Climate Change, Climatic Extremes and Food Security in Bangladesh: An Econometric Analysis of Panel Data in Rural Disaster Prone Areas

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(Degree)
博士（学術）
(Date of Degree)
2022-03-25
(Date of Publication)
2023-03-01
(Resource Type)
doctoral thesis
(Report Number)
甲第8250号
(URL)
https://hdl.handle.net/20.500.14094/D1008250

博士論文

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(バングラデシュの気候変動、極端気象、および食料安全保障:
災害が発生しやすい農村地域におけるパネルデータの計量経済分析）

2022 年 1 月

神戸大学大学院人間発達環境学研究科

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Doctoral Dissertation

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January 17, 2022

SUMMARY

Bangladesh, the poster child of human-induced climate change, bears the brunt of the consequences of extreme climatic events such as floods, droughts, cyclones, salinity, and sea-level rise (SLR). In addition, the frequency and intensity of these extreme climatic events are also shooting upward by jeopardizing households' consumption and households' expenditure in the locale where the outbreak and landfall of these extreme events are moderate and severe. Bangladesh has been combating climate variability and extreme climatic events to abate agricultural production loss for a long time. Nonetheless, food grain loss paved a long history over periods entangling almost all domains (food availability, food accessibility, food utilization, and food stability) of food security in the country. Meanwhile, a number of extreme events successively made land-fall and struck especially the people dwelling in the Southern (cyclone prone), North-western (drought prone), as well as East-northern and central (flood prone) belts by quivering and quizzing their agricultural production, disrupting food supply chain, price spiraling of essential commodities as well as farm income reduction by limiting farm operational options and actions those have substantial subsequent effect on 'household food security', 'household food consumption' and 'household expenditure'. Considering all these views are a serious problem for the country, using Bangladesh— the most climate-vulnerable country in the world as a case study, the study investigates—**first**, the dynamic trajectory between food grain loss and food security with reference to extreme climatic events in Bangladesh on the basis of data spanning from 1984 to 2017; employing Vector Auto-regression (VAR) model and derivative analyses which guide some policy implications linking with the existing national agricultural policy of the country as well. In this case, we judiciously consider five time-series variables viz.: food availability, food loss, food import, the gross domestic product (GDP) growth rate, and the inflation rate (consumer price index—CPI). Due to climate change and extreme climatic events, a plenty of food grain loss occurred throughout the year that has a serious impact on food availability, food import, and other economic factors. **Second**, whether the types of extreme climatic events—cyclones, droughts, and floods have heterogeneous impact on each region's agriculture through households' food consumption. Using 3-rounds of nationally representative longitudinal data sets and employing a difference-in-differences (DD) approach. **Third**, to seek the nexus between extreme climatic events and household expenditure by adopting Pooled-OLS, Fixed Effects, and Random Effects

model by using Bangladesh Integrated Household Survey (BIHS) 3-rounds (2011-12, 2015 and 2018-19) data sets which was administered by International Food Policy Research Institute (IFPRI). Findings of the research analyses are presented here chronologically on the basis of objectives aligned with some policy implications.

Firstly, the VAR model results show that the variable food grain loss has a reverse association with food security as well as it escalates food import from the world food market that lead to make dependency on import. Moreover, food loss instigates inflation significantly. But, in the case of the GDP growth rate, we found it as a weak provocateur. Therefore, we can argue that climate change and its correlations have a severe detrimental impact on food security as well as other economic factors of the country. **Secondly**, results from the DD analysis confirm that cyclone and saline-prone areas of the country are more vulnerable followed by drought and flood-affected areas in terms of cereal food consumption. In the long run (2011-19), Model 1 was significant at 1%, 10%, respectively in the cyclone, drought-prone areas, but for flood-prone areas it was insignificant. Moreover, analysis considering base year entire sample as control also underpinned that climate variability and their correlates impacting significantly negative on households' basic food consumption. So, it is proven that climate variability and the climatic extremes have heterogeneous impact on each region's agriculture. **Finally**, to meet the 3rd objective of our research we have brought results as follows—impact evaluation on 'household total expenditure', all the econometric models showed that the coefficient of the variable "affected group" were significant at 4%, 10% and 4% level with a negative sign, respectively. Additionally, Fixed Effects model (the most efficient) shows that climatic extremes lead to a fall of 3% in the average household expenditure. It confirmed that habitants who resided in the repeated climate hit and vulnerable areas spent less on their life and livelihood compared to the unaffected and more resilient group owing to less income, reduction in income, squeezed employment opportunities, less own farm production, and damage and loss to agricultural production over years. Moreover, in the case of 'household food expenditure' and 'non-food expenditure' "affected group" also demonstrated a negative coefficient at different significant levels. We can say that, therefore, climate change and weather extremes such as cyclones, droughts and floods have significant perilous effects on household income and subsequent household expenditure.

In the light of research findings, the study recommends some policy guidance to augment country's overall food security situations as well as those will be a part of adaptation and mitigation strategies of Bangladesh Climate Change Strategy and Action Plan (BCCSAP)—intensifying agricultural research through robust budget allocation, launching crop insurance scheme that are demand of time now, research on variety and technology development sustaining in the saline, drought, and flood-prone areas along with high promotion for the adoption of the cultivars, strengthening of flood forecasting and early warning system, income diversification through the creation of off-farm income generating activities (IGAs), emphasis on technology innovation sustaining in the changing climatic condition. Above all, international cooperation and collaboration are crucial for the survival and sustaining of climate hit vulnerable countries like Bangladesh.

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LIST OF ABBREVIATIONS

ADB	:	Asian Development Bank
AIC	:	Akaike Information Criterion
ADF	:	Augmented Dickey-Fuller
BBS	:	Bangladesh Bureau of Statistics
BDT	:	Bangladeshi Taka (currency)
BIHS	:	Bangladesh Integrated Household Survey
BCCSAP	:	Bangladesh Climate Change Strategy and Action Plan
BNWP	:	Bangladesh National Water Plan
BUP	:	Bangladesh Unnayan Parishad
BWDB	:	Bangladesh Water Development Board
BLS	:	Bureau of Labor Statistics
CO_2	:	Carbon-di-oxide
CPI	:	Consumer Price Index
CEGIS	:	Center for Environmental and Geographic Information Services
ºC	:	Degree Celsius
DiD	:	Difference-in-Differences
et al.	:	L. et elia (And others)
etc.	:	*Et cetra (L.*), and others
e.g.	:	*Exempli gratia* (L.), for example
EWS	:	Early Warning System
FFWC	:	Flood Forecasting and warning center
ºF	:	Degree Fahrenheit
FY	:	Fiscal Year
FAO	:	Food and Agricultural Organization
FFEWS	:	Flood Forecasting and Early Warning System
FAOSTAT	:	Food and Agriculture Organization Corporate Statistical Database
Fig.	:	Figure

FE	:	Fixed Effects
FSC	:	Food Supply Chain
GDP	:	Gross Domestic Product
GoB	:	Government of Bangladesh
GBM	:	The Ganges, the Brahmaputra and the Meghna
GCM	:	Global Climate Model
HYV	:	High Yielding Variety
ha	:	Hectare
HQIC	:	Hannan–Quinn Information Criterion
HIES	:	Household Income and Expenditure Survey
H_0	:	Null Hypothesis
H_1	:	Alternative Hypothesis
IPCC	:	Intergovernmental Panel on Climate Change
IFRC	:	International Federation of Red Cross and Red Crescent Societies
IUCN	:	International Union for Nature and Natural Resources (the World Conservation Union)
i.e.	:	(L. idest), that is
IC	:	Information Criterion
IFPRI	:	International Food Policy Research Institute
IGA	:	Income Generating Activities
IRFs	:	Impulse Response Functions
ICPSR	:	Inter-university Consortium for political and Social Research
INDDEX	:	International Dietary Data Expansion
Kg.	:	Kilogram
ln	:	Natural log
MoEF	:	Ministry of Environment and Forestry
Mha	:	Million Hectare
MMt	:	Million Metric Tons

MoF	:	Ministry of Food
MSE	:	Mean Squared Error
MDGs	:	Millennium Development Goals
OLS	:	Ordinary Least Square
OMS	:	Open Market Seal
OECD	:	Organization for Economic Cooperation and Development
ppm	:	Parts per mole
PPP	:	Purchasing Power Parity
PP	:	Phillips-Perron
PV	:	Present Value
RE	:	Random Effects
Sq. km	:	Square kilometer
SDGs	:	Sustainable Development Goals
SBIC	:	Schwartz-Bayesian Information Criterion
SLR	:	Sea-level Rise
SRDI	:	Soil Resource Development Institute
TV	:	Television
USAID	:	United States Agency for International Development
UN	:	United Nations
US$	:	United States Dollar (currency)
VAR	:	Vector Auto-regression
VHLSS	:	Vietnam Household Living Standard Survey
Viz.	:	Vide (L. vide licet), namely
VCD	:	Video Compact Disc
VCR	:	Video Cassette Recorder
WB	:	World Bank
WARPO	:	Water Resources Planning Organization
%	:	Percentage

LIST OF PUBLICATIONS

CHAPTER I

General Background and Motivation

1.1. Introduction

Bangladesh is an agrarian country having large number of population about 170 million and small geographical area of 147,570 sq.km. As per Household Income and Expenditure Survey (HIES, 2016) of Bangladesh, poverty rate is 24.3% and extreme poverty rate is 12.9%. Agriculture is a key economic sector accounting for nearly 14.74% of the GDP (gross domestic product) of the country and 65% of the labor force engaged in it (BBS, 2017). But, the bleak reality is that agricultural practices extensively depend on the mercy of nature that makes it more vulnerable. Intergovernmental Panel on Climate Change (IPCC, 2007) identifies Bangladesh, as one of the smallest country in the world that has been experiencing severe vulnerability to the issues related to climate change, extreme climatic events (e.g., cyclones, drought and flood) and anthropogenic hazards. According to "World Risk Report 2015" Bangladesh has been treated as the sixth most natural disaster prone country among 173 countries in the world. Frequent cyclones, tidal surges, saline water intrusion along with the coastal belts as well as annual flooding to lack of water during dry season by changing groundwater aquifer conditions gradually lower in the Northern parts in the country are common now-a-days. These situations are now becoming a great danger for agricultural production practices that leads to food insecurity in the country.

The climate change would affect particularly the economies of the rural areas where people are more dependent on livestock, fisheries and agriculture related activities for their livelihoods (IFAD, 2009). Households have for a long time needed to adapt to these dynamic conditions to maintain their livelihoods. All the extreme events of climate make rural people vulnerable. In FY (Fiscal Year) 2017-18, the amount of food grain imported 9773.64 thousand MT (MoFood, 2018). The achievement of food self-sufficiency remains a key development agenda for the country. Food security incorporates a measure of resilience to future disruption or unavailability of critical food supply due to various risk factors including cyclones, droughts, floods and economic instability. In the years 2011-2013, an estimated 842 million people were suffering from chronic hunger.

Extreme climatic events viz. cyclones, droughts and floods are becoming one of the prime environmental change drivers around the globe, impeding both sustainable development and poverty-reduction initiatives. IPCC predicts "by 2100, average global temperature increases 1.8 to 4.0^{o} C and climate change affects crop, livestock and fisheries production and people at hunger risk may be double by 2050". There is a close correlation between the trends of increased demographic pressure especially in developing countries that escalates environmental degradation, increased human vulnerability in terms of food insecurity and the intensity of the impact of extreme weather events. The agriculture sector comprises of crops, livestock, fisheries and forestry absorbs approximately 22 percent of the economic impact caused by medium- and large scale natural hazards and disasters in developing countries (FAO, 2015). In South Asia, Bangladesh is the hardest hit by climate induced extreme events, particularly by cyclones, droughts, floods, and saline water intrusion by tidal surge. These climatic extremes have negative economic and environmental impacts on the affected areas and the people who live there are the real sufferer.

As human induced climate change is the main drivers of extreme weather events and it causes substantial damage to crop, livestock, fisheries and environment. After some extreme events, Bangladesh experience soared price for basic commodities like food, water and fuel due to unavailability and the scarcity of goods. Monsoon rains trigger flooding across in northeastern Bangladesh, affecting millions of people remain under water affecting agricultural livelihoods. As a result, large area of paddy field goes under water and occurs huge economic loss to the farmers. In addition, application of huge amount of chemical fertilizer, pesticides, insecticides and herbicides by the farmers unscrupulously for increasing farm production of food grains and vegetables for augmenting household food security. Ultimately they are producing unsafe food, destroy their friendly environment and habitats by spoiling the eco-system and even these practices destroy the soil fertility status too. All these residuals of chemicals washed away by flood to fresh water bodies (lakes, rivers, estuaries, ponds) and contaminate them that are disastrous for all water living and loving species (fish, aquatic plants, other aquatic creatures). But, all of these hazardous chemical has a detrimental effect on human health, other living animals as well as environment through their residual effects. Besides, the ecosystem of the fresh water *haor* (quite a big low-land area) broken down due to down streaming of contaminated hazardous chemicals contaminated fresh open water bodies. It becomes increasingly difficult to secure adequate and safe foods in Bangladesh. So, safe food production for augmenting national food security and environmentally friendly technology for sustainable development is crucial.

1.2. Problem Statement and Research Questions

The impacts of human-induced climate change and climatic extremes – cyclones, drought and floods on the agriculture sector (crops, livestock and fisheries) and the natural resources (forests and top soil) as well as the environment as a whole can be direct or indirect as well as positive or negative. But, it is very common and easily understand that cyclone, floods, and droughts have the potential influence to reduce farm productivity- by damaging farm inputs, destroying crops suitable for harvesting and limits farm planting and operational options. Furthermore, cyclones and floods can damage farm supply routes and cause death or injury to farm workers. As a consequence, these direct and negative factors can further lead to indirect and negative impacts on agriculture and the economy. As a result, the overall cost of agricultural production increases; agricultural production output declines; food supply falls and food prices rise, and even it reduces income of the farm household significantly. Altogether, weather extremes threaten food security in the affected areas tremendously.

Therefore, researching the impacts of climate change and climatic extremes on national food security, household food consumption and household expenditure in Bangladesh will play a vital role to the global literature and academia. On the basis of aforesaid background and problem statement, the present study aims to investigate the following research questions:

Question 1. To what degree do climate change and climatic extremes (e. g., cyclones, droughts and floods) influence food security in Bangladesh?

1.1. How do climate change and climatic extremes influence national food security (availability dimension)?

1.2. How do climate change and climatic extremes influence national food import from global food market?

1.3. How do climate change and climatic extremes influence consumer price index (CPI) (inflation)?

Question 2. To what extent do climate change and climatic extremes (e. g., cyclones, droughts and floods) have heterogeneous impact on region specific agriculture through food consumed by the farm households?

2.1. Through which way climate change and climatic extremes influence household cereal food consumption?

2.2. Through which way climate change and climatic extremes influence to purchase cereal food for household consumption?

2.3. Through which way climate change and climatic extremes influence to spent on purchase of cereal food for household consumption?

Question 3. To what magnitude do climate change and climatic extremes (e. g., cyclones, droughts and floods) influence on household expenditure?

3.1. How do climate change and climatic extremes influence on household total expenditure?

3.2. How do climate change and climatic extremes influence on household food expenditure?

3.3. How do climate change and climatic extremes influence on household non-food expenditure?

1.3. Objectives of the Study

The main objective of this study is to analyze the impacts of climate change and extreme climatic events such as cyclones, droughts, and floods on country's overall food security through agricultural production in Bangladesh. The specific objectives are as follows:

I. To evaluate the impact of climatic extremes on national food security through agricultural production damage and loss;

II. To evaluate whether the types of climatic extremes - cyclones, droughts, and floods have heterogeneous impact on region specific agriculture through food consumed by the farm households; and

III. To evaluate the impact of climatic extremes on household expenditure.

The ultimate aim for doing so is to recommend policy arising from the findings to beef up country's food security as well as to expedite the movement of sustainable development initiatives.

1.4. Significance of the Study

This study is unique, original and deem significant for the following grounds:

It is well discussed and generally accepted that Bangladesh is not only very prone to climate change and extreme climatic events such as cyclones, droughts and floods but also vulnerable to food insecurity due to population boom. An analysis of the impacts of weather extremes- cyclones, floods and droughts on agriculture, food security and the natural resources as well as environment of the Bangladesh will help to bring it further to light the nature and extent of these effects. Beyond Bangladesh context, for all economies largely depend on agriculture and natural resources, the knowledge gained from the study may be helpful in developing strategies to address the ill-effects of global warming and their correlates. Moreover, the results and findings may assist in identifying new studies about food security and climatic extremes. It is an important research concern which still lacks the necessary level of focus. The most appealing point of this study is the analysis of impacts of extreme climatic events on sustainable agriculture in the country that are highly prone to climate vulnerability and change.

There are some studies conducted on the issues. For example, Haque and Jahan (2016) found that coastal regions of Bangladesh—Barisal, Chittagong, and Khulna—are more vulnerable to cyclone disaster than are other parts of the country and the most affected sectors are agriculture along with other sectors. But sectoral losses vary widely across the regions. Global context research conducted by Wheeler and Braun (2013) argued that climate change could potentially interrupt progress toward a world without hunger. The stability of whole food systems may be at risk under climate change because of short-term variability in supply. Moreover, climate variability and change will exacerbate food insecurity in areas currently vulnerable to hunger and undernutrition. Sikder and Xiaoying (2014) found the strategies of adaptation to altered situation and Bangladesh's saline tolerant, flood tolerant and shorter maturity varieties of rice and other crops will help to augment national food security. From the literature review, it is clear that climate change is a great threat, influencing factor for happening repeated extreme natural events and subject to food insecurity. But, study taking under consideration of food security along with food safety and sustainability is scarce. Heterogeneous impacts of weather extremes on different geographic characteristics and climatic conditions is also a new aspect of the research. Food production with food safety and environmental friendly is still a matter of rigorous thinking in Bangladesh.

Above all, climate change related weather extremes are expected to rise and affecting mostly the poor countries and the poor section (Acevedo, 2014; Felbermayr and Groschl, 2014; Karim, 2018). Being a great challenge to food security and poverty eradication (Alamgir, et al., 2018; and ADB, 2002) as well for the country, it is eroding the economic foundation gradually. Besides, based on macro sense, covering the whole country considering time-series and panel data research findings are worthy, whereas there are some studies taking only the most affected areas with cross-sectional data (Hossain and Majumder, 2018; Saha, 2017; Xenarios et al., 2013). This research is a good evidence for the country's policy formulation and a reference to present in front of international community that Bangladesh is suffering from food security owing to global warming.

