) and the community-based climate change adaptation (CBACC) strategies. In addition, not all disasters produce food shortage, the nature of food availability and access depends on the type of disaster, the duration, size and the area affected (FAO, 2023).

Moreover, one concerns the adaptation to natural disasters represented by a community-based approach. This coping strategy is registered only for the second round of 2012, which does not permit studying the role of community groups over time as a coping strategy measure to natural disasters and reducing their negative impact on food security, resulting in possibly only measuring the ex-post effect on food security of CBA.

Furthermore, as mentioned in the context, in Bangladesh there was a devastating cyclone called Sidr in 2007 the most harmful between 1876 and 2009.
The intervention of the Cyclone Preparedness Programme (CPP) by the Bangladesh Red Crescent Society saved a lot of lives. This was possible thanks to CPP's integration of protective infrastructure like coastal polders, cyclone shelters, and early warning and evacuation systems into its comprehensive disaster management approach, encompassing early warnings, search and rescue, evacuation, First Aid, relief distribution, and rehabilitation to safeguard the coastal region (Paul, 2009). This constitutes a problem of endogeneity, cause or the households put in place some adaptation strategies in response to natural disasters or they are still impacted by this devastating cyclone. To address this limitation, collecting longitudinal data becomes crucial. Tracking changes in adaptation strategies over time allows for a more nuanced understanding of the dynamics at play. Longitudinal data can help differentiate adaptations influenced by the CPP intervention from those that are independently developed by households over time.
In addition, another problem of endogeneity is related to the fact that there is a possibility that the decision to join the group is related to endogenous factors correlated with the outcome, as well as there may be a selection bias, the household’s member who joins the group may are different from who did not and this does not take into account the participation in the community activities, and the depth and duration of involvement.

Regarding food security, food data strongly depends on the survey design. The recall period, indicating how long respondents are asked to recollect their food consumption, is a crucial factor in ensuring accurate measurements. A prolonged recall period poses a risk, as households may struggle to remember the food they consumed or acquired (Smith and Subandoro, 2007). For the FCS the period considered by the surveys used is 14 days instead of 7 days as the theory suggests. In this case, it is still within the minimal safe limits of two weeks.

In the case of household expenditure, the recall period is too long, 30 days and this leads to possible recall errors (Smith et al., 2014; Moltedo et al., 2014). Furthermore, HFES is not deflated by the monthly food and consumer price index (FPI, CPI), this constitutes an error in the estimation as the monetary value of food commodities varies not only among the different regions within countries due to the cost of trade but also over time, due to fluctuations of prices, so it becomes crucial to account for the effects of inflation and deflation.

Possible extensions

There are several extensions for this research. First, concerning commodities, it would be interesting to examine which items are produced locally and which are not, and if they are produced which are exported and which are consumed. To further explore the measure of wealth, estimating the wealth index to investigate the different behaviors adopted by poor and rich households. Furthermore, it would be interesting to investigate food security at the individual level, as individuals within households do not necessarily share the same preferences, nor do they have the same bargaining power over the allocation of products to individual members (Quisumbing, 2013). As far as the role of communities is concerned, it would be good to explore more fully the measure of trust, to have more information on the relationship with groups and to have data on the first round as well (Bernard, et al., 2021).

In conclusion, as several researchers have already said, to have more accurate results, it is advisable to look at geographical differences in the effect of climate and food security status, looking at different AEZs, which allow for more control over the possible negative effects of climate shocks, which may change respecting different areas.

6.2 Policy Discussion

Several policy implications can be considered. The focus for policies concerns developing countries where agriculture is a primary sector of growth and climate variability could slow overall growth and limit the expansion of choice that typically accompanies economic development (Burke et al.,2010).

As presented in Section 2, several adaptation measures improve food security. However, in developing countries, the input markets are poorly functioning, and the poor households are unable to protect consumption from climate variability if they do not have access to the credit market, assets are not available, and they cannot migrate. Furthermore, ex-ante strategies may reduce risk but, on the other hand, lower the value of the harvest, resulting in long-term costs (Rosenzweig, 1993). Similarly, this is the case if we consider the liquidation of productive assets such as livestock or land, they may sustain consumption in one year but reduce access to food and productivity in subsequent years. In addition, for local governments and actors, it may be difficult to identify the most appropriate and effective approaches because of the range of possible interventions (IPCC, 2014).

Therefore, the intervention of governments and institutions is needed beyond what can be done by individual choices. Making the market work for the poor, protecting them, and improving social safety is important. This can include expanding the availability of credit and insurance to most vulnerable subjects such as farmers and poor households, which can help them to smooth incomes to face production shortfalls, and encourage diversification out of low-risk, low-return crops and into higher-reward activities (Jayachandran 2006).

Enhancing transportation infrastructure is vital for reducing costs, facilitating market access, and improving the overall efficiency of food supply chains.

Implementing conditional cash transfer schemes in which payments are made to households in the face of a shock, conditional on some behaviour (e.g. sending their children to school); or food aid, where donors contribute either food or cash, which is then distributed to households (in the case of direct food aid) or used by various organisations to purchase food locally which is then distributed.

The policy suggestions are consistent with the NFNSP in Bangladesh (National Food and Nutrition Security Policy Action Plan 2021-2030) (MoF, 2021).

The action agenda includes the expansion and maintenance of transportation infrastructure, the extension of financial services to develop agro-processing, the improvement of financial market access and the stabilisation of food markets.

Food access is achieved if food products are physically and economically accessible this means reducing the impact of shortfalls in domestic production and preserving the purchasing power of the poorest and most vulnerable stabilising prices and incentivizing food exports by boosting regional trade (covering those areas with a lack of food access by the production of regions with more production (Burke et al., 2010). National and subnational governments play coordinating roles in providing support and developing standards and implementation guidance. Therefore, multilevel institutional coordination between different political and administrative levels is a crucial mechanism for promoting adaptation planning and implementation.

In summary, the government should embrace a comprehensive approach that covers all aspects of risk management, playing coordinating roles in providing support and developing standards and implementation guidance. This shift from a single-agency response to an all-encompassing strategy is vital for addressing community vulnerability. Recognizing the effectiveness of community-driven decision-making is crucial (Few, 2003). Climate adaptation depends on the context, and it is linked to location. This makes it principally a local government and community level of action (IPCC, 2014). Educational campaigns should be broad ranging, spanning local, national, regional, and international levels. A multi-sectoral and interdisciplinary approach, involving both formal and informal education, is essential (Ahamed, 2013; Leach, 1999). Public awareness programs, conducted through public information, education, and collaboration with local NGOs (ISDR, 2002), can play a pivotal role in changing perceptions and fostering disaster preparedness.

7. Conclusion

This study investigates the relationship between natural disasters (tornados, droughts, cyclones, and floods) and food security and the role of adaptation played by communities.
The results indicate that more natural disasters reduce food security and exacerbate vulnerability. More precisely, tornadoes have a negative impact on food security as measured by the FCS. Tornadoes increase HFES, causing the shock to impact household income and make them more vulnerable of households
Furthermore, the community-based approach, using local knowledge, participation, and informal and formal mechanisms, can play an adaptive role concerning the impact of floods on food security in 2012. These results suggest that when at least one household member is part of a group, the group can enjoy several benefits. Such as mutual aid, knowledge, and actions to be taken that can benefit adaptation to natural disasters.

However, it is important to acknowledge that the limited precision of the data restricts the possibility of extending these results to a general perspective.
To address this limitation future researchers could consider a longer panel data for assessing more precisely the impact of natural disasters and the role of the community-based approach on food security.
Furthermore, it would be appropriate to use these surveys to analyze the perception of natural disasters and the level of trust within communities, one of the fundamental factors of social capital. If this is not the case, it is desirable to consider an external source for climate variables to avoid possible bias due to qualitative surveys.

In summary, while this study sheds light on the relation between natural disasters and food security, the limitations and the data constraints highlight a further investigation regarding the role of the community in adaptation, a complex fundamental for improving adaptation, especially in developing countries.

Bibliography:

- Acemoglu, D., & Johnson, S. (2005), "Unbundling institutions", *Journal of Political Economy*, 113(5), 949–995.
- Adedeji, M. O., Gieck-Bricco, J., & Kehayova, M. V. V. (2016), *Natural disasters and food crises in low-income countries: macroeconomic dimensions*, International Monetary Fund.
- Adger, W.N. (2000), "Social and ecological resilience: are they related?", *Progress in Human Geography, 24*, 347 - 364.
- Adhikari, K. P., & Goldey, P. (2010), "Social capital and its "downside": the impact on sustainability of induced community-based organizations in Nepal", *World Development*, *38*(2), 184-194.
- Aggarwal, R. (2021), "Impacts of climate shocks on household consumption and inequality in India", *Environment and Development Economics*, *26*(5-6), pp.488-511.
- Ahamed, M. (2013), "Community based approach for reducing vulnerability to natural hazards (cyclone, storm surges) in coastal belt of Bangladesh", *Procedia Environmental Sciences*, *17*, 361-371.
- Akerele, D. (2015), "Household food expenditure patterns, food nutrient consumption and nutritional vulnerability in Nigeria: implications for policy", *Ecology of Food and Nutrition*, *54*(5), 546-571.
- Alamgir, M. S., Furuya, J., Kobayashi, S., Binte, M. R., & Salam, M. A. (2018), "Farmers' net income distribution and regional vulnerability to climate change: an empirical study of Bangladesh", *Climate*, *6*(3), 65.https://doi.org/10.3390/cli6030065
- Angrist, J. D., & Pischke, J. S. (2009), *Mostly harmless econometrics: An empiricist's companion*, Princeton University Press.
- Baland, J. M., & Platteau, J. P. (1996), *Halting degradation of natural resources: is there a role for rural communities?*, Food & Agriculture Org.
- Banerjee, Abhijit, V., and Duflo E. (2010), "Giving Credit Where It Is Due", *Journal of Economic Perspectives*, 24 (3): 61-80**.** DOI: 10.1257/jep.24.3.61
- Barrett, C. B. (2010), "Measuring food insecurity", *Science*, *327*(5967), 825-828.doi: 10.1126/science.1182768. PMID: 20150491.
- Barua, S. and Banerjee, A. (2020), "Impact of Climatic Shocks on Household Well-being: Evidence from Rural Bangladesh", *Asia-Pacific Journal of Rural Development*, *30*(1-2), pp.89-112.
- BBS, (2019), Report on agriculture and rural statistics, *Statistics and Informatics Division (SID) Ministry of Planning*

- Bernard, T., Dänzer, P. N., Frölich, M., Landmann, A., Viceisza, A., & Wouterse, F. (2021), "Building trust in rural producer organizations: results from a randomized controlled trial", *Agricultural and Resource Economics Review*, *50*(3), 465-484.

- Burke, M., & Lobell, D. (2010), "Climate change and food security, Adapting Agriculture to a Warmer World", *Advances in Global Change Research (AGLO, volume 37*), ISBN : 978-90-481-2952-2, https://doi.org/10.1007/978-90-481-2953-9

- Carter M. R. & Barrett C. B. (2006), "The economics of poverty traps and persistent poverty: An asset-based approach", *The Journal of Development Studies*, 42:2, 178-199, DOI: 10.1080/00220380500405261

- Casson, M. C., Della Giusta, M., & Kambhampati, U. S. (2010), "Formal and informal institutions and development", *World Development*, *38*(2), 137-141.

- Coates, J., Swindale, A., & Bilinsky, P. (2007), "Household Food Insecurity Access Scale (HFIAS) for measurement of food access: indicator guide: version 3".

- Dasgupta, S., Huq, M., Khan, Z. H., Ahmed, M. M. Z., Mukherjee, N., Khan, M., & Pandey, K. D. (2010), "Vulnerability of Bangladesh to cyclones in a changing climate: Potential damages and adaptation cost", *World Bank Policy Research Working Paper*, (5280)

- Deaton, A. (2003), "Health, Inequality, and Economic Development", *Journal of Economic Literature*, 41 (1): 113-158**.**

- Delaporte, I., & Maurel, M. (2018), "Adaptation to climate change in Bangladesh", *Climate Policy,* 18:1, 49-62. DOI: 10.1080/14693062.2016.1222261

- Dell, M., Jones, B. F., & Olken, B. A.. (2014), "What Do We Learn from the Weather? The New Climate-Economy Literature", *Journal of Economic Literature*, 52 (3): 740-98 https://doi.org/10.1257/jel.52.3.740

- Del Ninno C., Dorosh P., Smith L. C. and Roy D. K. (2001), "The 1998 floods in Bangladesh: disaster impacts, household coping strategies, and responses", No 122, *Research reports, International Food Policy Research Institute* (IFPRI), https://EconPapers.repec.org/RePEc:fpr:resrep:122.

- Demeke, A. B., Keil, A., & Zeller, M. (2011), "Using panel data to estimate the effect of rainfall shocks on smallholders food security and vulnerability in rural Ethiopia", *Climatic change*, *108*(1-2), 185-206.

- De Vreyer P. and Lambert S.(2013), "Household Risk Management in Senegal", background paper for the 2014 World Development Report, *Managing Risk for Development,* World Bank, Washington

- De Weerdt, J., Beegle, K., Friedman, J., & Gibson, J. (2016), "The challenge of measuring hunger through survey", *Economic Development and Cultural Change*, *64*(4), 727-758.