1.5. Organizational Structure of the Dissertation

This dissertation will be arranged into five chapters. The organization of these chapters are as follows: chapter one delineates the conception of research and provides some brief information regarding the importance of present research stemma in general. The issues of food security, food loss and climate change in Bangladesh are explained overtly in chapter two. Heterogeneous impact of extreme climatic events and their correlations on the region specific agriculture are illustrated chiefly in chapter three. In chapter four, we elaborately discuss about the nexus between climatic extremes and household expenditure. And finally, chapter five arrives with conclusion and policy implications based on research findings and testimonials in this dissertation.

CHAPTER II

Food Security, Food Loss and Climate Change in Bangladesh

2.1. Introduction

As the planet becomes warmer because of relentless global economic development, mostly affecting the poorer countries (Acevedo, 2014; Felbermayr and Groschl, 2014; and Karim, 2018), climate change-related natural disasters are expected to rise. Additionally, climate change poses a significant challenge for poverty eradication and food security (Alamgir et al., 2018; ADB, 2002) because repeated catastrophic events lead to significant income losses over time. Climate disasters, today, are a serious concern, with the probability of upending decades of development gains, apart from exacerbating social inequality.

Moreover, climate change adversely affects food production and delivery systems (Godfray et al., 2010). Josef and Tubiello (2007) have pointed out the deleterious impacts of climate change on food security: by 2080, anywhere between five and 170 million people worldwide may face severe food scarcity. Moreover, the potential impacts of climate change and extreme climatic events are diverse and vary in scale (Chavez et al., 2015). For instance, paddy loss due to floods in Bangladesh and India is estimated at 4 MMt/year, which can feed 30 million people (Asada and Matsumoto, 2009).

In Bangladesh, rice is a staple food—it constitutes 94% of all cereals produced annually in the country (Paul, 1998; Mohajan, 2014); wheat holds the second position.[1] In 1970–71, total area under rice cultivation measured 9.91Mha and total husked rice production was 10.87MMt. Forty-five years later, in 2014–15, the gross area under rice cultivation was 11.42Mha and total production of husked rice was 34.71MMt (BBS, 2018). Similarly, in 1971, the population of Bangladesh was around 66.4 million; today, it is 164.67 million. On the one hand, the country has the highest population density on Earth; on the other hand, its per capita gross domestic product (GDP) (US$1,968 per annum) (World Bank, 2021) is among the lowest worldwide. Rice production in Bangladesh has increased in tandem with a population super-boom, engendering

[1] In FY (July to June) 2015–16, total production of cereal food was 37.16MMt, which included cereals such as maize, jowar, barley, and bajra; total rice production was 33.36MMt and total wheat production was 1.35MMt. The ratio of rice to wheat production was approximately 25:1, that is, 96% rice and 4% wheat (BBS, 2017).

concerns about food security.[2] Bangladesh's progress in terms of food self-sufficiency[3]—amid fluctuations in domestic production—is not surprising: food security is the country's national priority. Incidentally, it is also a key sustainable development agenda of the United Nations (UN, 2015). Almost every year, governments worldwide import enormous quantities of food grain from the world food market.[4] In the case of Bangladesh, its total food import in FY 2019–20 matched the value of 23% of its total merchandise export (FAOSTAT, 2020).

As in other countries, price spiraling[5] of agricultural commodities is common in Bangladesh, which produces dire consequences for the poor. For instance, in 2003 and 2009, the prices of essential commodities in Bangladesh spiraled out of control, erasing 36.7% of gross income from poor and middle-income groups (Mohajan, 2014).

Bangladesh is an agrarian and riparian State, and, therefore, farming is the mainstay of livelihoods—and economy (Huda et al., 2014; Yu et al., 2010). The agriculture sector is now semi-labor-intensive and highly mechanized even at the subsistence level, but it still relies heavily on natural sources of water, especially during the cultivation of the *Aman* variety of rice. Climate variability and changes are the apex dangers for this sector—and food security, in Bangladesh. Crop production is assumed to decrease by up to 30% by 2050, raising a fearful spectre of severe food insecurity and hunger (Climate Change Cell, 2007; Karim et al., 2012). However, food production, availability, and distribution are causes of anxiety even now, owing to climatic hazards.[6] The World Bank has designated Bangladesh as one of the most vulnerable countries to climate change and natural disasters worldwide.

Bangladesh is a low-lying delta, configured by the confluence of three turbulent rivers: the Ganges, the Brahmaputra, and the Meghna. Additionally, more than 200 rivers crisscross its

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[2] The definition of food security has been continually evolving since the birth of the concept. According to the Food and Agriculture Organization of the United Nations, "food security refers to when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (2002).

[3] In FY 2012–13, in terms of rice production, Bangladesh achieved food self-sufficiency (Daily Star, 2013; Mainuddin and Kirby, 2015). Production and consumption have grown in mutual competition over time.

[4] In FY 2017–18, the government and private importers together imported 9,774 Mt of rice and wheat using foreign aid from international organizations (MoF, 2020).

[5] As an illustration, the rice price shocks in 2007 and 2008. According to Srinivasan and Jha (1999), a 1MMt increase in rice export or import by India can impact the world rice market price by 4.7%.

[6] Climatic hazards are disaster agents affecting human settlements and the environment. Hazardous atmospheric phenomena encompass flood, drought, cyclone, thunderstorm, hailstorm, extreme precipitation, extreme temperatures, heat weaves, etc.

topography.[7] Climate change-induced rise in sea level is expected to inundate 19.5–25.7% of its coastal belt (Dasgupta et al., 2009), turning the area into a potential fatal hotspot because of mostly unprotected embankment (Dasgupta et al., 2009; 2010). Another important point in the context of climate change is that over 80% of the annual precipitation received by Bangladesh is discharged during the monsoon season[8]—from June to September. The above-stated hydro-meteorological factors make the country vulnerable to an array of extreme climatic events, such as floods, cyclones, and droughts. The evidence from the past is overwhelming: from July to September 2007, Bangladesh suffered a massive flood, which caused enormous damage to agricultural production and left nearly 13 million homeless. Then, on 15 November 2007, Extremely Severe Cyclonic Storm Sidr made landfall, killing 3,406 and destroying a million tons of rice—the *Aman*[9] variety was, at that time, ripe for harvest; total economic loss was estimated at over $1.7 billion (GOB, 2008). Likewise, Cyclonic Storm Rashmi (2008), Severe Cyclonic Storm Aila (2009), and Extremely Severe Cyclonic Storm Fani (2019) battered the country's coastal zones. The latest entry in this list is the Super Cyclonic Storm Amphan, which made landfall on May 20, 2020 and left in its wake losses worth BDT11 billion (equivalent to US$129 million), including damage to 149,000 hectares of agricultural lands and destruction of fish farms worth BDT3.25 billion (equivalent to US$ 36 million) (IFRC, 2020).

Climate change, extreme climatic events, and their correlations have left the country vulnerable in terms of food security. From early on, Bangladesh's policy planners have wisely equated "food security" with domestic "food self-sufficiency"—this is now jeopardized by frequent floods, flash floods, cyclones, tidal surges, salinity, and droughts throughout the country.

Monsoon floods, flash floods, and tidal floods are other forms of natural hazards that wreck the country frequently and threaten its food security by adversely impacting its agricultural

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[7] From the geo-morphological standpoint, approximately 80% of the country is floodplains; the remaining is hills. Besides, it has the Bay of Bengal in the south, encompassing 19 administrative districts out of the country's 64, and measuring 42,750 km^2 of coastal zones, which provide livelihood to 40 million people. According to the Flood Forecasting and Warning Centre (FFWC) of the Bangladesh Water Development Board, on average, 76%, 16%, and 8% of its citizens are affected by floods, cyclones, and droughts, respectively.

[8] Based on the climate of Bangladesh (sub-tropical monsoon), the Bangla calendar year is traditionally divided into six seasons: summer (mid-April to mid-June); monsoon (mid-June to mid-August); autumn (mid-August to mid-October); late autumn (mid- October to mid-December); winter (mid-December to mid-February); and spring (mid-February to mid-April) (Banglapedia, 2021). However, from a meteorological perspective, there are three distinct seasons: summer (March to June); monsoon (June to October); and winter (October to March).

[9] In Bangladesh, rice is cultivated throughout the year; broadcast *Aus* rice is cultivated from early March to late August; transplanted *Aus* rice from April to August; broadcast *Aman* rice from late February to November; transplanted *Aman* rice from July to late December; and *Boro* rice from January to late June (IUCN 2002).

production. Every year, floods submerge 20.5% of the country's land areas (Dasgupta et al., 2011; Mirza et al., 2001) and severe floods occur every 4–5 years, causing catastrophic damage. For example, the 1998 flood inundated approximately 67% of the country, destroying 4.5Mt of crops—especially rice (approximately 2 million tons equivalent to 10% of annual consumption)—and hurtling nearly 10 million households toward severe food insecurity (Nino et al., 2003). In 2017, Bangladesh braved three floods and lost enormous agricultural produce: 220,000 hectares of *Boro* rice; 40,000 hectares of *Aman* rice; and 16,000 hectares of other crops (FAO, 2017).

Drought also hampers crop production greatly, leading to food grain shortage. Since its independence in 1971, Bangladesh has had a painful history of droughts: 1973, 1978, 1979, 1981, 1982, 1989, 1992, 1994, and 1995 (Hossain, 1990; Adnan, 1993; Erickson et al., 1993). Geographically, its northern and northwestern parts are draught prone, and agricultural production there is hindered almost every year. The 1995 drought reduced rice and wheat production by 3.5×10^6 tons (Afrin et al., 2018; Rahman and Biswas, 1995). Afrin et al. (2018) employed the standardized precipitation index (SPI) to find that Bangladesh's northern zones experienced severe droughts in 2000, 2003, 2005, 2007, 2009, 2010, 2012, 2015, 2016, 2018, and 2019—among these, the droughts in 2012, 2014, and 2016 are categorized as extreme droughts.

Bangladesh's national agricultural policy, which duly considers the pernicious effects of nature's whims, emphasizes domestic production improvement via research, agricultural mechanization, agricultural education, environmental protection, and coordination among the government and national and international organizations. However, the policy requires a few modifications.

Therefore, the above discussion on food grain loss, climate change, extreme climatic events, and dependence on the mercy of nature for farming activities proves that extreme events and their correlations have profound negative impacts on the food security of Bangladesh. Food grain loss not only hinders a country's food self-sufficiency, it also increases its dependence on the world food market—which is inadvisable for a country's economic development. There are many good studies on food production (Hossain and Silva, 2013; Islam et al., 2011; Kobayashi and Furuya, 2011), food demand (Kumar et al., 2012), national food shortages, and food security (Salam et al., 2016; Mainuddin and Kirby, 2015; Carletto et al., 2013). However, these studies have seldom analyzed and rarely clarified the relationship between extreme climatic events and food security. This study investigates the prospective impacts of climate change, extreme climatic events, and their correlations on the food security of Bangladesh, and the results could be of significance to both academia and policy makers.

The remainder of this article is organized as follows: Section 2 is a review of related literature from contemporary research at home and abroad. The vector auto-regression (VAR), data, and key variable definitions are presented in Section 3. Section 4 presents the empirical analysis and results of building a nexus between food loss and food security, along with policy discussion. Finally, in Section 5, we present the concluding remarks based on the findings.

2.2. Related literature from contemporary research

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), Bangladesh is among the hardest hit countries worldwide, facing extreme vulnerability to climate change, natural disasters, and anthropogenic hazards. The bleak reality is that climate change is occurring and increasingly hitting the impoverished segments and resource-poor rural peasant communities, pushing them precariously close to severe food shortage (Alamgir et al., 2018; ADB, 2002).

Changing precipitation patterns and temperature fluctuations in different regions of Bangladesh are significantly higher than those predicted by the IPCC. This variability has a negative impact on rice and wheat production (Hossain et al., 2013) and significant production reduction will occur in the future due to climatic variability (Islam et al., 2011) and concomitant extreme climatic events (Wassmann et al., 2009). Future food production is a strategic and cross-cutting challenge to maintain food security in Bangladesh.

According to the fifth assessment report of the IPCC, food production in Asia will vary and show a decreasing trend in many parts of the regions under the impact of climate change (IFPRI, 2013). Shrestha et al. (2017) highlighted the vulnerability of farm households in northern Thailand to the negative impact of climate change.

Bangladesh is a hotspot of natural disasters and catastrophes. Floods, droughts, and cyclones are recursive in nature, and the economic burden caused by these natural hazards is enormous (Nino et al., 2003; Khandker, 2007; Sarker et al., 2012). Habibullah et al. (1998) showed that due to saline water intrusion and increase in salinity, loss of rice production was projected at 272,000 tons and 443,690 tons in the 2030 and 2050, respectively. Karim et al. (1996) asserted that climate variability could significantly impact food grain (rice and wheat) production. Taking

1990 as the base year, 330ppm CO_2 with a 2^0 C rise in the mean temperature would lead to a rice and wheat production loss of 9.46 x 10^6 and 0.67 x 10^6 tons annually, respectively. An empirical study by Kobayashi and Furuya (2011), "Comparison of Climate Change Impacts on Food Security of Bangladesh" revealed that rice production is seriously hampered by high temperature, which poses a great danger to the country's food security.

The existing literature regarding climate change and food security in Bangladesh provides a plethora of information. For instance, Karim (2018) plotted the impact of a climatic disaster on household income, expenditure, assets, and labor market outcomes. Alamgir et al. (2018) argued that climate change has a potential influence on farmers' net income distribution and regional vulnerability. A geo-statistical approach to the seasonal precipitation effect on *Boro* rice production in Bangladesh—a seminal work by Bhowmik and Costa (2012)—pointed out that precipitation change significantly affects rice production.

Additionally, most existing studies have focused on identifying and estimating the economic loss related to particular crops due to climatic events. For example, households situated in fully inundated areas in the 1994 flood lost approximately 90% of their livestock, poultry, and crops (Khandker, 2007; Mottaleb, et al., 2013). Paul (1998) indicated that the 1994–95 drought forced about 90% of farm households to sell their resources. In another study, Paul and Rashid (1993) calculated that floods reduced total rice production by almost 4% annually in Bangladesh. Yu et al. (2010) strategically argued and showed that using the Global Climate Model (GCM), all rice production projections exhibit a declining trend considering medium variation. For illustration: *Aus* -1.5%; *Aman* -0.6%; and *Boro* -3% by the 2030s and -5% by the 2050s—all due to climate change.

2.3. Materials and method

2.3.1 Vector auto-regression model

Sims (1980), in his magnum opus *Macroeconomics and Reality,* introduced vector auto-regression (VAR) as a tool to simplify the joint dynamic movement of a collection of variables. Ever since, it has been a leading analysis approach in the investigation of dynamic economic systems. In our study also, we have taken the VAR model considering the following specification of order p, as shown in equation 1.

$$Y_t = C + \sum_{i=1}^{p} \varphi_i y_{t-i} + \varepsilon_t \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(1)}$$

Where,

$Y_t = (y_{1t}, y_{2t}, \dots y_{nt})$ is an n × 1 vector of endogenous variables, while y_{t-i} is the corresponding lag order i. φ_i is the n × n matrix of autoregressive coefficients of vector $y_{t-i,}$ for i = 1, 2, …, C = (c_1, c_2, … c_n), and is the n × 1 intercept vector of the VAR model. $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \dots \varepsilon_{nt})$ is the n x 1 vector of the White Noise process.

Climate change will have a negative and detrimental influence on all four dimensions of food security: food availability, food accessibility, food utilization, and food stability systems. Human health, livelihood systems, food production, food distribution channels, market flows, and even changing purchasing power parity (PPP) are also affected by it (FAO, 2008). In order to address the issue of food grain loss due to climatic extremes, cyclones, droughts, and floods induced by anthropogenic climate change, we follow the methodologies of Lemi (2005), Schneider (2021), Roy et al. (2018), Applanaidu et al. (2014), and Greene et al. (2012). Our aim was to estimate the increase in food loss due to global warming and extreme climatic events. The growth rate of GDP and the rate of inflation are taken to seize the influence of the loss of food grain shocks on GDP and inflation. For this, we have taken five endogenous variables: the amount of cereal food grain supply for consumption (**FS**); the amount of import of cereal food grains from the world food market to meet the domestic demand deficit (**I**); quantity of food grain loss due to climate variability and extreme climatic events (**L**); the growth rate of gross domestic product (**GDP**); and the rate of inflation, which is the consumer price index (**CPI**). First, the order of the VAR model is estimated based on some information criteria, and the concrete form of the VAR model is determined. Based on the minimum Akaike information criterion (AIC), the Hannan–Quinn

Information Criterion (HQIC), the Schwartz–Bayesian Information Criterion (SBIC), etc., Table 1 shows the VAR model with lag order 1, as shown in Equation 2.

Table 1. Information criteria (IC) values for lag order selection

Lag	LogL	FPE	Del (Sigma_ml)	AIC	HQIC	SBIC
1	62.84	9.59e-08	1.53e-08	-1.99	-1.53	-0.63
2	77.90	1.90e-07	5.29e-09	-1.43	-0.59	1.08
3	102.65	2.76e-07	9.15e-10	-1.46	-0.25	2.23
4	163.91	7.22e-08	1.24e-11	-3.92	-2.35	0.97

Source: Authors' estimation.

More generally, the specification of the most parsimonious VAR model is as follows:

$$\begin{pmatrix} FS_t \\ I_t \\ L_t \\ GDP_t \\ CPI_t \end{pmatrix} = \phi_0 + \phi_1 \begin{pmatrix} FS_{t-1} \\ I_{t-1} \\ L_{t-1} \\ GDP_{t-1} \\ CPI_{t-1} \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \\ e_{5t} \end{pmatrix} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

2.3.2 Data

The following five endogenous variables are formed in this unrestricted VAR system.

Table 2. Variable definition, symbol, and data sources

Sl. No.	Variables	Definitions	Data sources
1.	Food supply for consumption (FS) from domestic sources	The staple food of Bangladesh includes rice and wheat. Food supply for consumption is predominantly dependent on domestic food production and food import. Here, rice (milled equivalent-tons), wheat, and wheat products are considered as the main food grain supply for consumption from domestic sources.	Food and Agriculture Organization web site. (FAOSTAT).
2.	Import of food grain (I)	Due to less food production and grain loss due to extreme climatic events, Bangladesh imports food	

		grain from the world food market to meet the domestic demand deficit for staple food. In this case, rice and wheat import data are taken and the unit of food grain import was ton (t).	
3.	Loss of food grains (L)	In Bangladesh, food loss is more acute at the production stage than the consumption stage (Joardder and Masud, 2019). These days, due to erratic climate patterns and extreme climatic events, huge losses occur in agricultural production. Food grain wastage at the time of harvesting (33%), post-harvesting (32%), storing and processing (10%), transportation (9%), and consumption waste (16%) (BBS, 2018; Ananno, et al., 2021) induce severe food shortage at the household level, battering the lives and livelihoods of millions. The unit of measurement was ton (t).	
4.	Growth rate of gross domestic product (GDP)	The growth rate of gross domestic product here is termed **GDP**. Here, we have taken annual percentage (%) of the growth rate.	Bangladesh Bureau of statistics (BBS).
5.	Inflation rate (CPI)	More generally, the consumer price index (**CPI**) is the proxy of inflation of the respective country's economy. The annual percentage of the rate of inflation is considered for estimation.	