- Di Falco, S., Veronesi, M., & Yesuf, M. (2011), "Does adaptation to climate change provide food security? A micro-perspective from Ethiopia", *American journal of agricultural economics*, *93*(3), 829-846.

- Dorband, I. I., Jakob, M., Kalkuhl, M., & Steckel, J. C. (2019), "Poverty and distributional effects of carbon pricing in low-and middle-income countries–A global comparative analysis", *World Development*, *115*, 246-257.

- Eckstein, D., Künzel, V., & Schäfer, L. Bonn, (2021), *The global climate risk index 2021*. Germanwatch.

- Eskander, S., Fankhauser, S. R., & Jha, S. (2016), "Do Natural Disasters Change Savings and Employment Choices? Evidence from Bangladesh and Pakistan", *ADB Economics Working Paper Series.*

- FAO, IFAD and WFP, Rome (2015), *The State of Food Insecurity in the World 2015. Meeting the 2015 international hunger targets: taking stock of uneven progress*

- FAO, (2021)*, The impact of disasters and crises on agriculture and food security.* Rome. https://doi.org/10.4060/cb3673en

- FAO, Rome, (2022), *Bangladesh – Shocks, agricultural livelihoods and food security: Monitoring report,* https://doi.org/10.4060/cb8249en

- FAO, IFAD, UNICEF, WFP and WHO. Rome, (2023), *The State of Food Security and Nutrition in the World 2023*. *Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum*. https://doi.org/10.4060/cc3017en

- Few R. (2003), Flooding, vulnerability, and coping strategies: "Local responses to a global threat", *Prog Dev Stud* 2003;3(1):43-58.

- Filmer, D., & Pritchett, L. H. (2001), "Estimating Wealth Effects without Expenditure Data-or Tears: An Application to Educational Enrollments in States of India", *Demography*, *38*(1), 115–132. https://doi.org/10.2307/3088292

- Gross, R., Schoeneberger, H., Pfeifer, H., & Preuss, H. J. (2000), "The four dimensions of food and nutrition security: definitions and concepts", *Scn news*, *20*(20), 20-25.

- Gustafson D., GutmanA., Leet W., Drewnowski A., Fanzo J., and Ingram J., (2016), "Seven Food System Metrics of Sustainable Nutrition Security", *Sustainability*, 8, (3), 1-17

- Hammer, B., Prskawetz, A., & Freund, I. (2015), "Production Activities and Economic Dependency by Age and Gender in Europe: A Cross-Country Comparison", *The Journal of the Economics of Ageing* 5 :86–97. https://doi.org/10.1016/j.jeoa.2014.09.007.

- Hossain, M. S., Arshad, M., Qian, L., Zhao, M., Mehmood, Y., & Kächele, H., (2019), "Economic impact of climate change on crop farming in Bangladesh: An application of Ricardian method", *Ecological Economics*, 164(March). https://doi.org/10.1016/j.ecolecon.2019.106354

- Hsiang, S. M., Burke, M., & Miguel, E. (2014), "Climate and conflict", *Natl. Bur. Econ. Res*, *7*, 577-617.

- Hsiang, Solomon (2016), "Climate Econometrics", *Annual Review of Resource, Economics*, https://doi.org/10.1146/annurev-resource-100815-095343

- Index, G. H. (2023), 2023 Global Hunger Index: The Power of Youth in Shaping Food Systems. https://www.globalhungerindex.org/pdf/en/2023.pdf.

- International Food Policy Research Institute (IFPRI), (2014), "Bangladesh Climate Change Adaptation Survey (BCCAS), Round I", Washington, DC; Dhaka, Bangladesh; Bonn, Germany: International Food Policy Research Institute (IFPRI); Data Analysis and Technical Assistance (DATA); Center for Development Research (ZEF). http://dx.doi.org/10.7910/DVN/27704

- International Food Policy Research Institute (IFPRI), (2014), "Bangladesh Climate Change Adaptation Survey (BCCAS), Round II", Washington, DC; Dhaka, Bangladesh; Bonn, Germany: International Food Policy Research Institute (IFPRI); Data Analysis and Technical Assistance (DATA); Center for Development Research (ZEF). http://dx.doi.org/10.7910/DVN/27883

- IPCC, Geneva, Switzerland, (2007), Climate Change: *Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*

- IPCC, (2014), "Adaptation planning and implementation", *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*

- IPCC, 2019: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management,foodsecurity,andgreenhousegasfluxesinterrestrialecosystems*[P.R.Shukla, J.Skea,E.CalvoBuendia,V.Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

- Isaac Gershon Kodwo Ansah, Cornelis Gardebroek, Rico Ihle, (2022), "Using assets as resilience capacities for stabilizing food demand of vulnerable households", *International Journal of Disaster Risk Reduction*, Volume 82,103352, ISSN 2212-4209, https://doi.org/10.1016/j.ijdrr.2022.103352

- ISDR. Disaster Risk and Sustainable Development. (*2002), Understanding the Link between Development, Environment and Natural Hazards Leading to Disaster, Geneva.*

- Islam, M.S., Okubo, K., et al. (2022), "Investigating the effect of climate change on food loss and food security in Bangladesh"*, SN Bus Econ 2, 4,* https://doi.org/10.1007/s43546-021-00177-z

- Israel, D. C., & Briones, R. M. (2012), "Impacts of natural disasters on agriculture, food security, and natural resources and environment in the Philippines", (No. 2012-36). PIDS discussion paper series.
- Jayachandran, S. (2006), "Selling labor low: Wage responses to productivity shocks in developing countries", *Journal of Political Economy* 14 (3): 538–575.
- Jiliang, M. J., & Maystadt, J. F. (2016), "Weather shocks, maize yields and adaptation in rural China", *Working Papers 104825642, Lancaster University Management School, Economics Department.*
- Kalkuhl, M., & Wenz, L. (2020), "The impact of climate conditions on economic production. Evidence from a global panel of regions", *Journal of Environmental Economics and Management*, *103*, 102360.
- Kuku-Shittu, O., Mathiassen, A., Wadhwa, A., Myles, L., & Ajibola, A. (2013), "Comprehensive food security and vulnerability analysis: Nigeria" (Vol. 1275), *Intl Food Policy Res Inst.*
- Leach, M., Mearns, R. and Scoones, I. (1999), "Environmental entitlements: dynamics and institutions in community-based natural resource management", *World Development* 27(2), 225–47.
- Lele et al. (2016), "Measuring food and nutrition security: An independent technical assessment and user's guide for existing indicators"*, Food Security Information Network.*
- Libois, F. (2022). "Success and failure of communities managing natural resources: Static and dynamic inefficiencies", *Journal of Environmental Economics and Management*, *114*, p.102671.
- Libois, F., Baland, J.M., Delbart, N. and Pattanayak, S. (2022), "Community Forest Management: The story behind a success story in Nepal" (pp. 44-p), *Paris School of Economics.*
- Mafuru, J. M. & Marsh, Thomas L., Denver, Colorado (2003), "An Analysis Of Household Food Expenditure Systems In Tanzania", *Western Agricultural Economics Association.*
- Manyong, V. M., Okike, I., & Williams, T. O. (2006), "Effective dimensionality and factors affecting crop-livestock integration in West African savannas: a combination of principal component analysis and Tobit approaches", *Agricultural economics*, *35*(2), 145-155.
- Marfai, M.A., Sekaranom, A.B. & Ward, P. (2015),"Community responses and adaptation strategies toward flood hazard in Jakarta, Indonesia", *Nat Hazards* 75, 1127–1144 (2015). https://doi.org/10.1007/s11069-014-1365-3
- Maxwell D., Watkins B., Wheeler R., Collins G . (2003), "The coping Strategies Index: A tool for rapidly measuring food security and the impact of food aid programs in emergencies", *Agriculture and Economic Development Analysis Division*

- Maxwell, Daniel, Jennifer Coates, and Bapu Vaitla, (2013), "How Do Different Indicators of Household Food Security Compare? Empirical Evidence from Tigray", *Feinstein International Center, Tufts University: Medford, USA*.

- Mbow, C., Rosenzweig, C., Barioni, L. G., Benton, T. G., Herrero, M., Krishnapilla, M., Liwenga, E., Pradhan, P., Rivera-Ferre, M. G., Sapkota, T., Tubiello, F. N., & Xu, Y. (2019), Chapter 5 "Food Security". In N. Benkeblia, A. Challino, A. Khan, & J. R. Porter (Eds.), *Climate Change and Land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* (pp. 439-550). Cambridge University Press. https://doi.org/10.1017/9781009157988.007

- Messer N., Townsley P. (2003), *Local institutions and livelihood: Guidelines for analysis*, Rural Development Division, FAO

- Meyer, J. (2023), "How do forests contribute to food security following a weather shock? Evidence from Malawi", *World Development*, *169*, 106307.