Source: Created by the authors

The data employed in the estimation of the referred model are collated from a wide range and are yearly. The period ranges from 1984 to 2017, so they are time-series data of 34 years as a national-level account. Food grain supply for consumption, total food grain imports, and loss of food grain are calculated in tons. All variables were log-transformed.

2.3.3 Descriptive analysis

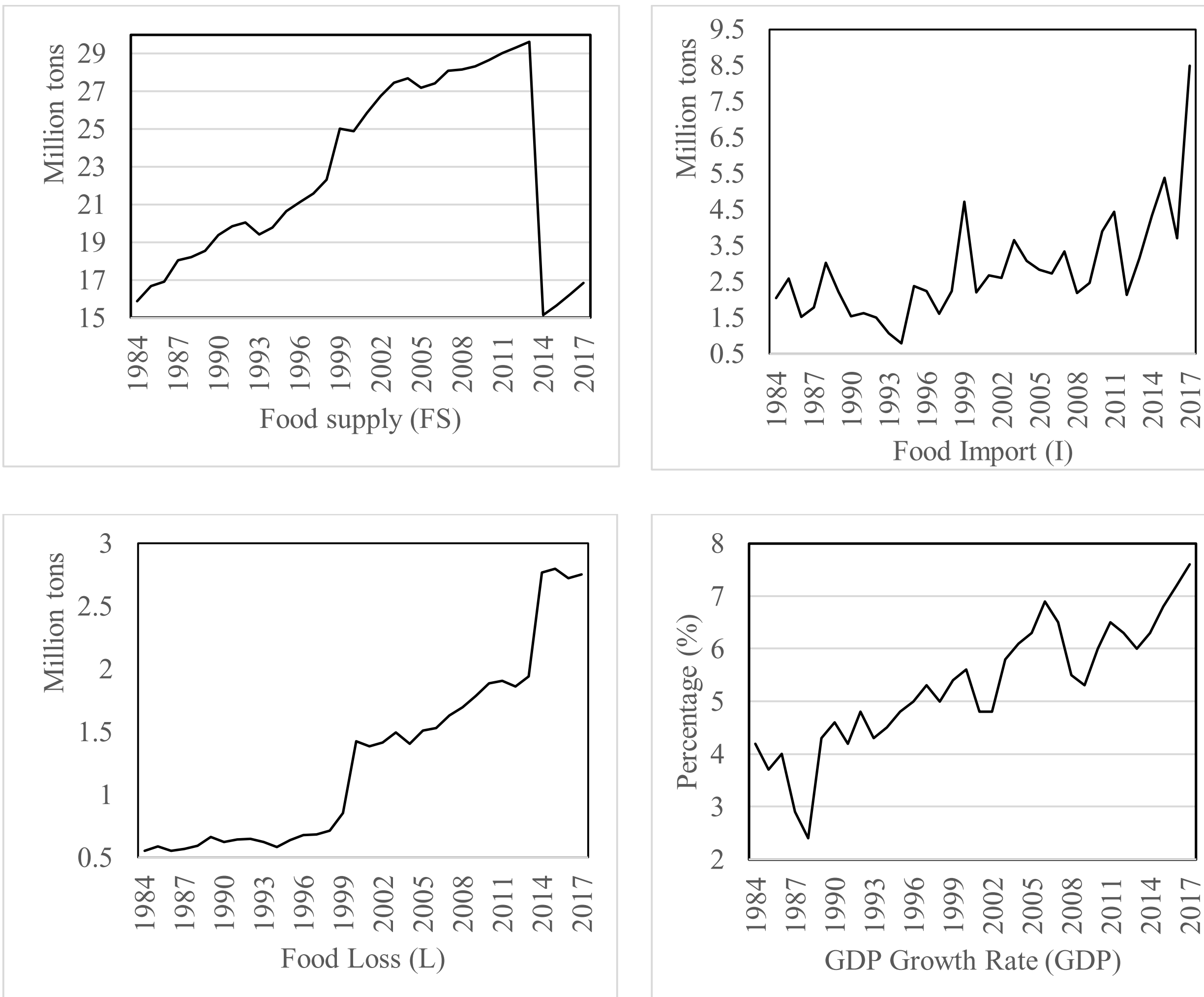
Table 3 provides a descriptive analysis of the time-series variables. Here, almost all the variables demonstrate normal skewness (equivalent to 0), except for variable food import (I), which followed a long-right tail (positive skewness). Likewise, the variable food supply (FS) and inflation (CPI) exhibit platykurtic (< 3) distribution, food import (I) shows leptokurtic (> 3), and the GDP growth rate has a mesokurtic (equal to 3) distribution. The Jarque–Bera test statistic runs under the null hypothesis (H_0) that series are normally distributed and we found variable food loss (L), where the GDP growth rate and inflation (CPI) are normally distributed, where the variable food supply (FS) and food loss (L) reject the null hypothesis at the 5% significance level. Most importantly, all independent variables show a positive monotonic relationship with food supply (FS)—the dependent variable.

Table 3. Descriptive analysis

Statistic	FS	I	L	GDP	CPI
Mean	2.25e+07	2822941	1297342	5.29	7.05
Std. Dev	4908563	1456225	733302	1.19	2.71
Min	1.51e+07	777671	552406	2.40	1.91
Max	2.96e+07	8493000	2798000	7.60	11.46
Skewness	0.04	1.87	0.69	-0.26	-0.20
Kurtosis	1.46	7.95	2.39	2.79	2.01
Jarque–Bera	17.66	19.63	3.85	0.54	3.49
Probability	0.00*	0.00*	0.15	0.76	0.17
Obs.	34	34	34	34	34
Correlation					
FS	1.00				
I	-0.01	1.00			
L	0.18	0.72	1.00		
GDP	0.36	0.62	0.82	1.00	
CPI	-0.15	-0.01	-0.18	-0.25	1.00

Source: authors' calculation. (* Rejection of null hypothesis at 5% p value.)

From Figure 1—the series period from 1984 to 2017—it is clear that cereal food supply for consumption has an upward trend up to 2013 and then falls, whereas food grain loss due to climate change and extreme climatic events is continually increasing. Food imports from exporting countries are also skyward, with some fluctuations in the periods. Similarly, the growth rate of gross domestic product (GDP) demonstrates a slight increase after 1988. However, the consumer price index means inflation oscillates widely over the time span.



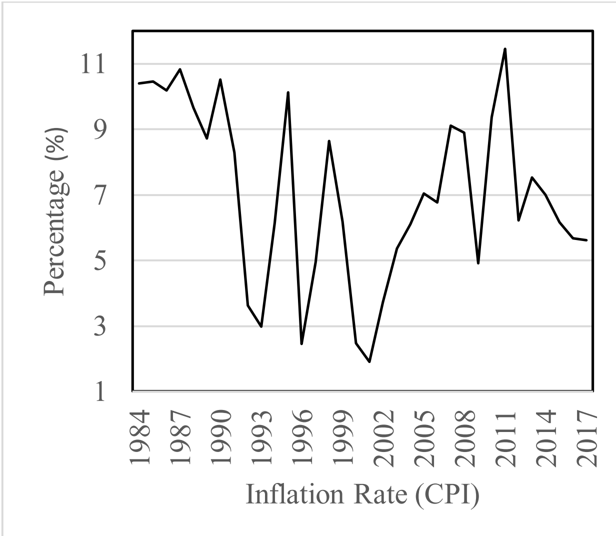


Figure 1. Trend of endogenous variables

2.4. Empirical analysis and results

2.4.1 Unit root test of the variables

In this case, for the analysis of the gathered time-series data, the unit root test was conducted first to make a judgment of data stationarity in the order of their integration. In order to test the stability of the variables, the method is generally known as the unit root test, which is the basis for assessing co-integration. For this, the widely applied method is called the Dickey–Fuller test, namely the unit root test. More generally, we performed the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests.[10] The test of the null hypothesis (H_0) is that the series has a unit root or is non-stationary at this level. The alternative hypothesis (H_1) is that the series does not have a unit root or is stationary. Only when the absolute value of "test statistic" is less than the absolute value of "critical value," the null hypothesis is accepted, rather than rejected (normally, we choose a 5% critical value). Here, we decided that the series is non-stationary or has a unit root. The results of these two distinct unit root tests are presented in Table 4.

[10] The Augmented Dickey–Fuller and Phillips–Perron tests are two distinct techniques widely used by economists to test the existence of unit root in the time-series when observations are correlated serially. The methods were proposed by Dickey and Fuller (1979) and Phillips and Perron (1988), respectively. The drama of these two approaches is that they construct their own test statistics, and emit asymptotic distributions and simulated critical values for varying test and sample sizes. For more information and elaborated explanation, please surf the original textbook and valid as well as standard sources.

From the table, it can be seen that the results are demonstrated in two ways: series in level and series in first log difference form. The first three columns of Table 4 outline the test results for the variables at level. It is obvious that all the series are non-stationary, except for the CPI. As our aim is to obtain a stationary series, we took the logarithmic form and first difference for all variables. The first logarithmic form of the variable is the actual growth rate. The second three columns of Table 4 list the test results of the first log-difference form for every variable. The results indicated that the null hypothesis of having a unit root is rejected for all the series at the 1% level of significance, meaning that all the first log-difference variables are stationary. In this analysis, we considered all the series in the first log-difference form.

Table 4. Unit root test of the variables

Variables	In level (I_0)			In first log-difference (I_1)		
	ADF test	PP test	Decision	ADF test	PP test	Decision
LnFS	-1.75	-1.81	NS	-5.64***	-5.64***	S
	(0.41)	(0.37)		(0.00)	(0.00)	
LnI	-2.30	-2.06	NS	-7.21***	-8.57***	S
	(0.17)	(0.26)		(0.00)	(0.00)	
LnL	-0.09	-0.04	NS	-7.17***	-5.15***	S
	(0.95)	(0.96)		(0.00)	(0.00)	
LnGDP	-1.46	-1.21	NS	-6.10***	-6.64***	S
	(0.55)	(0.67)		(0.00)	(0.00)	
LnCPI	-3.37***	-3.22**	S	-6.11***	-7.21***	S
	(0.01)	(0.02)		(0.00)	(0.00)	

Source: Authors’ estimations.

Note: NS and S refer to non-stationary and stationary conditions, respectively. ***p<0.01, **p<0.05, and *p<0.1 percent significant level, respectively; Values within parentheses denotes p-values.

2.4.2 Johansen test of co-integration

For the analysis of the time-series data, we conducted the Johansen test of co-integration beforehand. The results showed that the variables are not co-integrated but are integrated in the same order. We found that the values of "Trace statistics" and "Max statistics" were always lower than their 5% critical value, indicating that they were not co-integrated. The VAR model is a non-structural dynamic analysis method that forecasts multiple relevant time-series economic indicators. The results of the Johansen test of co-integration are presented in Table 5.

Table 5. Johansen test of co-integration

Max. rank	Parms	LL	eigenvalue	Trace statistics		Max statistics	
				value	5% critical value	Value	5% critical value
0	30	47.59	.	60.61	68.52	25.95	33.46
1	39	60.57	0.56	34.66	47.21	23.26	27.07
2	46	72.19	0.52	11.41	29.68	6.98	20.97
3	51	75.69	0.20	4.43	15.41	4.34	14.07
4	54	77.86	0.13	0.08	3.76	0.08	3.76
5	55	77.90	0.00	-	-	-	-

Source: authors' estimation.

This segment enlightens with the empirical results of the VAR model estimation that are elaborately delineated. The VAR estimation, the Granger causality test, and the impulse response function (IRF) analysis are thoroughly interpreted here. Our primary focus is on the influence of food grain loss on food supply for consumption and food grain import. The secondary purpose is to discover the indirect effect of the loss of food grain on GDP and inflation, which is the consumer price index.

2.4.3 Vector auto-regression

Bangladesh is among the most climate-vulnerable countries. Almost every year, extreme climatic events cause huge economic losses, especially agricultural damage in terms of food grain loss, bringing inexpressible miseries to common people. Food crisis is among the worst dimensions of their sufferings. Additionally, Bangladesh's dependence on food grain imports from exporting countries, as well as food aid, increases. Moreover, such catastrophes stifle the pace of economic activity. We can draw a meaningful message from Table 6, that the predictor variable loss of food grain significantly influenced food grain import under a confidence level of 1%. Furthermore, although food grain loss is insignificant, it has a negative relationship with food grain availability for consumption, which is extremely practical and matches the real-world situation. Our second focus is on the movement of GDP growth rate and the rate of inflation—we have received highly admissible clarification in this regard. At this stage of food grain loss, we can say that it is not a significant player to shake the country's GDP growth rate. However, food grain loss positively contributes to swell the inflation rate at the 10% significance level. Similarly, food grain import has a negative association with the rate of inflation at a 5% level of significance, which complies with our realistic views and insights. It is noted that most of the food grain imports are done by the government authority to pave the way for a smooth food supply and to control inflation. This is because the government does not have a profit motive.

Table 6. Vector auto-regression: Use the first difference series of data

Equation	Parms	RMSE	R-sq	Chi2	p>chi2
LnFS	6	0.36	0.53	37.38	0.00
LnI	6	0.11	0.96	981.48	0.00
LnL	6	0.13	0.75	102.03	0.00
lnGDP	6	0.41	0.33	16.48	0.00
LnInf	6	0.12	0.71	84.74	0.00

Dep. Var.	Constant	LnI (-1)	LnL (-1)	LnGDP (-1)	LnCPI (-1)	LnFS (-1)
LnI	8.59*	0.04	0.71***	-0.25	0.16	-0.25
	(0.09)	(0.83)	(0.00)	(0.51)	(0.19)	(0.38)
LnL	-3.30**	0.11**	0.88***	0.04	0.01	-3.30**
	(0.03)	(0.05)	(0.00)	(0.70)	(0.63)	(0.03)
LnGDP	-3.21*	0.12*	0.08	0.54***	-0.04	0.05
	(0.09)	(0.08)	(0.26)	(0.00)	(0.34)	(0.61)

LnCPI	3.21	-0.45**	0.42*	-0.51	0.54***	-0.04
	(0.59)	(0.04)	(0.08)	(0.26)	(0.00)	(0.89)
LnFS	3.26*	0.01	-0.06	0.08	-0.02	0.83***
	(0.07)	(0.8)	(0.40)	(0.54)	(0.54)	(0.00)

Source: Authors' estimations.

Note: The lagging phrase is considered on the basis of the minimum Akaike information criterion (AIC) and the Schwartz–Bayesian information criterion (SBIC) values. ***p<0.01, **p<0.05, and *p<0.1 percent significant level. Values in parentheses indicate the probability.

2.4.4 Granger causality test

In order to examine the causal behavior among the variables considered in this analysis, we ran the Granger causality test.[11] Our main aim was to focus on the causal relationship between food loss and food availability and food grain import, which is dependent on the world food market. Here, we segregate the whole sample into two sub-samples arbitrarily so as to determine the more recent climate change effect and explore the estimation results of all three sample periods: 1985–2017, 1985–2000, and 2001–2017; we found extremely pragmatic and acceptable results. The Granger causality test results for all periods are systematically depicted in Table 7, from which it is observed that during 1985–2017, there is a two-way Granger causality relationship between food grain loss and food grain imports. Under a 1% significance level of confidence, food grain loss Granger causes food grain import, indicating that large-scale damage to food grain production and harvest by extreme natural events in Bangladesh lead to rely on food import and food aid. During 1985–2000 and 2001–2017, we found the same results under a 5% significance level of confidence. This is a threat to the country's national food security and economy. Concurrently, food grain import Granger causes food grain loss at a 5% significance level, which is impractical

[11] Clive Granger proposed an approach for testing causality. One of the most accepted maxims for econometrician and statistician is: "correlation does not mean causality." Correlation or covariance is a symmetric or bivariate relation, that is, cov (x, y = cov (y, x) and generally we cannot infer anything about the direction of causality between x and y by observing non-zero covariance. The distribution of y_t is thought by the lagging value of y_t and x_t. Whenever a variable y cannot help forecast another variable x, we can say that y does not Granger Cause x. In other words, y fails to Granger Cause x if for all s>0, the mean squared error (MSE) of a forecast of x_{t+s} based on (x_t, x_{t-1} …) is as same as the MSE of forecast of x_{t+s} that uses both (x_t, x_{t-1}…) and (y_t, y_{t-1}…).

in the real sense, meaning that it is difficult to monitor the loss of food grain only by food grain import. The variables food grain loss and food grain availability for consumption have a unidirectional Granger-cause relation. Under 5% and 10% levels of significance, the variable food grain supply is affected[12] by the variable food grain loss during 1985–2017 and 1985–2000. However, during 2001–2017, we found that food grain loss Granger caused food supply for consumption under a 5% significant level of confidence, indicating that in the recent past, loss and damage to food grain production has been more than in earlier periods due to floods, cyclones, droughts, etc. Economic loss and damage from climatic events such as cyclones, droughts, and floods is not new or surprising. However, the scale and frequency of devastation nowadays is alarming—this is supported by the above findings. Weather extremes are a substantial threat to the country's overall food security and an obstacle to achieving the sustainable development goals (SDGs) set by the United Nations, especially the stand-alone goals 1 (no poverty) and 2 (zero hunger). As all the goals are intertwined and mutually inclusive, if the pursuit of one goal is hampered, all other goals will be impacted. Our secondary concern is to monitor the GDP growth rate and rate of inflation. We found that the variable GDP growth rate and food grain imports have a one-way Granger-cause relation. Under a 10% level of significance, we reject the null hypothesis of "LnI does not Granger cause LnGDP" rather than accept the alternative hypothesis. If we look up the variable inflation rate, food grain loss, and food grain import, we find a surprising remark. The variable inflation does not Granger cause the variable food grain loss and the variable food grain import, but it has been significantly influenced[13] by both the variables, food grain loss and food grain import, under 10% and 5% levels of confidence, respectively. These results are pertinent to our mundane knowledge and expectations.

Table 7. Granger causality Wald tests results

Variables	Null hypothesis (H_0)	df	1985-2017	1985-2000	2001-2017
			χ^2-statistic	χ^2-statistic	χ^2-statistic
InI	LnI does not Granger cause LnL	1	3.78** (0.05)	1.48 (0.22)	0.54 (0.46)

[12] The word "affect" is employed in the same sense as Granger Causality.
[13] The word "influence" is also used as parallel to the Granger Causality.

	LnL does not Granger cause LnI	1	11.62*** (0.00)	4.46** (0.03)	4.33** (0.03)
LnL	LnL does not Granger cause LnFS	1	0.70 (0.40)	0.07 (0.77)	3.61** (0.05)
	LnFS does not Granger cause LnL	1	3.81** (0.05)	3.29* (0.07)	2.19 (0.13)
LnGDP	LnGDP does not Granger cause LnI	1	0.43 (0.51)	0.64 (0.42)	0.19 (0.66)
	LnI does not Granger cause LnGDP	1	2.96* (0.08)	0.04 (0.84)	0.30 (0.58)
	LnCPI does not Granger cause LnL	1	0.22 (0.64)	2.55 (0.11)	0.21 (0.64)
LnCPI	LnL does not Granger cause LnCPI	1	3.03* (0.08)	1.01 (0.31)	0.51 (0.47)
	LnCPI does not Granger cause LnI	1	1.69 (0.19)	8.05*** (0.00)	1.28 (0.25)
	LnI does not Granger cause LnCPI	1	3.96** (0.04)	2.43 (0.11)	0.02 (0.87)

Source: Authors' calculations.

Note: ***p<0.01, **p<0.05, and *p<0.1 percent significance levels, respectively.

2.4.5. Impulse-response functions analysis

In this section, we use the IRFs[14] to determine the dynamic trajectory of food grain loss in the VAR system. In order to measure, in detail, the interaction among the variables that are considered in this study: food grain availability (LnFS), food grain loss (LnL), food grain import (LnI), the growth rate of GDP (LnGDP), and the rate of inflation (LnCPI), we have constructed Impulse-response function. The graph obtained from the impulse response functions exhibits the mutual relations of the variables, food grain loss and food availability for consumption; food grain

[14] The IRFs delineate the mutual relation of the system to trace the effect of a shock or innovation to one endogenous variable on the others. More specifically, they measure the dynamic marginal effects of each impulse or innovation or shock on all of the variables over time.

import and food available for consumption; food loss and food import; food loss and the GDP growth rate; and food loss and inflation rate. The results of the co-integration test (Granger causality test) and the results of the impulse response functions are homogenous in nature. One-unit impact is given to a variable, and the response figure is demonstrated accordingly. In this impulse-response function analysis, we adopted the "Cholesky One Standard Deviation Innovations" approach. In the graph of impulse-response functions, the horizontal axis denotes the number of lagging periods (unit: year) of the impulse effects, and the vertical axis represents the responses from specific variables.

As shown in Figure 2, when considering one standard deviation positive shock of food grain loss on food availability for consumption, in the current phase, it contributes to a gradual negative inclination of food grain availability, and then decreases, reaching a minimum in the third period. From the fourth period onward, it moved steadily until the tenth period. This means that certain shocks of food grain loss generate homodromous shocks to food grain availability for consumption, that is, the increase in food loss will have stable pushing effects on food grain availability, indicating that there is a negative association both in the short- and long-run. In general, there is always a negative deviation.

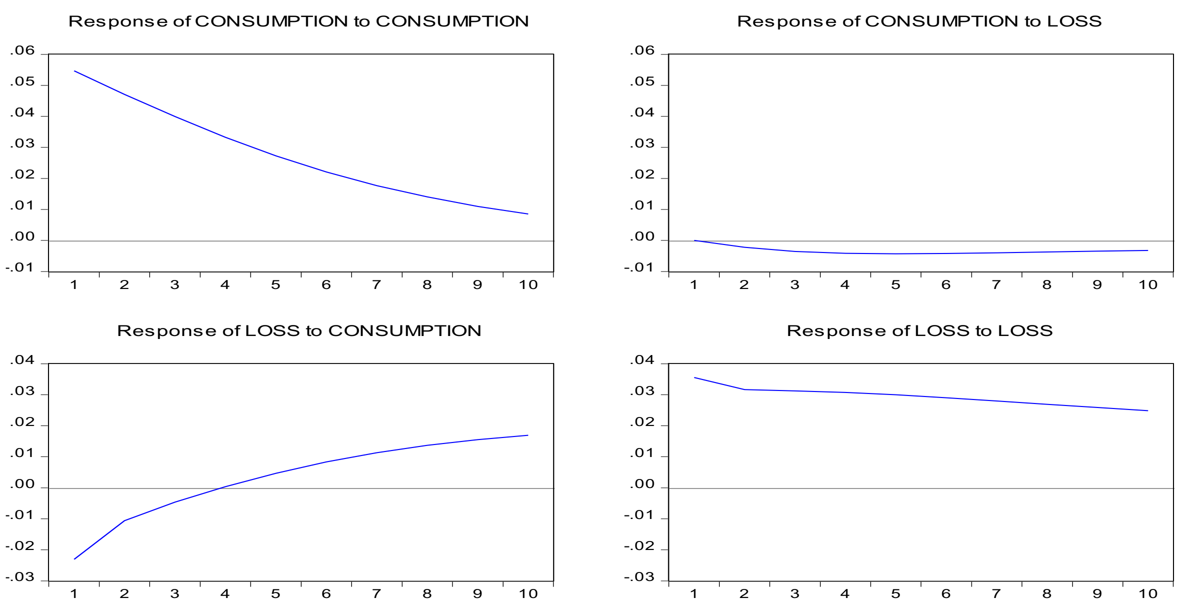


Figure 2. The graph of impulse-response functions of food grain availability for consumption (LnFS) and food grain loss (LnL)

As shown in Figure 3, when exerting one standard deviation positive shock to import food grain in the current stage, it leads to a steady response of cereal food availability for consumption, which means that there is a significant effect on food availability for consumption, indicating that certain shocks or impulses to food grain import will lead to homodromous shocks to food grain availability for consumption, that is, the rise of food grain imports will have stable pulling effects on food supply for consumption, meaning that there is a positive relationship in the short-run. However, in the long-run, the effects almost die out.

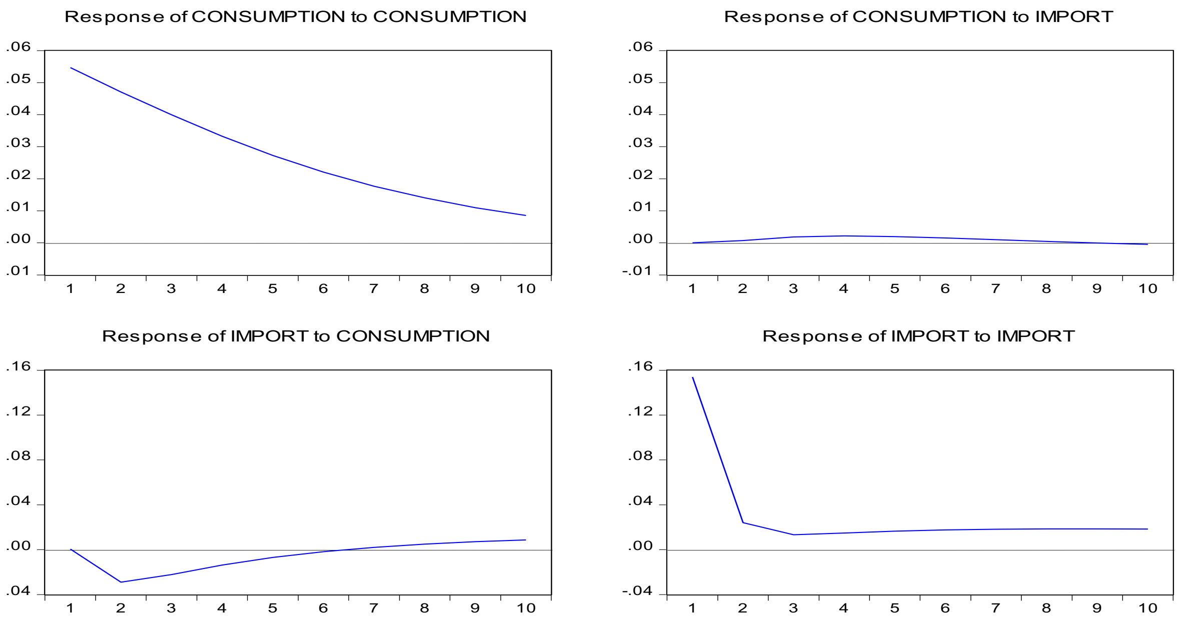


Figure 3. The graph of impulse-response functions of food availability for consumption (LnFS) and food grain import (LnI)

As shown in Figure 4, when exerting one standard deviation positive shock to food grain loss in the current phase, it produces a sharp rise and reaches a peak in the second period. After reaching the maximum positive deviation, it weakens slightly; we can state that it becomes almost flat and continues that way up to the tenth period. This suggests that a shock to food grain loss brings a homodromous shock to food grain import to increase the availability of food supply, that is, more natural havoc means more food loss, which forces greater dependence on food imports. Ultimately, it creates food vulnerability and poses a serious threat to the country’s food self-sufficiency.

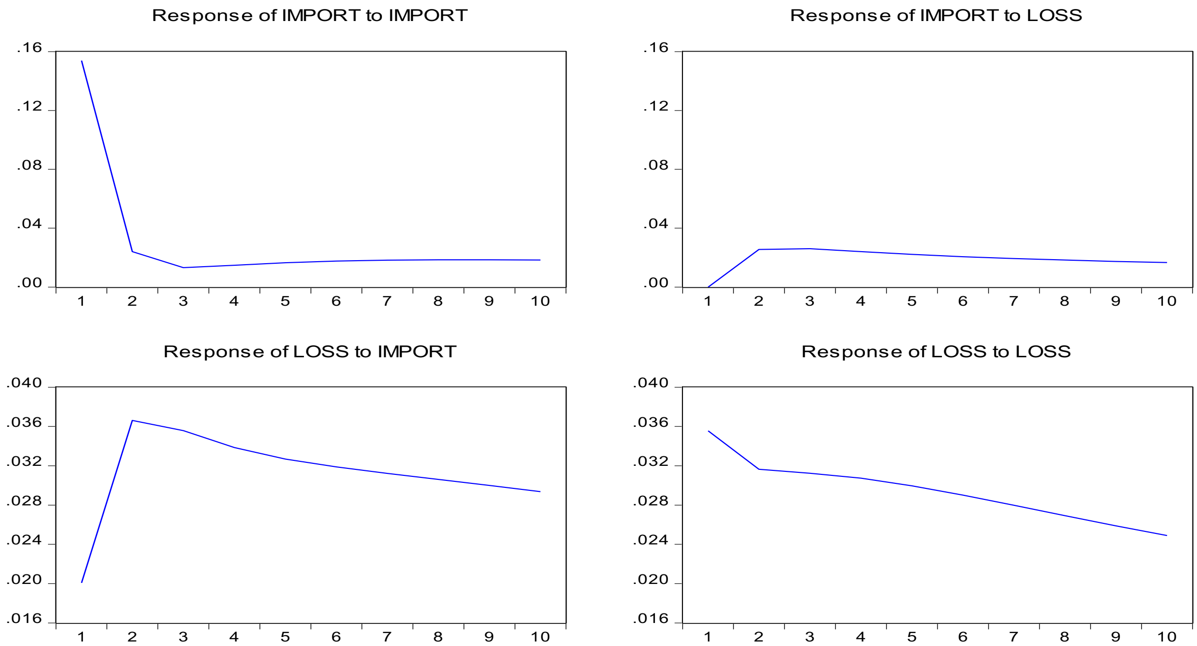


Figure 4. The graph of impulse-response functions of food grain import (LnI) and food grain loss (LnL)

2.4.6. Variance decomposition analysis

Variance decompositions appraise the necessity of each shocks considering as a part of overall variance of each of the variables over time. It segregates the variation in an endogenous variable into the component shocks to the model, and gives judgment regarding the relative importance of each random shock in affecting the variables in the VAR system. More formally, it's a method of decomposition of mean squared error (MSE) or mean squared deviation (MSD) through variance decomposition. After that, proportion of variables' contribution is measured. In this section, we mainly shed light on the variance decomposition of food grain availability for consumption, food grain imports to meet the domestic demand for food, the growth rate of GDP, the rate of inflation, and the loss of food grain due to extreme climatic events to observe how many of the unanticipated changes of these variables are justified by each type of different shocks. The decomposition results are given in the following figures.

As we can see in Figure 5, although consumption shock itself a great source of influence of variability but it is undeniable that the rest of the variables have considerable importance for the fluctuation of food grain availability for consumption. The results are consistence with our expectation and practical situation, intuitively. If we explain the results in other way, in the short run, i.e. in 3rd quarter, an impulse to consumption account for 97.86 percent variation of the fluctuation is in consumption itself. We can call its own shock. And the other shocks are shock to food grain import can cause 1 percent influence in consumption, in the same way, shock to GDP is 0.06 percent, shock to inflation rate is 0.82 percent, and shock to food grain loss is 0.25 percent. On the other hand, in the long run, i. e. in 10th quarter, shock to consumption is estimated 93.74 percent as its own shock and shock to import of food grain, GDP growth rate, inflation rate, and loss of food grain are 2.74 percent, 0.15 percent, 2.19 percent, and 1.18 percent, respectively.

In the short run, food grain import can cause about 1 percent in the fluctuation of consumption, but in the long run, it is 2.74 percent, meaning that import of food grain plays an important role for the supply of food grain for domestic demand. In case of growth rate of GDP, in the short run, it can cause 0.06 percent and in the long run, it is 0.15 percent meaning that a shock to GDP growth rate con not contribute much in the fluctuation of consumption neither in short run nor in the long run. Inflation rate can cause 0.82 percent and 2.19 percent, in the short run and in the long run, respectively, indicating that it has a significance influence to explain the volatility of food grain availability for consumption both in short run and long run. In addition, loss of food grain is also a good source for causing fluctuation of food availability for consumption because a shock to food grain loss produces 0.25 percent and 1.18 percent variation in the short run and in the long run, respectively (see Appendix I).

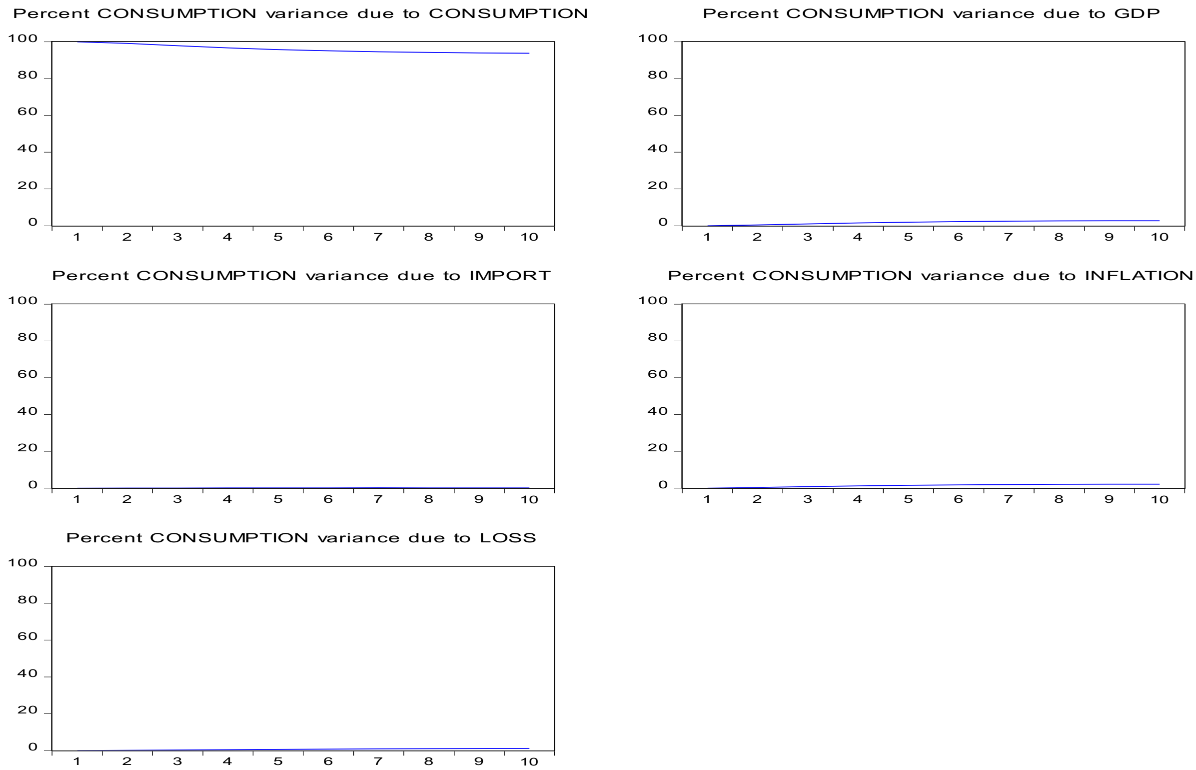


Figure. 5 Variance decomposition of food grain availability for consumption (LnFS)

As is shown in Figure 6, we can see that an impulse to the growth rate of GDP produces various significant influence to GDP. Apparently, it is obvious that food grain loss has a vital source of influence in the fluctuation of growth rate of GDP. That is very much justified in the pragmatic situation. In addition, in the short run, an impulse to the growth rate of GDP makes 86.46 percent variation of the fluctuation in the GDP itself. We may treat it as own shock. Other shocks are as consumption shock 4.72 percent, import of food 1.42 percent, inflation rate 2.70 percent and loss of food grain 4.70 percent in the short run. On the other hand, in the long run, a shock to GDP growth can cause influence to GDP is account for 78.54 percent whereas consumption is 5.09 percent, import of food grain is 1.47 percent, inflation rate 2.74 percent and loss of food grain in 12.16 percent. Here, consumption shock 4.71 percent and 5.09 percent indicates that the variable food grain availability for consumption has influence to GDP growth rate neither in the short run nor in the long run basically. In case of the food grain import, the value 1.42 percent and 1.47 percent means that the story remain unchanged like food grain availability both in the short run and in the long run to GDP. The inflation rate is as same as the variables food availability for consumption and food grain import because it takes value in the short run is 2.70 percent and in the long run is 2.74 percent without doing any significant influence in the growth rate of GDP. But, in case of variable food grain loss, the value is estimated 4.70 percent and 12.16 percent in the short run and in the long run, respectively. Meaning that the variable food grain loss has a significant role in producing variation in the fluctuation of the growth rate of GDP (see Appendix I).