- Millimet, D., & Bellemare, M. F. (2023), "Fixed Effects and Causal Inference". IZA Discussion Paper No. 16202, http://dx.doi.org/10.2139/ssrn.4467963

- Mirza, M. M. Q. (2011), "Climate change, flooding in South Asia and implications", *Regional environmental change*, *11*(Suppl 1), 95-107.

- MoEF, (2008), *Bangladesh Climate Change Strategy and Action Plan 2008,* Ministry of Environment and Forests, Government of the People's Republic of Bangladesh.

- MoEF, (2022), *National Adaptation Plan of Bangladesh 2023-2050,* Ministry of Environment and Forests, Government of the People's Republic of Bangladesh.

- MoF, (2021), *National Food and Nutrition Security policy, Plan of Action 2021-2030,* FPMU, Ministry of Food Government of the People's republic of Bangladesh

- Moltedo A., Troubat N., Lokshin M., Sajaia Z., (2014), *Analyzing food security using household survey data,* World Bank, 978-1-4648-0140-2, http://hdl.handle.net/10986/18091

- Moreno, J. (2018), "The role of communities in coping with natural disasters: Lessons from the 2010 Chile Earthquake and Tsunami", *Procedia Engineering*, *212*, 1040-1045.

- Mottaleb, K. A., Rahut, D. B., Kruseman, G., and Erenstein, O., (2018), "Evolving food consumption patterns of rural and urban households in developing countries: A Bangladesh case", *British Food Journal,* Vol. 120 No. 2, pp. 392-408. https://doi.org/10.1108/BFJ-12-2016-0620

- Nguyen, G., & Nguyen, T. T. (2020), "Exposure to weather shocks: A comparison between self-reported record and extreme weather data", *Economic Analysis and Policy*, *65*, 117-138.

- Nguyen, N, Johnson, LW. (2020), "Consumer behaviour and environmental sustainability", *J Consumer Behav*. 2020; 19: 539–541. https://doi.org/10.1002/cb.1892

- Nickell, S. (1981), "Biases in Dynamic Models with Fixed Effects", *Econometrica*, *49*(6), 1417–1426. https://doi.org/10.2307/1911408
- North, D. C. (1991). Institutions. *Journal of economic perspectives*, *5*(1), 97-112.
- Oskorouchi, H. R., & Sousa-Poza, A. (2021), "Floods, food security, and coping strategies: Evidence from Afghanistan", *Agricultural Economics*. vol. 52(1), pages 123-140, January.
- Ostrom, E. Cambridge, (1990), *Governing the Commons: The Evolution of Institutions for Collective Action* (Political Economy of Institutions and Decisions), Cambridge University Press.
- Parven, A., Pal, I., Witayangkurn, A., Pramanik, M., Nagai, M., Miyazaki, H., & Wuthisakkaroon, C. (2022), "Impacts of disaster and land-use change on food security and adaptation: Evidence from the delta community in Bangladesh", *International Journal of Disaster Risk Reduction*, *78*, 103119.
- Paul, B. K. (2009), "Why relatively fewer people died? The case of Bangladesh's Cyclone Sidr", *Natural Hazards*, *50*, 289-304.
- Pawlak, K. and Kołodziejczak, M. (2020), "The role of agriculture in ensuring food security in developing countries: Considerations in the context of the problem of sustainable food production", *Sustainability*, *12*(13), p.5488.
- Quisumbing, A. R. (2013), "Generating evidence on individuals' experience of food insecurity and vulnerability", *Global Food Security*, *2*(1), 50-55.
- Rakib, M.and J.A. Matz, (2014), "The impact of shocks on gender-differentiated asset dynamics in Bangladesh". *IFPRI Discussion Paper* 1356.
- Rakib, M. and J.A. Matz, (2015), "Protecting Assets and Enhancing Welfare: The Gender-Differentiated Potential of Group-Based Approaches in Bangladesh", *CAPRi Working Paper No. 119. Washington, DC: International Food Policy Research Institute*. https://doi.org/10.2499/CAPRiWP119
- Rawlani, A.K., Sovacool, B.K. (2011), "Building responsiveness to climate change through community-based adaptation in Bangladesh", *Mitig Adapt Strateg Glob Change* 16, 845–863 (2011). https://doi.org/10.1007/s11027-011-9298-6
- Reddy, V., Devi, M. J., & Anbumozhi, V. (2019), "Ensuring Food and Nutritional Security in the Face of Disasters and Climate Change: What is the Adaptive Solution?", *Towards a Resilient* ASEAN Volume 1 pp. 290-330.
- Reed, C., Anderson, W., Kruczkiewicz, A., Nakamura, J., Gallo, D., Seager, R., & McDermid, S. S. (2022). "The Impact of Flooding on Food Security across Africa." *Proceedings of the National Academy of Sciences* 119, no. 43: e2119399119. https://doi.org/10.1073/pnas.2119399119.
- Reid H., Alam M., Berger R., Cannon T., Huq S., Milligan A. (2009), "Community-based adaptation to climate change: An overview. Participatory Learning and Action" 60 11–33