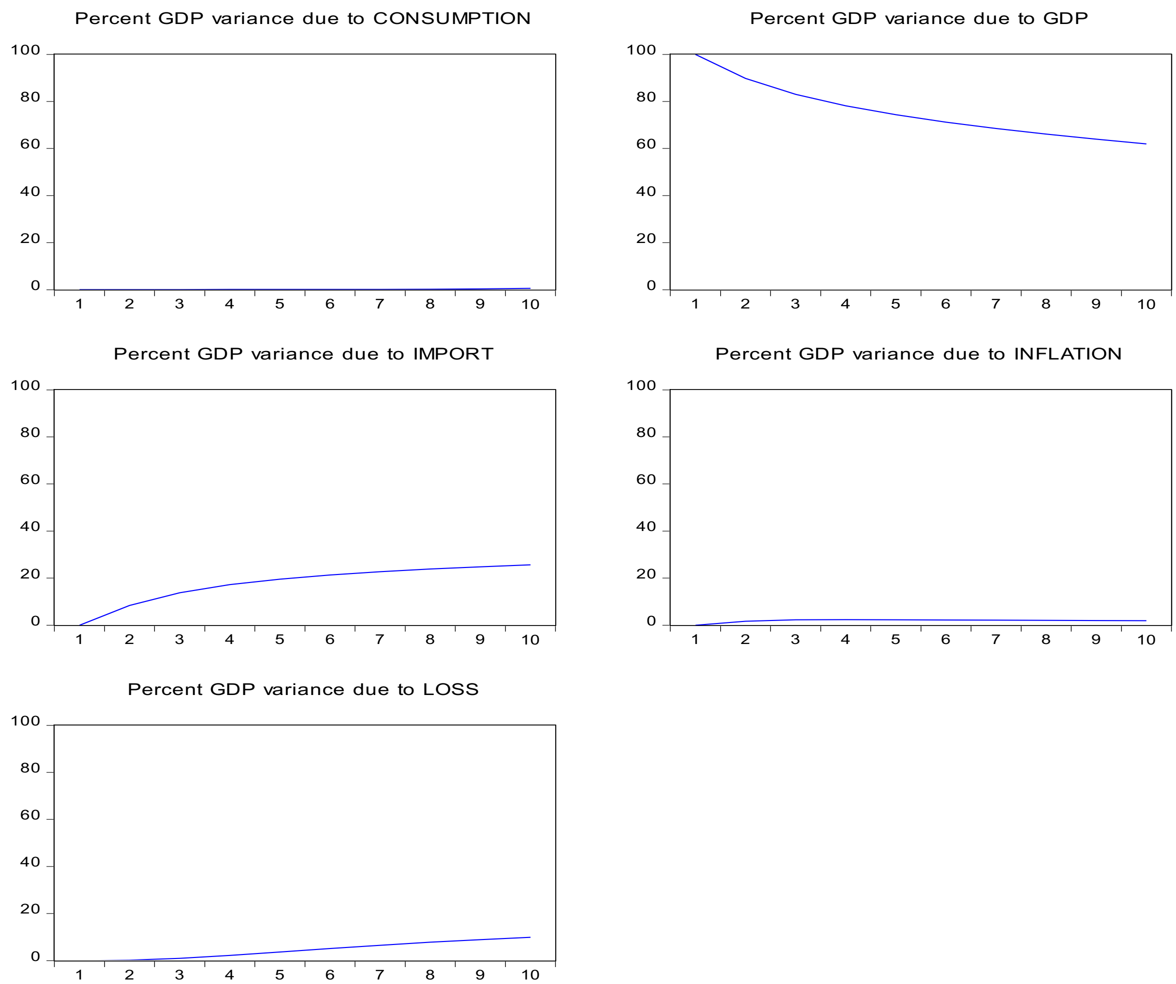


Figure 6. Variance decomposition of the growth rate of gross domestic product (LnGDP)

From the Figure 7, it is noted that a shock to food grain import induced most of the variation to its fluctuation by itself as an own shock. And the rest of the variables have also responsible to make fluctuation in the food grain import. In short run, an impulse or shock to food grain import account for 82.97 percent variation of the fluctuation in the food grain import as own shock whereas, in the long run, the value is estimated 61.98 percent. The other shocks in the short run to food grain import are food availability for consumption 0.045 percent, GDP growth rate 13.77 percent, rate of inflation 2.24 percent and food loss 0.97 percent. Food grain availability for consumption can cause 0.05 percent and 0.59 percent, respectively in the short run and in the long run in the variation of fluctuation to food import meaning very low but has influence to food grain import. The growth rate of GDP can cause 13.77 percent and 25.63 percent in the short run and in the long run, respectively in the variation to food grain import, indicating that the variable GDP growth has role in the fluctuation of food grain import both in the short run and in the long run. Inflation rate takes the value 2.24 percent in the short run whereas in the long run 1.91 percent meaning that the story remains unchanged or we can treat it a little weaker in the long run than the short run to the influence of food grain import. In case of loss of food grain, in the short run, it causes 0.96 percent variation in the fluctuation of food import whereas in the long run, it is estimated 9.89 percent meaning that the variable food grain loss really causes in the fluctuation of food grain import which is very much consistence to our practical knowledge and experience (see Appendix I).

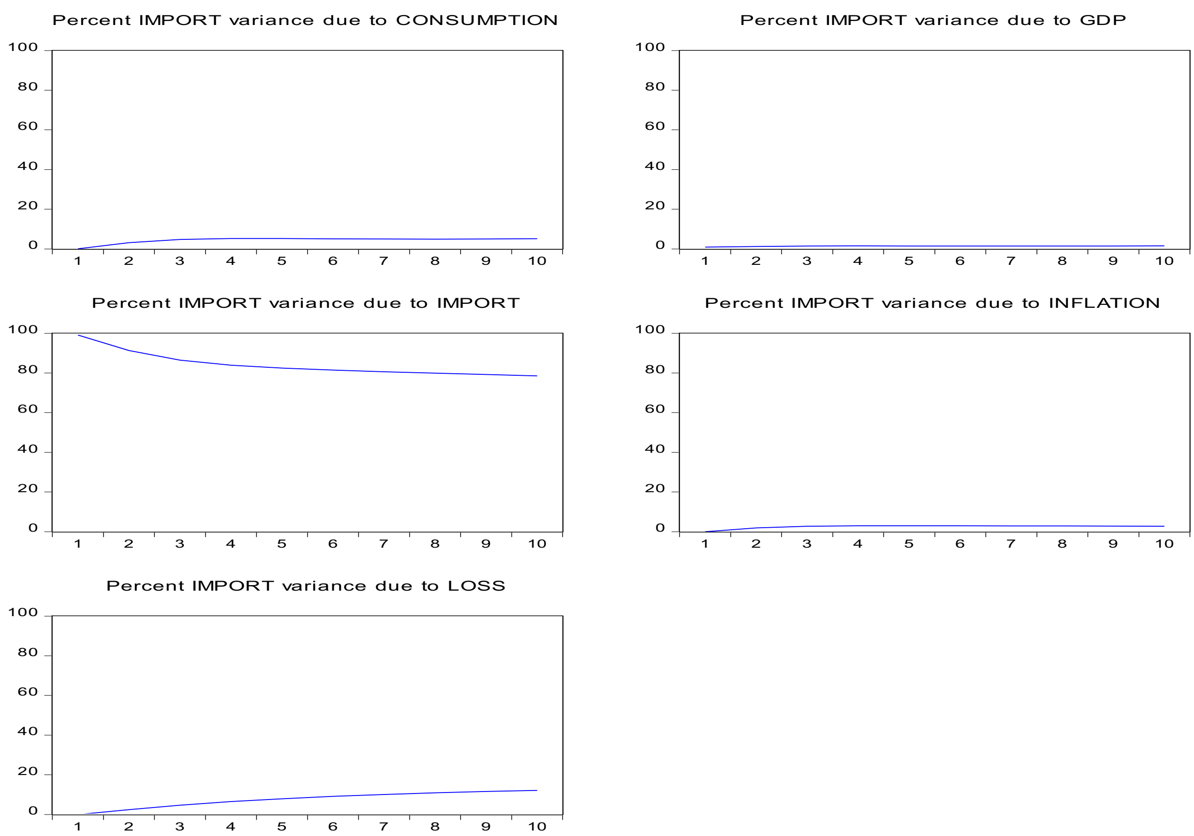


Figure 7. Variance decomposition of food grain import (LnI)

As we can notice from Figure 8, that an impulse to rate of inflation constructs a detail map of variation of fluctuation by the series variables. No wonder that most of the variation of fluctuation to rate of inflation by its own creation which are very common and natural. In the short run i.e. in

3rd quarter, a shock to rate of inflation builds 87.24 percent of variation to the fluctuation by inflation rate whereas in the long run it is 84.46 percent, indicating gradually weaken in the long run.

In the short run, a shock to consumption can cause 0.26 percent, import 3.45 percent, GDP 8.43 percent and loss 0.63 percent variation to the fluctuation to inflation rate whereas in the long run, consumption1.17 percent, import 4.10 percent, GDP 9.47 percent and loss 0.80 percent. From the value above, it is apparent that except import and GDP, rest two series are non-significant of producing variation in the fluctuation of inflation both in short run and in long run. But, import and GDP are a good source of variation in the decomposition of variance of inflation (see Appendix I).

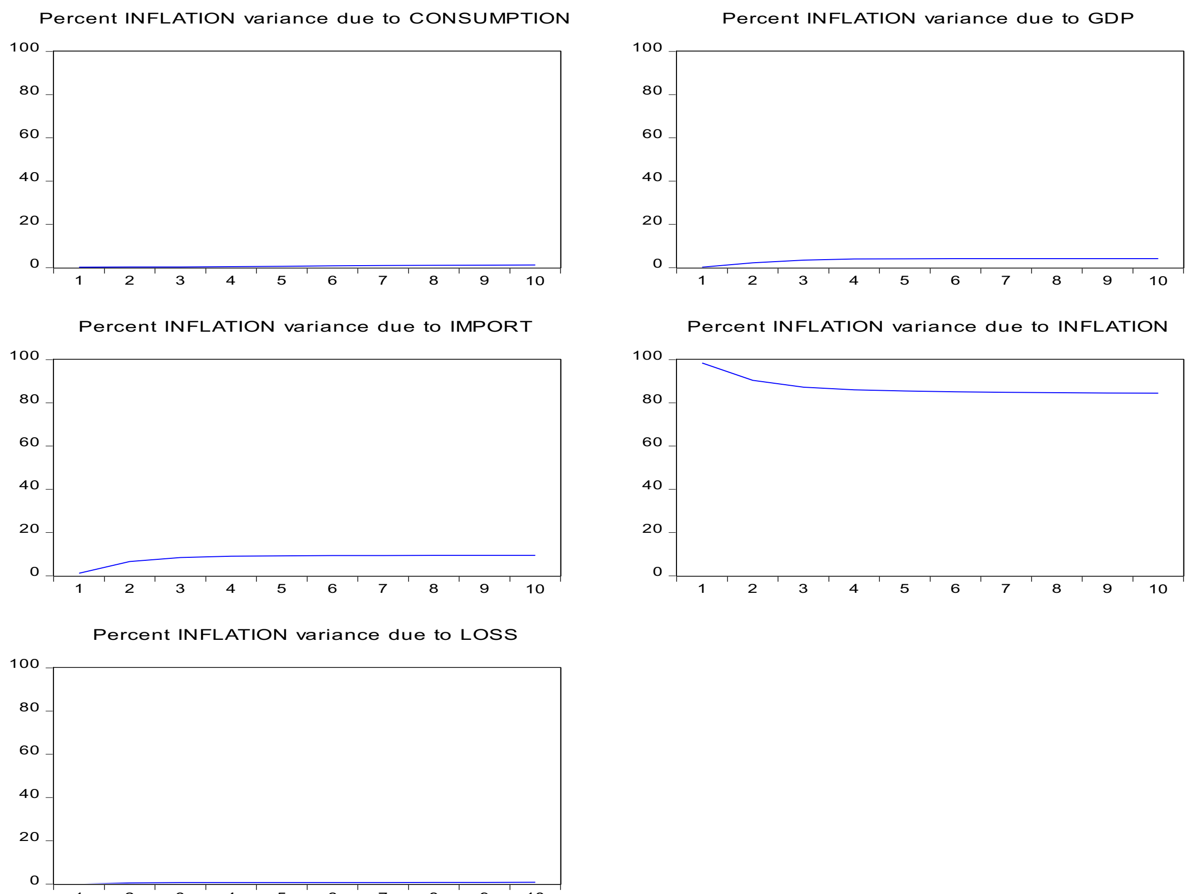


Figure 8. Variance decomposition of rate of inflation (LnCPI)

As is depicted in Figure 9, a shock to food grain loss demonstrate a very vivid facts of volatility of fluctuation to food grain loss. Here, it is very surprising, most of the variation of fluctuations come from other sources instead of food grain loss. In the short run, own fluctuation of variation of food grain loss is estimated 44.87 percent whereas in the long run 41.36 percent that means gradually declining trend.

Other series, in the short run, a shock can cause such as food grain availability for consumption 9.21 percent, food grain import 2.27 percent, the GDP rate 41.68 percent and inflation rate 1.98 percent to the fluctuation of food grain loss, on the other hand, in the long run, food grain availability, food grain import, the GDP rate and the inflation rate respectively 7.59 percent, 3.29 percent 47.03 percent and 0.73 percent. In this case, the GDP rate has a strong influence to the fluctuation of food grain loss (see Appendix I).

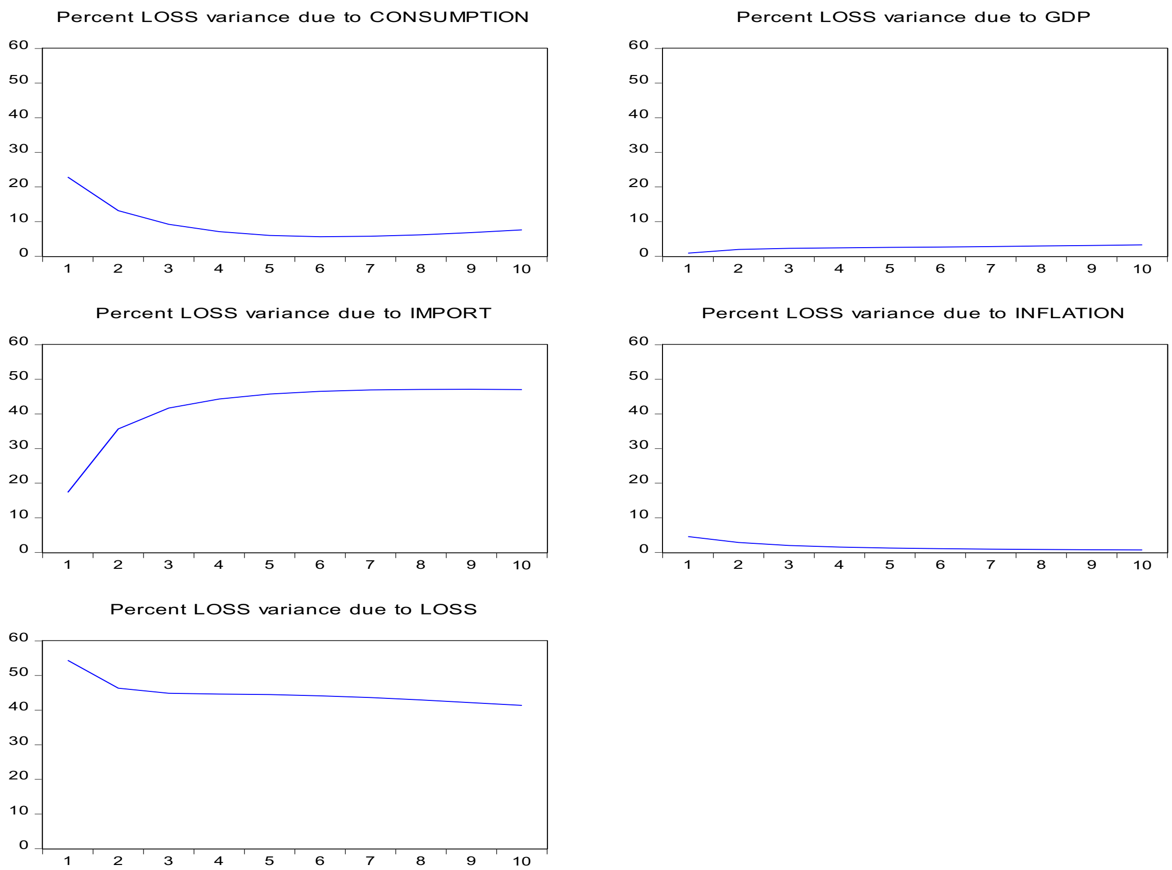


Figure 9. Variance decomposition of food grain loss (LnL)

2.4.7. Stability test of VAR

After developing a vector auto-regressive (VAR) model over a long period of time, then it's structural stability is a matter of concern. For a country like Bangladesh, climate change and extreme climatic events such as flood, flash flood, cyclone, tidal surge, saline water intrution, see level rige, and draught are common natural catastrophy that strick the agricultural production and the economy almost every year and sometimes hit several times within a year, is a precondition to appraise the stability status of the VAR system. It is cristal clear from the Fig. 6 that all the eigenvalues lies inside the unit circle. Hence, the VAR model is stable and the results are reliable for the predictions (see Appendix II).