- Rijai, A., & Choudhury, J. (2019), "Integrating Community–Based adaptation into afforestation and reforestation programs in Bangladesh: mid-term review report", *UNDP Bangladesh*.
- Rose, E., (2001), "Ex ante and ex post labor supply response to risk in a low-income area", *Journal of development economics*, *64*(2), pp.371-388.
- Rose et al. (2013), "Food security assessment at WFP. Report on continue development and testing of a standardized approach"
- Rosenzweig MR, Binswanger HP (1993) "Wealth, weather risk and the composition and profit- ability of agricultural investments", *Econ J* 103:56–78
- Schipper, E.L., Ayers, J., Reid, H., Huq, S., & Rahman, A. (Eds.). (2014), *Community-Based Adaptation to Climate Change: Scaling it up (1st ed.)*. Routledge. https://doi.org/10.4324/9780203105061
- Schmidhuber, J., & Tubiello, F. N. (2007), Global food security under climate change, *Proceedings of the National Academy of Sciences*, *104*(50), 19703-19708.
- Shah M.I., Ahmmed S., Khalid U. (2022), "Exploring the nexus between natural disasters and food (in)security: Evidence from rural Bangladesh", *Geographical Journal*, 188 (2), pp. 223-244. https://orcid.org/0000-0001-9978-0569View this author's ORCID profile
- Shariff, Z. M., & Khor, G. L. (2008), "Household food insecurity and coping strategies in a poor rural community in Malaysia", *Nutrition research and practice*, *2*(1), 26-34.
- Skidmore, Mark, and Hideki Toya, (2005), "Economic Development and the Impacts of Natural Disasters", *Working Paper 05-04, UW-Whitewater, Department of Economics*.
- Smith & Subandoro (2007), "Measuring food security using household expenditure surveys", *International Food Policy Research Institute*
- Smith, L.C., Dupriez, O. and Troubat, N. (2014), "Assessment of the reliability and relevance of the food data collected in national household consumption and expenditure surveys", *International Household Survey Network*, *82*.
- Strategy, B.C.C. and Plan, A., (2009), Ministry of environment and forests. *Dhaka, Bangladesh: Government of the People's Republic of Bangladesh*.
- "The Rome Declaration on World Food Security", (1996), *Population and Development Review* 22, no. 4: 807–9. https://doi.org/10.2307/2137827.
- 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.*
- Townsend, R. M. (1994), "Risk and Insurance in Village India", *Econometrica*, *62*(3), 539–591. https://doi.org/10.2307/2951659

- Uddin, M. N., Bokelmann, W., & Entsminger, J. S. (2014), "Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh", *Climate*, *2*(4), 223–241. https://doi.org/10.3390/cli2040223
- UNDP, (2021), *Efficiency and Effectiveness*, Study of ICBAAR
- UNISDR (United Nations International Strategy for Disaster Reduction). (2019), *What is disaster risk reduction* https://www.unisdr.org/who-we-are/what-is-drr.
- United Nations and the World Bank. (2010), (forthcoming). *UnNatural Disasters: the Economics of Reducing Death and Destruction.*
- Van Diemen, R. (2019), "AI annex I: glossary", *Climate Change Land*, *803*.
- Vyas S., Kumaranayake L.(2006), "Constructing socio-economic status indices: how to use principal components analysis", *Health Policy and Planning*, Volume 21, Issue 6, Pages 459–468, https://doi.org/10.1093/heapol/czl029
- WFP. Rome (2017), *Country strategic plan, Bangladesh (2017–2020)*.
- Wooldridge, Jeffrey, M. (2003), "Cluster-Sample Methods in Applied Econometrics", *American Economic Review*, 93 (2): 133-138
- World Bank (2010), "Development and Climate Change", *World development report*
- World Bank. (2014), "Natural Disasters in the Middle East and North Africa: A Regional Overview"
- World Bank. (2016), Bangladesh: Growing the Economy Through Advances in Agriculture.
- World Bank, (2019), *Bangladesh Climate-Smart Agriculture Investment Plan*. World Bank.
- Yu, W., Alam, M., Hassan, A., Khan, A.S., Ruane, A., Rosenzweig, C., Major, D., & Thurlow, J., (2010), "Climate Change Risks and Food Security in Bangladesh" (1st ed.), *Routledge*. https://doi.org/10.4324/9781849776387
- Yulianto, E., Yusanta, D. A., Utari, P., & Satyawan, I. A. (2021), "Community Adaptation and Action during the Emergency Response Phase: Case Study of Natural Disasters in Palu, Indonesia", *International Journal of Disaster Risk Reduction* 65: 102557. https://doi.org/10.1016/j.ijdrr.2021.102557.