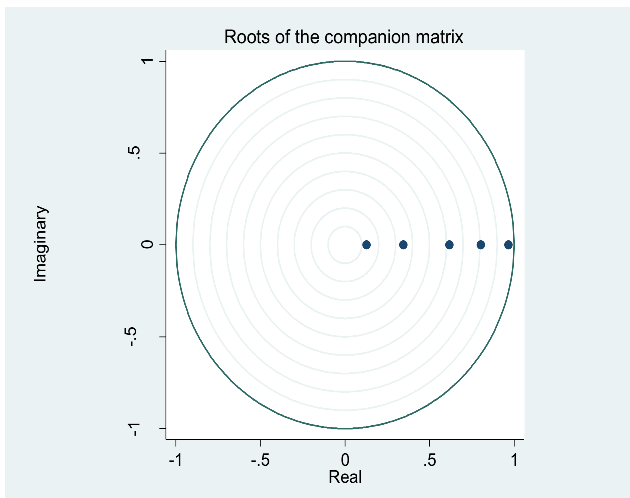


Figure 10. Roots of the companion matrix

2.5. Policy discussion

Climate variability and change, as well as their correlations, have long-term consequences for Bangladesh's economy (Karim, 2018; Mottaleb et al., 2013; IPCC, 2007). Concurrently, the country is striving to achieve the SDGs, especially the first two goals, by increasing agricultural production to offset the unfavorable effects of climate change and extreme climatic events. The stand-alone goal-1, "end poverty in all its forms everywhere" and goal-2, "end hunger, achieve food security and improved nutrition through sustainable agriculture" are intertwined and necessitate massive caution on the part of the country, which frequently suffers massive crop damage. According to the Global Food Security Index in 2019, Bangladesh ranked 83rd out of 113 countries globally, and South Asia held the lowest position in terms of food security. Based on our findings, food loss has a reciprocal relationship with food supply and is emerging as a prominent factor. These results support recent research by Wang (2010) and Miyan (2015) that climate change will have a significant adverse effect on food security in the current times. However, the existing national agricultural policy of Bangladesh states that agricultural production will be increased by means of modern technology and improved farming practices. Additionally, it promotes research on developing crop varieties and technologies suitable for drought, flood, and high salinity areas. Moreover, it emphasizes price stabilization in the event of crop damage, and the preservation of agricultural land. The reality, however, is that cultivable land is being progressively lost (Hasan et al. 2013) to rapid urbanization and industrialization, and budget allocation for agricultural research and development is scanty. In our view, the existing strategies for curbing price rise of essential commodities and protecting small and marginal farmers in the event of crop failure, constitute, ironically, the very shortcomings of the current version of the national agricultural policy. In light of our justified outcomes, we suggest innovation and adoption of climate-smart technologies to buffer household and national levels of food supply against erratic climatic shock. Policy planners must allocate a separate budget for agricultural sector research and development corresponding to present climate variability. Additionally, crop insurance and agricultural commercialization (Cazzuffi et al., 2020; King and Singh, 2020) are recognized worldwide as sustainable strategies. Furthermore, adaptation and mitigation strategies for farming practices for long-term resilience (Alam et al., 2017; Niles et al., 2015; Gandure et al., 2013; Rosenzweig et al., 2013; Adger et al., 2003), may deliver positive results in terms of national food security.

The sudden shock to agricultural production, food price volatility, and rising trade protectionism in the national and international food markets caused acute inflation, depleting household savings (Newman and Trap, 2020) and, in some instances, forcing them to borrow money from private or public sources. Based on our findings, we suggest a logical and admissible subsidy policy for agricultural inputs, where monetary policy must be used in accordance with fiscal policy to stabilize food prices in the national market, which will augment the country's aggregate food production. We also recommend enhancing cooperation with international aid organizations.

The is a positive correlation between food loss and food import—greater crop loss and damage leads to higher grain import. Additionally, price volatility in the international food market threatens food security in the importing country. Bangladesh imports food from the predatory world market, which hurts its economy with long-term policy implications. As argued by Iddrisu and Alagidede (2020), a restrictive monetary policy stabilizes food prices. Our suggestion is similar: formulation of a national monetary policy to check inflation.

2.6. Conclusions

Global climatic scenarios are evolving gradually, and their devastating effects have severely affected the agricultural sector worldwide. Crop loss and dependence on food import make Bangladesh vulnerable in terms of food security as well as other economic factors, such as low per capita GDP, dwindling household savings etc. In this article, we meticulously examined the effects of climate change and their correlations in the context of the agricultural sector, especially regarding production of staple foods such as rice and wheat in Bangladesh. Rice, wheat, and maize production are critically hampered by extreme climatic stress, which leads to food grain loss and forced food import. This vicious circle jeopardizes Bangladesh's economy and increases its dependence on the world food market. We investigated the adverse effects of climate variability and changes in food grain production by analyzing data based on yearly time-series spanning from 1984 to 2017, engaging the VAR model—the most demanding and appropriate method currently applied in this field of study. Our findings are interpreted and concluded as follows:

First, Bangladesh is located in South Asia—the region most vulnerable to climate change impacts, as mentioned in the IPCC Third Assessment Report (McCarthy et al., 2001). A deeply concerned international community admits that it is the most vulnerable country in terms of climatic aggressions of hydrogeological, and the concomitant, socioeconomic kinds as it is densely populated and highly dependent on agriculture, which is a gamble on the vagaries of nature. Our VAR model results conveyed lucid evidence that crop loss aggravates the country's long-term dependence on the global food market. We found that food grain loss is a key player in boosting food imports at a 1% level of confidence, and that it has a negative association with food grain availability for consumption. Additionally, the rate of inflation increases significantly at a 10% level of confidence. However, regarding GDP growth rate, we did not see the variable food loss only a potential barrier for its growth.

Second, we provide a glimpse of the Granger causality analysis. We found a bidirectional relationship between food grain loss and food grain imports. Food grain loss Granger causes food grain imports at a 1% significance level. Likewise, food grain import Granger causes food grain loss at a significance level of 5%—this is unrealistic and contradictory to real-world phenomena, which means it is difficult to explain food grain loss only with food grain import. The series of food grain loss and food grain availability for consumption have a one-way causality. Food grain availability was Granger caused by food grain loss at a 5% level of significance. As our secondary attention was on the movement of the GDP growth rate and rate of inflation in the context of food grain loss and food grain import, we found that the variables GDP growth rate and food grain import exhibited unidirectional Granger causality. Food grain import Granger causes a GDP growth rate under a 10% level of significance. Additionally, the association between the variables inflation rate, food grain loss, and food grain import revealed that under 10% and 5% confidence intervals, the variable inflation rate is Granger caused by the variables food grain loss and food grain import, respectively.

Third, based on the results of the IRFs of the linear impact model, in Bangladesh, food grain availability for consumption and food grain loss always have a negative relationship. Food grain import has been positively associated with the supply of food for consumption over the years. The impact of the impulse response of food grain availability on food grain loss is steadily negative and, food grain loss induces the continuous import of food.

These findings reveal that changes in climate and their correlations exacerbate a country's food security situation be causing massive losses and damages to its agricultural production, especially of cereals. Humanity's potential last-ditch effort to stave-off these horrendous impacts is through developing environmentally friendly and climate-benign sustainable technologies for green agriculture and green economy to increase overall global food supply and boost vulnerable nations' food security.

CHAPTER III

Climate change, Climatic extremes, and households' food consumption

3.1.1. Introduction

In Bangladesh, agriculture is a leading sector of the economy. However, it is under pressure from both climatic (e.g., cyclone, drought, and flood) and non-climatic stresses (e.g., population growth, rapid urbanization). For instance, due to climate extremes, the country loses 2% of its GDP each year, and it is predicted that this loss will go up at around 17% by 2050 (the Daily Star, 2021). Moreover, demand for food is growing continuously (Ramamasy and Baas, 2007) due to the population boom (growth rate 1.3%). The preference for quality food is also changing due to urbanization by shifting the standard of life and livelihood upward through income multiplication and augmentation.

Global warming and its resultant climate change and variability escalate (IPCC, 2011a, b) and jeopardize the sector enormously by causing an intensification of extreme climatic events (Khan and Rahman, 2007) and their devastation to the sector. However, depending on the country's geomorphological attributes and features, the impact of climate change and extreme climatic events on the agriculture sector, especially on cereal crop production by the farm household, are varied in scale and magnitude.

Bangladesh is a poster child of human-induced climate change. It suffers the consequences of extreme climatic events such as the following: flood, flash flood, river erosion, drought, cyclone, tidal surge, salinity, sea-level rise (SLR), low rainfall in the dry season, heavy rainfall in the rainy season by aggravating long-term flood and stagnation, heatwave, cold wave, and frequent thunderstorms while raining, prolonged summer season, and shorter winter season. These are all indications of a clear and visible footprint of climatic variability and change. These extreme events are recurrent (Paul and Routray, 2011; Paul, 1998). Moreover, the frequency and intensity of these extreme climatic events are increasing, leading to the plundering of livelihood through damage to crops and compelling the victims to eat less and even starve (Patwary, 2016). Owing to its more diverse physiographical location (Brammar, 2014) than was ordinarily perceived, the country feels the potential impact of the risk and uncertainty from climate variability and extreme climatic events every year.

Extreme climatic events such as cyclones, droughts, and floods hamper agricultural production. In Bangladesh—a cyclone-prone country associated with saline water intrusion by the tidal surge—coastal erosion significantly impacts agriculture due to crop damage and loss. In particular, the coastal zones are the fatal hotspots for destruction (Ali, 1999 and Paul, 2009a), and people suffer more than any other havocs. Additionally, these are viewed as the most disastrous catastrophes globally that surpass the earthquake (Zerger et al., 2002; Benavente et al., 2006). Every year, at least one severe cyclone landfalls (Mooley, 1980 and Haque, 1997) with maximum damage and loss to the agriculture and other sectors. For example, between 1891 and 1985, more than 174 mighty cyclones have struck the coastal zones, vandalized, and ransacked overtly. Although these areas' populations predominantly rely on agriculture, fishery, forestry, and salt farming (Mian, 2005), life and livelihood are now under considerable threat and vulnerable to climate change and extreme climatic events. Likewise, the country has a lengthy history of drought over the years 1981, 1982, 1984, 1989, 1994, and 2000, affecting approximately 53% of the population, covering 47% of the geography (BBS, 2018). Moreover, almost every five years, Bangladesh suffered a major country-wide drought (Dey et al., 2011). For example, a high-level drought can cause over 40% production loss to broadcast *Aus* rice. Moreover, it causes significant loss to *T. aman*[15] rice; nearly 2.32 million hectares and 1.2 million hectares of agricultural land face drought in the *Kharif*[16] and *Rabi*[17] seasons, respectively, each year (Dey et al., 2011 and Ibrahim, 2001).

Like cyclones and drought, floods demonstrate a high-level threat to the country's food security depending on the frequency, magnitude, and time of occurrence. Every year, floods inundate approximately 20.5% of the entire territory (about 3.03 million hectares) (Chowdhury, 2000; Mirza et al., 2001) due to its low lying landmass (nearly about 60%) being less than 6 meters above the mean sea level (USAID, 1988; GoB, 1992). Normal floods are often considered a blessing than a curse because of their economic and environmental benefits (Smith, 1996; Handmer, Penning-Rowsell and Tapsell, 1999). However, severe floods are considered ravaging (Paul, 1997; Paul and Routray, 2010). Ordinary floods cause arable land and alluvial soil that is a factor for bumper agricultural production (Brammer, 1990), while disastrous, long-stay, and

[15] Rice cultivars generally grown between mid-June and November in Bangladesh popularly are called *T. aman* rice.
[16] *Kharif* season starts from mid-March and ends in mid-November in Bangladesh.
[17] *Rabi* season is prolonged over mid-November to mid-March.

repeated flooding cause widespread destruction of crops along with life and livelihood (Rasid, 1993; Few, 2003).

On May 20, 2020, super cyclone "Amphan" made landfall (the Daily Star, 2020). The entire country was inundated by the flood leading to economic loss and damage of agricultural production along with other sectors. Doocy et al. (2013) highlighted that the least developed and developing countries are the hotspots and are affected disproportionately by these extreme climatic events.

Some examples might illustrate the point by transcending Bangladesh's climatic coverage and its return. On November 1, 2020, super typhoon[18] "Goni" battered the Philippines. Further, there are massive and successive hurricanes in the Caribbean Sea and the Mexican Gulf in the local time zone. All these indicate that the globe has crossed its threshold level of human-induced climate change impacts.

However, it is already proven and established via empirical research and observed data measurement and modeling that climate change would have far-reaching impacts on cereal production and other associated agro-components (Lobell et al., 2011; Campbell et al., 2016). Nevertheless, climate change will have detrimental effects on all four domains of food security—availability, access, utilization, and stability (Vermeulen et al., 2012).

We admit that several academic scholars highlighted issues of global warming and climate variability and their effects on agricultural production, more specifically cereal food production (Kobayashi et al., 2011; Salam et al., 2016), food demand, food consumption, adaptation, and coping strategies (Paul and Routray, 2011). Additionally, they underlined the spectrum of food security building nexus with floods, droughts, cyclones, salinity, SLR, coastal erosion, coastal flooding, river erosion, low precipitation in the dry season, and temperature rise (Ruane et al., 2013; Yu et al., 2010 and Asaduzzaman et al., 2010), among others. However, these earlier studies concerning natural calamities and devastation and household food consumption scrutinized and left some research gap. Moreover, most research considered a specific region (Brammer, 2014; Mallick et al., 2011; Paul and Routray, 2011), not covering samples from the entire country, and analyzed based on cross-sectional data (Hossain et al., 2008; Islam et al., 2014). Nevertheless, little

[18] Typhoons, hurricanes and cyclones, all are the same extreme climatic events. In different locations, they call in different names, i. e. in the Pacific Ocean "typhoon", in the Atlantic Ocean "hurricane" and in the Indian Ocean "cyclone".

research has been conducted on whether extreme climatic events have a heterogeneous impact on each region's agriculture through household cereal food consumption using macro-level, longitudinal/panel survey with national coverage generated by the International Food Policy Research Institute (IFPRI), the United Nations' apex institution in the food policy arena. Therefore, this study focuses on aggravated extreme climatic events through household cereal food consumption in the respective geographic location and agro-ecological zones where cyclones, droughts, and floods have heterogeneous impacts. Additionally, attention has been paid to explain how different control variables, including age, gender, farm size, family size, education, access to safe drinking water, sanitary latrine usage, and availability of electricity in the household, respond to these climatic hazards.

3.1.2. Background of climate change and climatic extremes in Bangladesh

According to geo-physiological standpoint, Bangladesh lies in between 20°34' and 26°38' north latitude and 88°01' and 92°41' east longitude bounded by neighboring India on the west-north and north-east, Myanmar on the south-east, and the Bay of Bengal on the South. The country's 147,570 sq. km consists of approximately 80% plain land, around 11% hilly area in the south-east, and the remaining high land in the northern regions. The entire area is crisscrossed by a well-connected network of rivers—the Ganges, the Brahmaputra, and the Meghna (GBM)—which have more than 230 flowing tributaries. Bangladesh enjoys a sub-tropical monsoon climate bracing six seasons in a year where the Winter season starts in November and ends in February with a fluctuated temperature ranging from a minimum of 7°c–13°c (45°F–55°F) to a maximum of 24°c–31°c (75°F–85°F). In the summer season, maximum temperature demonstrated 37°c (98°F) and in some places rises to 41°c (105°F) occasionally. The average annual rainfall varies from 1,429 to 4,338 millimeters, and the maximum rainfall (80%) occurs during the monsoon (July to October).

Currently, Bangladesh is governed through eight administrative divisions:[19] Chattogram, Barisal, Khulna, Dhaka, Rajshahi, Sylhet, Mymensingh, and Rangpur (see Table 2 and Map 1). The Southern part of the Country-Barisal division and most Khulna and Chattogram divisions are prone to cyclones and salinity (Map 2). Table 1 presents recent cyclones and the economic loss

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[19] In Bangladesh, four tires of the administrative system are under operation where the division is the top unit, and the union is the bottom unit in the order of the tire. The tire order is as follows: division > district > upazila > union.

and damage. The North and North-West parts of the country—Rajshahi, Rangpur, and Khulna—were affected by drought, especially agricultural drought[20] (Map 3). Additionally, Dhaka, Sylhet, Mymensingh, and some parts of the Rangpur division are flood-prone areas (Map 4). Therefore, the agricultural farm households belonging to these two regions are considered the treatment group for specific action.

Table 1. Recent cyclones in the country

Year	Cyclone	Economic loss (US$)
November 15, 2007	Sidr	1.7 billion
October 26–27, 2008	Rashmi	-
April 19–21, 2009	Bijli	-
May 27–29, 2009	Aila	269.28 million
May 16–17, 2013	Viyaru	35.3 million
July 29, 2015	Komen	18.1 million
May 21, 2016	Roanu	19.3 million
May 29–31, 2017	Mora	34.2 million
May 4, 2019	Fani	63.6 million
November 9, 2019	Bulbul	31 million
May 20, 2020	Amphan	131 million
May 26, 2021	Yaas	21.3 million

Source: Wikipedia, GoB, reliefweb.

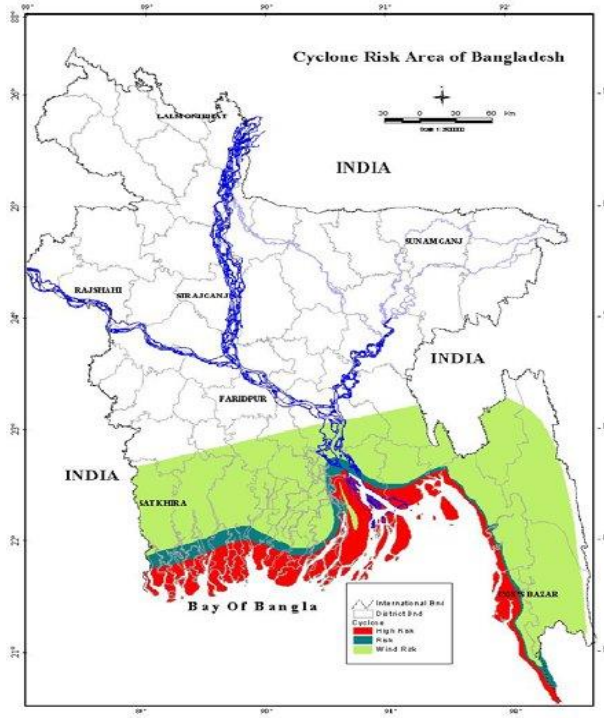
[20] Agricultural drought refers to soil moisture deficiency that makes plants under water tress that leads to crop failure and less crop yield and biomass production and significantly affects profitability over a sustained period (Narasimhan and Srinivasan, 2005).

Table 2. Administrative divisions along with districts of Bangladesh

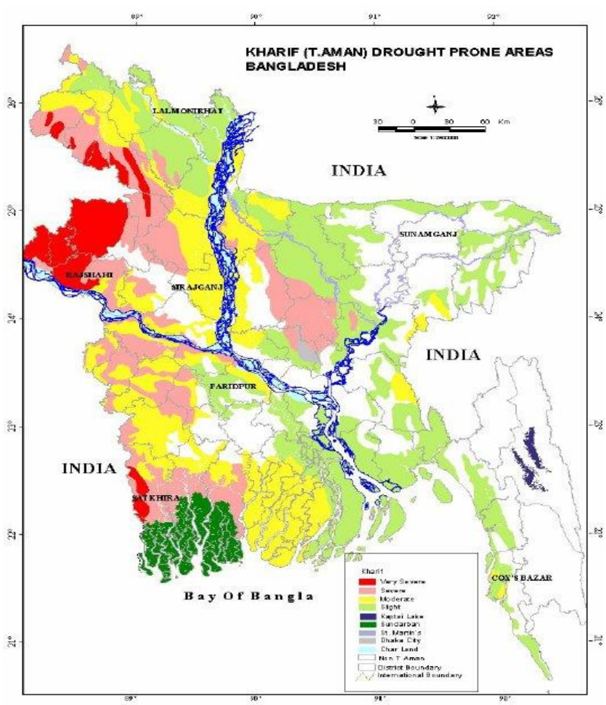
Sl. No.	Divisions name	District name
1.	Chattogram	Cumilla, Feni, Brahmanbaria, Rangamati, Noakhali, Chandpur, Lakshmipur, Chattogram, Cox's Bazar, Khagrachhari, and Bandarban
2.	Khulna	Jashore, Satkhira, Meherpur, Narail, Chuadanga, Kushtia, Magura, Khulna, Bagerhat, and Jhenaidah
3.	Barisal	Jhalakathi, Patuakhali, Pirojpur, Barisal, Bhola, and Barguna
4.	Dhaka	Narsingdi, Gazipur, Shariatpur, Narayanganj, Tangail, Kishoreganj, Manikganj, Dhaka, Munshiganj, Rajbari, Madaripur, Gopalganj, and Faridpur
5.	Sylhet	Sylhet, Moulvibazar, Habiganj, and Sunamganj
6.	Mymensingh	Sherpur, Mymensingh, Jamalpur, and Netrokona
7.	Rajshahi	Sirajganj, Pabna, Bogra, Rajshahi, Natore, Joypurhat, Chapainawabganj, and Naogaon
8.	Rangpur	Panchagarh, Dinajpur, Lalmonirhat, Nilphamari, Gaibandha, Thakurgaon, Rangpur, and Kurigram

Source: Bangladesh National Information Desk, 2018.

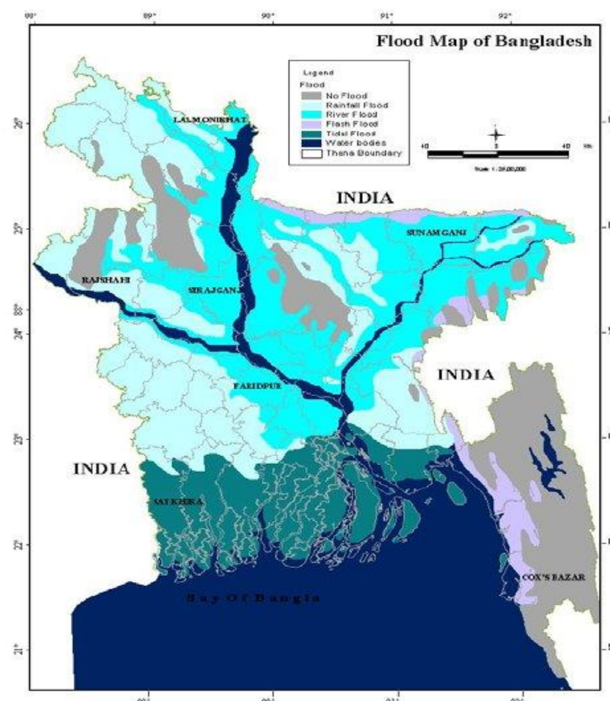
Map 1. Bangladesh



Map 2. Cyclone and saline prone areas



Map 3. Drought prone areas



Map 4. Flood prone areas

Figure 1. Maps indicating different extreme climatic events vulnerable regions of Bangladesh. Sources: Soil Resource Development Institute (SRDI), 2001; Water Resources Planning Organization (WARPO).

The remainder of this paper is arranged as follows. Section 2 presents our review of existing literature related to climate change, extreme climatic events, and their impacts on food consumption at home and abroad. Section 3 details materials and methods in which data source, variable definitions, measurement of variables, and analytical procedures are elucidated. Further, Section 4 presents the empirical results of the analysis. Finally, Section 5 highlights few policy implications and concludes the paper.

3.2. Climate Change, Climatic Extremes, and Food Consumption: Review of Existing Evidence

The IPCC assessment projected that crop yields would decline from 3% to 10% (Challinor et al., 2014b) due to per degree of global warming. Contemporary parallel research also warrants that a one-degree rise in temperature will lead to a 6% reduction in wheat production globally (Assen et al., 2015).

In a study on "poverty and natural disasters," Karim and Noy (2016) propose heterogeneous consequences in the household emerging from natural disasters, particularly the household per capita income and decline in consumption. Drought and other extreme weather events unfavorably impact Northern Kenya's household food security and food consumption with other rural livelihoods (Maione, 2020).

A study on the extreme events of tropical storms and households' food consumption showed that per capita consumption of food reduced nearly about 1.1% due to losses and damages by hurricanes. Affected households were forced to shift funds from non-food expenditures and compelled to spend more on consumption (Henry et al., 2019). Thomas et al. (2010) and Arouri et al. (2015), using cross-sectional and panel data in Vietnam, highlighted that extreme climatic events like storms significantly diminish household consumption levels by 1.5%. Anttila-Hughes and Hsiang (2012) underlined that the household food consumption in the Philippines reduced from 5.9% to 7.1% due to devastating typhoons.

A study on the post-cyclone in Bangladesh revealed an almost 9% to 14% rise in the vulnerability of the meal consumption frequencies of the marginalized rural households (Hasan, 2014). This means that moderate drought-prone households sacrifice at least 9% of their consumption, pushing them into poverty. Additionally, inflation of essential commodities due to crop failure, crop damage, and less crop production due to the drought resulted in a 14% reduction in the urban communities with little education (Hill and Porter, 2017).

Carpena (2019) empirically researched "drought impact households' food consumption and nutritional intake in rural India" and estimated that median dry shock households spend 1% less per capita per month on food consumption leading to 1.4% fewer macronutrients.[21] Auffret (2003), in his empirical study on the impact of catastrophic events on 16 countries (ten from Latin America and the rest six from the Caribbean), considered data spanning 1970–1999 and focused on several aspects encompassing consumption, production, and investment. The effects of catastrophic events on household consumption volatility constitute transforming production shock into consumption shock. This research finding affirmed that catastrophic events lead to a more moderate drop in consumption growth where private consumption declines in contrast to public consumption.

The effects of climate change, extreme climatic events, and related issues have garnered considerable attention from research scholars and academicians at home and abroad. Nonetheless, it suffers from a lack of research. Moreover, many of the published articles were not prevalent with their country coverage. Therefore, we seek the novelty of researching up-to-date, comprehensively organized data collected by IFPRI on household cereal food consumption largely affected by climate change and extreme climatic events in the areas where cyclones, droughts, and floods are the prime threat to household food security.

Based on research findings, we can determine the most vulnerable regions regarding food security through agricultural production and suggest appropriate policies for alleviating or mitigating these adverse effects from region-specific agricultural production. Thus, this study will be evidence for researchers, academicians, and policymakers to formulate regional development strategies.

[21] Macronutrients are those nutrients that provide energy and calories to our body and are required in larger amounts—carbohydrates, protein, and fat. However, micronutrients are those that our body needs in smaller amounts, such as vitamins and minerals.

3.3. Materials and Method

This part of the research provides information on the data source, the definition of the variables, and the model applied for the study chronologically.

3.3.1. Analytical technique: the Difference-in-Differences

This analysis adopted the Difference-in-Differences (DD or DiD) approach[22] (Khandker, Koolwal, and Samad, 2009) to evaluate the adverse consequences and extreme climatic events of climate change on household food consumption in climate-vulnerable geographic locations. The DD method is generally accepted as an impact assessment technique that compares two population groups (the treated and the non-treated) based on the time sequence of before and after action situations. Whenever the intervention group shows off the better or worse trends over their controlled counterpart (considering other influencing factors as ceteris paribus), the treatment (a course of actions) is considered effective toward the outcome. Here, we assume climate variability and its correlation—extreme climatic phenomena, such as cyclones, salinity, droughts, and floods—that cause agricultural production loss and damage[23] in areas where these natural havocs repeatedly occur, as a treatment to household cereal food consumption, amount of cereal food purchase, and the money spent on the cereal food purchase.

To grasp the impact of climate change and the extreme climatic events on household cereal food consumption, we consider Model 1 with the following econometric expression:

$$\text{ConsPerHH, } Y_{it} = a_0 + a_1 Year_{it} + a_2 Treatment_{it} + a_3 Year*Treatment_{it} + \sum_{j=1}^{J} a_j SocioDemo_{jit} + \sum_{k=1}^{K} a_k Economical_{kit} + \varepsilon_{it} \text{ ----------------------(1)}$$

Here, the null hypothesis (H_0) to be tested is that the regression coefficient of the household cereal food consumption is significant at various confidence levels with a negative sign, indicating the adverse impact of climate change and the extreme climatic events on the household cereal food consumption. Conversely, rejecting the null hypothesis means that climate change and extreme

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[22] A Difference-in-Differences method is a quasi-experimental approach that estimates the effects of a treatment by comparing the average changes in the outcomes over time between a treatment and control group of the population and is widely applied in econometrics and quantitative research in the field of social sciences as well as others.

[23] Loss refers to things that cannot be brought back, and damage refers to things that can recover partially but not completely as before.

climatic events are not the influencing factors in the climate-vulnerable areas. Additionally, we proposed Model 2 to identify the effects of the climatic hazard that households have less production due to damage and loss and are compelled to purchase more food from other sources with the following econometric progression:

$$PurPerHH,\ Y_{it} = b_0 + b_1 Year_{it} + b_2 Treatment_{it} + b_3 Year*Treatment_{it} + \sum_{j=1}^{J} b_j SocioDemo_{jit} + \sum_{k=1}^{K} b_k Economical_{kit} + \varepsilon_{it} \text{ -----------------------(2)}$$

The null hypothesis is that the regression coefficient of the amount of household cereal food purchase (Kg) from other sources is significant with positive signs—climate change and extreme climatic events adversely impact farm household cereal production. Likewise, Model 3 has been considered to assess households spending more money to purchase more cereal food (BDT). The shortage of food escalates the price hike of essential goods during unfavorable situations. Similarly, the null hypothesis that the regression coefficient of the amount of money spent by the household for purchasing the required cereal food is significant with a positive sign highlighting that climate change and extreme climatic events negatively impact household cereal food consumption through damage and loss to farm cereal production. Additionally, the economic specification is as follows:

$$ExpPerHH,\ Y_{it} = c_0 + c_1 Year_{it} + c_2 Treatment_{it} + c_3 Year*Treatment_{it} + \sum_{j=1}^{J} c_j SocioDemo_{jit} + \sum_{k=1}^{K} c_k Economical_{kit} + \varepsilon_{it} \text{ -----------------------(3)}$$

where Year is a binary variable, 1 = year considered after treatment (2015 & 2018–19) and 0 = the base year or the year considered before treatment (2011–12 & 2015). Treatment is a binary variable of a course of actions of intervention (1 = Treated group; 0 = Non-treated group) redeeming that climate change and extreme climatic events repeatedly affect the country, especially in the vulnerable areas with huge agricultural losses on paddy and wheat production over the years. Consequently, it affects the household cereal food consumption and the expenditure on procurement by reducing the cereal food consumption, increasing the expenditure on cereal food, and making them fragile and dependent on external sources. Additionally, to judge the treatment effect of climate variability and extreme events as a whole over time, we run DD analysis by considering all samples in the base year as a control group and equal to zero (0). Hence, the typical DD regression model leaves off the treatment variable as the same as in the Year and Treatment interaction variable (Year*Treatment) for collinearity. i denotes household with i = 1, 2, 3, …, n; and t indicates 2011–12, 2015, and 2018–19. The consumption, purchase, and expenditure on purchase of cereal food per household are regressed by modeling Eq. (1), (2), and (3), respectively, using a multinomial regression method (Moeis et al., 2020).

3.3.1.1. Measurement of the dependent variables

This study considers three dependent variables—household cereal food consumption; amount of cereal food purchase by the household from outsources (markets) because of less farm production; and the amount of money (BDT[24]) spent by the farm household for purchasing that amount of cereal food beyond farm production. The purpose is to evaluate the impact of climate variability and extreme climatic events on household cereal food consumption via agricultural production, especially cereal food production (rice, wheat, and maize). Generally, consumption per household (ConsPerHH) means the cereal food (chiefly rice and wheat) a household consumed in the last seven days during the survey. Purchase per household (PurPerHH) means the amount of cereal food (physical term (Kg.)) a household purchased beyond their farm produce for their consumption in the last seven days during the survey. Additionally, expenditure per household (ExpPerHH) means the money a household spent (in monetary terms (BDT)) for purchasing that amount of cereal food in the last seven days during the survey administered. Accordingly, our null hypotheses (H_0) are as follows. Households in climate-vulnerable areas consume less. Conversely, they purchase more from other sources and spend more than in the base year due to climatic shocks. Notably, we used the deflated price of the cereals in the treatment year to curb the inflationary influence.

[24] Currency introduced by the Central Bank of Bangladesh on behalf of the People's Republic of Bangladesh. Here, 1 US dollar is equivalent to 84.70 Bangladeshi Takas (as of March 24, 2021).

3.3.1.2. Measurement of the independent variables

The independent (control) variables comprise a set of “Socio-Demographic” and “Economic” features of the farm households. The “socio-demographic” attributes encompass farm size, family size, gender, dependency ratio, active member, age, marital status, literacy, and education level. Additionally, the “economic” attributes are a set of control variables, including access to a sanitary latrine, safe drinking water, and availability of electricity to households. All these variables are considered to be relevant to explain the response of the outcome variable.

3.3.2. Definition of the variables

As rice and wheat are the staple foods in Bangladesh, and among these cereals, rice covers more than 94% (Paul, 1998; Mohajan, 2014), wheat around 4%, and corn approximately 2% (BBS, 2017). The Bangladesh Integrated Household Survey (BIHS), implemented by the IFPRI, collated information on household cereal food intakes and other information during the last seven days of the survey. These include information on the consumption of rice, wheat, and corn (maize, jowar, barley, and bajra) in various forms—parboiled rice, non-parboiled rice, coarse rice, fine rice, rice flour, suji (cream of wheat/ barley), atta (wheat), Maida (wheat flour), semai/ noodles, chira (flattened rice), and muri/ khoi (puffed rice). Table 3 provides the variable definitions used here.

Table 3. Definition of the variables

Variables	Definition
DD	Typical difference-in-difference (DD) is an interaction variable between year and the treatment variables
Year dummy	1 = treatment year, and 0 = base year
Treatment dummy	1 = treatment group, and 0 = control group
Farm size	Using land under operation to agricultural production by household (own land plus rented in)
Family size	Total number of members in a family
Gender	1 = yes, if household head is female, and 0 = male
Dependency ratio	No. of dependent/no. of working members in the family

Active member	Household members aged between 15–60 years considered active family working members for earnings
Age	Household head's age in years
Marital status	1 = yes, if the household head is married, and 0 = otherwise
Literacy	1 = literate, if a household head can read and write, and 0 = otherwise
Education level	Year of schooling
Sanitary latrine	1 = access to sanitary latrine, and 0 = otherwise
Drinking water	1 = usage of tube-well water or related for drinking and household activities, and 0 = otherwise
Electricity access	1 = households have electricity connection, and 0 = otherwise

Source: authors' assumption.

3.3.3. Data

This empirical study was conducted using the household survey data collected during 2011–12, 2015, and 2018–19, administered by the IFPRI along with its technical assistance. It drew samples from the then seven (currently nine) divisions covering the entire country. A multi-stage stratified random sampling technique was adopted to collate primary data. First, they considered 325 primary sampling units across the country and then included 20 farm households from each primary sampling unit; therefore, the total volume of the sample size was 6500. The data were popularized as the BIHS data, which had thoroughly and uniquely captured all attributes of households through a well-defined, structured questionnaire. Further, it is fine to disclose that the attrition rate from the baseline survey (in 2011–12) to the second follow-up survey (in 2015) is 4.41% (Ahmed, 2016). In the third phase, however, it was approximately 13.78%, as the total sample was 5604. The IFPRI has conducted these three rounds of household surveys in Bangladesh. We analyzed all the data sets by considering the periods 2011–2015 (short-run), 2015–2019 (short-run), and 2011–2019 (long-run) to make a visual comparison between different time zones. Therefore, these data sets are nationally representative and consistently persuasive, considering all aspects.

3.3.4. Descriptive statistics

Table 4 reports the descriptive statistics of the variables of interest. In 2011–2019, 2011–2015, and 2015–2019, the total number of observations was 11759, 12718, and 11701, respectively. The mean and standard deviation of each variable are explicitly presented in the table. Additionally, we examined the correlation among the variables included in this analysis. The correlation matrix results show no strong correlation among the main explanatory variables (see Appendix III, IV, and V).

Table 4. Descriptive statistics for the periods 2011–19, 2011–15, and 2015–19

Variable	Obs.	2011–19	2011–15	2015–19
		Mean	Mean	Mean
Consumption (Kg.)	11759	13.87 (6.50)	14.21 (6.60)	13.23 (6.26)
Purchase volume (Kg.)	11759	7.55 (7.29)	7.98 (7.50)	7.64 (7.23)
Purchase volume (BDT)	11759	146.52 (203.96)	239.93 (228.36)	176.98 (267.14)
Year dummy	11759	0.46 (0.49)	0.49 (0.50)	0.46 (0.49)
Treatment group	11759	0.46 (0.49)	0.49 (0.50)	0.46 (0.49)
Farm size	11759	56.23 (102.87)	60.26 (117.09)	56.82 (108.04)
Family size	11759	4.16 (1.67)	4.57 (1.86)	4.57 (1.92)
Gender	11759	0.80 (0.39)	0.81 (0.38)	0.80 (0.39)
Dependency ratio	11759	0.88 (0.77)	0.84 (0.74)	0.85 (0.78)
Active member	11759	2.42 (1.18)	2.49 (1.18)	2.51 (1.23)
Age	11759	45.32 (13.90)	45.00 (13.90)	46.14 (13.79)
Marital status	11759	0.90 (0.30)	0.90 (0.29)	0.89 (0.31)
Literacy	11759	0.49 (0.50)	0.23 (0.42)	0.24 (0.43)
Education level	11759	3.50 (3.97)	3.85 (4.18)	4.08 (4.21)
Sanitary latrine	11759	0.38 (0.49)	0.58 (0.49)	0.70 (0.45)
Drinking water	11759	0.56 (0.49)	0.24 (0.43)	0.30 (0.45)
Electricity access	11759	0.64 (0.47)	0.52 (0.49)	0.71 (0.45)

Source: Authors' estimation based on BIHS conducted by IFPRI. Values in the parentheses denote standard deviation.

3.4. Empirical Results

3.4.1. Impact of climate change and extreme climatic events on households' consumption

Tables 5–7 present the results of impact evaluations on household cereal food consumption, cereal food purchase, and the amount spent on that cereal purchase. According to all our regression results obtained from longitudinal data analyses, we observed that in the long run, between 2011 and 2019, households located in cyclone and drought-prone areas suffered extreme climatic events and consumed less. Additionally, they had to purchase cereal food under inflated prices from other sources, as the markets were largely hampered by extreme climatic events such as cyclones, tidal surges, saline water intrusion, coastal erosion, low precipitation, temperature rise, and drought. However, households in flood-stricken areas exhibit a lesser probability of lesser consumption as our recommended model for estimating the flood effect was found insignificant.