Sitography:

- The World Bank, https://data.worldbank.org
- Asian Development Bank, https://www.adb.org
- Food Security Cluster, https://fscluster.org/handbook/index.html
- International Dietary Data Expansion Project, https://inddex.nutrition.tufts.edu
- United Nations, Sustainable Development Goals, https://sdgs.un.org/goals

Appendices

Appendix 1: Weight for nutritional value per food group

Food Groups	Weights
Cereals	2
Pulses	3
Fruits	1
Vegetables and Leafy Vegetables	1
Meat, animal Product,	4
Fish	4
Milk and dairy product	4
Sugars/ Sugar products	0.5
Fat Oils/Edible Oil	0.5
Spices and tea	0

Table A. 1: Standard food groups and current standard weight

Appendix 2: Food Items for each type of food

Main Items
Cereals: Rice, Fine Rice/scented rice, Wheat, Rice Flour, Atta/moida, Chia, Sooji, Other cereals
Pulses: Lentil, Indian pea, Mash kalai, Mung, Black gram, Chickpea, Other pulses
Fruits: Mango, Black berry (jam), Jack Fruit, Litchis, Watermelon, Dates, Olive, Banana, Guava, Papaya, Orange, Pomelo, Apple, Dalim/Pomegranate, Grapes, Coconut, Lemon, Other fruits
Vegetables: Potol/ Pointed gourd, Eggplant, Tomato, Drumstick, Pumpkin, Cucumber, Cauliflower, Cabbage, Green Banana, Long bean, Carrot, Radish, Potato, Green Chili, Onion, Garlic, Soybean, Other vegetables, Spinach, Drumstick leaves
Meat animal product: Chicken, Duck, Pigeon, Birds, Beef, Pork, Egg, Other meat
Fish: Grass carp, silver carp, Hilsa, Boal, Tilapia, Singi/Heteropneustes fossils, Surma fish, Baim/zig-zag eel, Dried Fish, Other big Fish, Tatkeni/ Bata /Bele/ Chewa/ Poa/ Baicha/ Kaikla/ Bacha/ Darkini/ Panch mishali,Prawn/shrimp/chingri,Kakra, Other small fish Pabda/ Palshe/ Chanda/rupchnada,Koi/ Meni/kholisha/ Foli /Taki/ Kajari, Puti/ Swarputi/ Tengra/Gulsha,Moa/ Dhela/ Kachki/ Batashi /Chapila/ Ghutum/ Chela.
Milk and dairy product: Cow and Goat Milk
Sugars: Sugar/Gur/Misri/tal Misri/rock sugar, Sweets, Biscuits, Powder milk, Condensed milk, Coke, Packaged Juice
Fat oils: Soybean, Palm Oil, Mustard, Sesame Oil, Other oil
Spice and Tea: Dried chilli, Tejpata, Turmeric (dried)/ Turmeric (not dried), Coriander/Mouri /Babuni/randhuni, Jira/Black cumin, Elachi/Cardamom, Cinnamon, Garam Masala, Panch phoron, Ginger, Salt, Other, Tea leaves, tea prepares

Table A. 2: Typologies of food items in the data

Appendix 3: Regression table effect of Natural disasters on Socio-Economic Score.

Variables	(1) SES (OLS)
Cyclone	-0.163
	(0.163)
Tornado	-0.279*
	(0.158)
Drought	-0.025
	(0.148)
Floods	-0.349**
	(0.161)
Constant	0.262
	(0.282)
Observations	800
Clusters	YES
R-squared	0.047

Standard errors are in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

Table A. 3: OLS Regression of the effect of natural disasters on Socioeconomic-Status (SES) in 2010