In the short run, during 2011–2015 and 2015–2019, we have obtained interesting results from the analysis by employing Eqs. 1–3 corresponding to Models 1–3. During 2011–2015, in the cyclone and saline hit areas, it is authenticated that Models 2 and 3 are significant at a 5% level, indicating that the farm households purchased cereals for their consumption from the market, and households had to spend more due to scarcity of food and soaring prices. However, during 2015–2019, Model 1 showed significance at a 1% level with a negative sign. Thus, it becomes evident that climate change and its resultants negatively impact households' cereal food production and consumption.

Likewise, in drought-prone areas, in the long run, between 2011 and 2019, Model 1 is significant at a 10% level, and the other two models are also significant. Nevertheless, they reject the null hypothesis (H0), meaning that households were vulnerable and consumed less because of agricultural drought. However, in the short run, during 2015–2019, Model 1 is significant at a 5% level with a negative sign. More recently, households sacrificed their meals due to droughts that occurred in their areas, restricting their agricultural production practices. Nonetheless, during 2011–2015, all models rejected the null hypotheses.

Table 7 presents the estimated results of impact evaluation in the flood-prone areas. During 2011–2019, all our models reject the null hypothesis (H0), indicating that households in flood inundated areas have no severe effect on cereal food consumption in the long run. However, in 2011 and 2015, we found that Model 1 is significant at a 5% level with a negative sign, indicating that flood has pernicious effects on household cereal food consumption in the short run. Conversely, between 2015 and 2019, we did not find any negative effects from the flood on household cereal food consumption and household farm cereal production.

In Table 8, we treated the base years' whole sample as controlled—equal to zero (0)—and evaluated the impact both in the long-run (2011–2019) and the short-run (2011–2015 and 2015–2019) periods. We found that the treatment group (also called the trend of the dependent variable, obtained from the year variable) is negative at various levels of significance, indicating that climate change and extreme climatic events as a whole have significant negative effects on households' cereal food consumption.

Additionally, control or explanatory variables provide insightful and logical guidance. For example, the education level shows that households with a higher level of education have a lower probability of being affected by extreme events—they are more resilient than those with a lower level of education, highlighting the necessity and importance of education for households. The education of the household heads may guide the households through better understanding and expert knowledge regarding agricultural production practices, mitigation, and adaptation during climate change and extreme climatic events. These findings also match with those of O'Donoghue and Heanue (2018), Oduroofori et al. (2014), and Awotide et al. (2016). Likewise, households having access to electricity, sanitary latrine, and safe drinking water sources are less vulnerable to climate change and extreme climatic events. This highlights that the modernization of agricultural farm practices is a precondition for the betterment of productivity, storage, and supply chain management of agricultural households. Our results follow those of Abdul-Salam and Phimister (2017).

Table 5. DD estimation results of periods 2011–19, 2011–15, and 2015–19 in cyclone and saline prone areas

Variables	(I) Cyclone and saline prone areas								
	2011–19			2011–15			2015–19		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
DD	-0.53***	1.00***	36.58***	0.34	0.63**	18.64**	-0.80***	-0.07	5.57
	(0.20)	(0.29)	(9.81)	(0.21)	(0.28)	(6.39)	(0.22)	(0.33)	(12.70)
Year dummy	-1.45***	-5.04***	-153.19***	-1.45***	-2.51***	-109.90***	-0.16	-2.18***	-43.21***
	(0.10)	(0.14)	(4.91)	(0.16)	(0.21)	(6.53)	(0.16)	(0.24)	(9.33)
Treatment dummy	-0.51***	-0.53***	-18.79***	-0.54***	-0.29	-11.93*	-0.21	0.36*	8.33
	(0.14)	(0.21)	(6.98)	(0.16)	(0.21)	(6.39)	(0.14)	(0.22)	(8.39)
Farm size	0.00***	-0.01***	-0.48***	0.00***	-0.00***	-0.26***	0.00***	-0.01***	-0.69***
	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.02)
Family size	2.18***	1.78***	58.77***	0.63***	0.65***	19.49***	0.79***	0.61***	23.28***
	(0.05)	(0.08)	(2.83)	(0.04)	(0.05)	(1.60)	(0.03)	(0.05)	(2.14)
Gender	-0.05	-0.33*	-20.25***	1.07***	0.82***	16.79***	0.75***	-0.05	-14.88**
	(0.12)	(0.18)	(6.02)	(0.13)	(0.17)	(5.34)	(0.12)	(0.18)	(7.12)
Dependency ratio	0.08	-0.06	-3.81	2.57***	2.08***	62.02***	1.91***	1.40***	50.47***
	(0.10)	(0.15)	(5.12)	(0.09)	(0.11)	(3.57)	(0.08)	(0.12)	(4.64)
Active member	0.97***	0.40***	13.81***	3.16***	2.29***	71.16***	2.64***	1.61***	61.67***
	(0.09)	(0.13)	(4.49)	(0.07)	(0.09)	(2.83)	(0.06)	(0.10)	(3.76)
Age	0.03***	0.01***	0.57***	0.03***	0.01***	0.58***	0.02***	0.00	0.01
	(0.00)	(0.00)	(0.15)	(0.00)	(0.00)	(0.13)	(0.00)	(0.00)	(0.18)
Marital status	0.45***	0.12	2.10	0.46**	0.23	3.89	0.53***	0.23	4.96
	(0.15)	(0.22)	(7.44)	(0.17)	(0.22)	(6.78)	(0.15)	(0.23)	(8.96)
Literacy	0.04	0.10	0.88	0.01	0.08	1.25	0.13	0.72***	27.31***
	(0.15)	(0.22)	(7.32)	(0.15)	(0.20)	(6.27)	(0.14)	(0.21)	(8.05)
Education level	-0.03**	-0.01	1.30	-0.06***	-0.10***	-1.71***	-0.06***	-0.09***	-1.88***
	(0.01)	(0.02)	(0.93)	(0.01)	(0.01)	(0.51)	(0.01)	(0.01)	(0.69)
Sanitary latrine	-0.41***	-0.53***	-10.08***	-0.37***	-0.68***	-10.91**	-0.40***	-0.46**	-4.19
	(0.08)	(0.12)	(4.17)	(0.11)	(0.15)	(4.69)	(0.10)	(0.15)	(5.74)
Drinking water	0.37***	-0.28**	-8.07**	0.38***	0.54***	18.09***	0.29**	-0.86***	-30.86***
	(0.08)	(0.12)	(4.27)	(0.14)	(0.18)	(5.61)	(0.12)	(0.19)	(7.33)
Electricity access	-0.55***	-0.51***	-0.64	-0.34***	-0.40***	3.89	-0.39***	-0.43***	1.92
	(0.10)	(0.14)	(4.82)	(0.09)	(0.12)	(3.71)	(0.10)	(0.15)	(5.74)
Constant	1.14***	4.95***	129.67***	-0.84***	1.96***	54.14***	-0.60***	3.62***	78.55***
	(0.22)	(0.33)	(10.96)	(0.25)	(0.33)	(10.13)	(0.24)	(0.37)	(14.07)
No. of obs.	9367	9367	9367	9092	9092	9092	10467	10467	10467
F-value	926.72***	353.35***	310.54***	710.83***	271.76***	290.24***	765.06***	185.55***	160.52***
R^2	0.59	0.36	0.33	0.54	0.30	0.32	0.52	0.21	0.18
Adj. R^2	0.59	0.36	0.33	0.53	0.30	0.32	0.52	0.20	0.18

Source: Authors' estimation based on BIHS conducted by IFPRI. Note: * p<0.10, ** p<0.05, and *** p<0.01. Values of "t" statistics are presented in parentheses.

Table 6. DD estimation results of periods 2011–19, 2011–15, and 2015–19 in drought-prone areas

Variables	(II) Drought prone areas								
	2011–19			2011–15			2015–19		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
DD	-0.46*	-1.76***	-44.92***	0.06	-1.24***	-23.72**	-0.50**	-0.52	-25.20*
	(0.26)	(0.37)	(12.52)	(0.28)	(0.37)	(11.33)	(0.25)	(0.37)	(14.20)
Year dmmy	-1.49***	-4.65***	-140.56***	-1.35***	-2.20***	-101.11***	-0.38***	-2.13***	-40.41***
	(0.09)	(0.13)	(4.60)	(0.16)	(0.20)	(6.27)	(0.15)	(0.23)	(8.83)
Treatment dummy	0.48**	0.63**	-16.74*	0.39*	0.43	-25.00***	0.34**	-0.57**	-46.94***
	(0.20)	(0.29)	(9.87)	(0.22)	(0.29)	(8.86)	(0.17)	(0.27)	(10.13)
Farm size	0.00***	-0.01***	-0.47***	0.00***	-0.00***	-0.25***	0.00***	-0.01***	-0.67***
	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.02)
Family size	2.18***	1.78***	58.33***	0.63***	0.64***	19.12***	0.79***	0.60***	22.79***
	(0.05)	(0.08)	(2.82)	(0.04)	(0.05)	(1.59)	(0.03)	(0.05)	(2.13)
Gender	-0.01	-0.31*	-17.88***	1.06***	0.85***	19.28***	0.78***	-0.01	-11.76*
	(0.12)	(0.18)	(6.00)	(0.13)	(0.17)	(5.34)	(0.12)	(0.19)	(7.11)
Dependency ratio	0.10	-0.80	-5.07	2.59***	2.08***	60.80***	1.92***	1.37***	48.14***
	(0.10)	(0.15)	(5.10)	(0.09)	(0.11)	(3.56)	(0.08)	(0.12)	(4.63)
Active member	0.97***	0.39***	13.32***	3.17***	2.29***	70.65***	2.63***	1.60***	60.60***
	(0.09)	(0.13)	(4.48)	(0.07)	(0.09)	(2.83)	(0.06)	(0.10)	(3.75)
Age	0.03***	0.01***	0.53***	0.03***	0.01***	0.54***	0.02***	0.00	-0.00
	(0.00)	(0.00)	(0.15)	(0.00)	(0.00)	(0.13)	(0.00)	(0.00)	(0.18)
Marital status	0.40***	0.13	2.95	0.44***	0.23	4.78	0.49***	0.26	6.82
	(0.15)	(0.22)	(7.42)	(0.17)	(0.22)	(6.76)	(0.15)	(0.23)	(8.92)
Literacy	0.02	0.09	0.34	-0.02	-0.05	-0.41	0.10	0.72***	27.35***
	(0.15)	(0.22)	(7.30)	(0.15)	(0.20)	(6.23)	(0.14)	(0.21)	(8.01)
Education level	-0.04***	-0.01	1.27	-0.06***	-0.10***	-1.69***	-0.07***	-0.09***	-1.79***
	(0.01)	(0.02)	(0.93)	(0.01)	(0.01)	(0.51)	(0.01)	(0.01)	(0.69)
Sanitary latrine	-0.42***	-0.50***	-8.81**	-0.36***	-0.69***	-12.08***	-0.42***	-0.45***	-3.76
	(0.08)	(0.12)	(4.15)	(0.11)	(0.15)	(4.68)	(0.10)	(0.15)	(5.72)
Drinking water	0.56***	0.26**	-6.42	0.50***	0.60***	21.44***	0.55***	0.87***	-30.07***
	(0.08)	(0.12)	(4.07)	(0.13)	(0.17)	(5.40)	(0.12)	(0.18)	(6.94)
Electricity access	-0.49***	-0.50***	-1.06	-0.32***	-0.41***	3.23	-0.33***	-0.46***	1.19
	(0.10)	(0.14)	(4.80)	(0.09)	(0.12)	(3.70)	(0.10)	(0.15)	(5.69)
Constant	-0.49***	4.79***	129.54***	-1.02***	1.85***	56.14***	-0.60***	3.79***	89.06***
	(0.10)	(0.33)	(10.91)	(0.25)	(0.33)	(10.06)	(0.24)	(0.37)	(14.04)
No. of obs.	9367	9367	9367	9092	9092	9092	10467	10467	10467
F-value	918.19***	355.02***	315.59***	710.33***	272.61***	295.06***	760.48***	186.99***	166.18***
R^2	0.59	0.36	0.33	0.54	0.31	0.32	0.52	0.21	0.19
Adj. R^2	0.59	0.36	0.33	0.53	0.30	0.32	0.52	0.21	0.19

Source: Authors' estimation based on BIHS conducted by IFPRI. Note: * p<0.10, ** p<0.05, and *** p<0.01. Values of "t" statistics are presented in parentheses.

Table 7. DD estimation results of periods 2011–19, 2011–15 and 2015–19 in flood-prone areas

Variables	(III) Flood prone areas								
	2011–19			2011–15			2015–19		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
DD	0.15	-0.28	-17.93**	-0.40**	-0.16	-6.44	0.55***	0.02	-7.24
	(0.16)	(0.23)	(7.75)	(0.17)	(0.23)	(7.05)	(0.16)	(0.25)	(9.38)
Year dummy	-1.64***	-4.68***	-136.66***	-1.12***	-2.28***	-102.89***	-0.72***	-2.16***	-36.04***
	(0.12)	(0.18)	(6.01)	(0.18)	(0.23)	(7.14)	(0.17)	(0.26)	(9.98)
Treatment dummy	0.42***	0.38**	26.87***	0.48***	0.33**	25.69***	0.11	0.19	22.55***
	(0.12)	(0.17)	(5.90)	(0.13)	(0.17)	(5.31)	(0.11)	(0.17)	(6.72)
Farm size	0.00***	-0.01***	-0.48***	0.00***	-0.00***	-0.26***	0.00***	-0.01***	-0.68***
	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.02)
Family size	2.17***	1.78***	58.65***	0.63***	0.64***	19.28***	0.78***	0.61***	23.05***
	(0.05)	(0.08)	(2.83)	(0.04)	(0.05)	(1.59)	(0.03)	(0.05)	(2.14)
Gender	-0.01	-0.34**	-21.14***	1.07***	0.82***	16.25**	0.78***	-0.06	-15.70**
	(0.12)	(0.18)	(6.00)	(0.13)	(0.17)	(5.33)	(0.12)	(0.18)	(7.11)
Dependency ratio	0.07	-0.07	-4.47	2.56***	2.07***	60.99***	1.89***	1.39***	49.22***
	(0.10)	(0.15)	(5.12)	(0.09)	(0.11)	(3.56)	(0.08)	(0.12)	(4.65)
Active member	0.97***	0.40***	13.92***	3.16***	2.30***	71.13***	2.62***	1.61***	61.49***
	(0.09)	(0.13)	(4.49)	(0.07)	(0.09)	(2.83)	(0.06)	(0.10)	(3.76)
Age	0.03***	0.01***	0.62***	0.03***	0.01***	0.61***	0.02***	0.00	0.08
	(0.00)	(0.00)	(0.15)	(0.00)	(0.00)	(0.13)	(0.00)	(0.00)	(0.18)
Marital status	0.46***	0.15	4.16	0.48***	0.25	5.99	0.54***	0.26	7.19
	(0.15)	(0.22)	(7.45)	(0.17)	(0.22)	(6.78)	(0.15)	(0.23)	(8.96)
Literacy	0.03	0.11	1.36	0.01	0.07	1.93	0.13	0.73***	27.79***
	(0.15)	(0.22)	(7.32)	(0.15)	(0.20)	(6.26)	(0.14)	(0.21)	(8.05)
Education level	-0.04**	-0.01	1.50*	-0.06***	-0.10***	-1.51**	-0.06***	-0.09***	-1.57**
	(0.01)	(0.02)	(0.93)	(0.01)	(0.01)	(0.51)	(0.01)	(0.01)	(0.69)
Sanitary latrine	-0.40***	-0.51***	-9.05**	-0.36***	-0.66***	-10.56**	-0.41***	-0.55**	-3.58
	(0.08)	(0.12)	(4.16)	(0.11)	(0.15)	(4.68)	(0.10)	(0.15)	(5.73)
Drinking water	0.52***	-0.31***	-9.95***	0.47***	0.58***	18.81***	0.48***	-0.95***	-35.64***
	(0.08)	(0.12)	(4.09)	(0.13)	(0.17)	(5.42)	(0.12)	(0.18)	(6.95)
Electricity access	-0.52***	-0.54***	-2.12	-0.34***	-0.43***	2.97	-0.34***	-0.47***	0.68
	(0.10)	(0.14)	(4.81)	(0.09)	(0.12)	(3.70)	(0.10)	(0.15)	(5.71)
Constant	0.81***	4.61***	109.95***	-1.24***	1.69***	36.25***	-0.65***	3.55***	65.96***
	(0.23)	(0.34)	(11.40)	(0.26)	(0.34)	(10.47)	(0.25)	(0.38)	(14.43)
No. of obs.	9367	9367	9367	9092	9092	9092	10467	10467	10467
F-value	923.97***	352.66***	311.48***	710.90***	271.73***	293.71***	764.61***	185.45***	161.63***
R^2	0.59	0.36	0.33	0.54	0.30	0.32	0.52	0.21	0.18
Adj. R^2	0.59	0.36	0.33	0.53	0.30	0.32	0.52	0.20	0.18

Source: Authors' estimation based on BIHS conducted by IFPRI. Note: * p<0.10, ** p<0.05, and *** p<0.01. Values of "t" statistics are presented in parentheses.

Table 8. DD estimation results of periods 2011–19, 2011–15 and 2015–19 irrespective of all climatic events

Variables	Climate change and extreme climatic events								
	2011–19			2011–15			2015–19		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
DD	-	-	-	-	-	-	-	-	-
Year dummy	-	-	-	-	-	-	-	-	-
Treatment group	-1.77***	-0.33***	-212.25***	-1.64***	-0.64***	-44.28***	-0.48***	-0.44*	17.32**
	(0.08)	(0.13)	(3.40)	(0.13)	(0.21)	(6.52)	(0.15)	(0.23)	(8.70)
Farm size	0.00***	-0.02***	-0.42***	0.00***	-0.01***	-0.55***	0.00***	-0.01***	-0.67***
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.21)
Family size	2.27***	1.38***	18.66***	0.71***	0.44***	13.48***	0.70***	0.51***	19.67***
	(0.05)	(0.09)	(2.28)	(0.03)	(0.05)	(1.72)	(0.03)	(0.05)	(2.00)
Gender	-0.00	-0.56***	-3.06	1.23***	0.04	-5.52	0.97***	-0.26	-21.35***
	(0.12)	(0.19)	(4.96)	(0.12)	(0.19)	(6.00)	(0.12)	(0.19)	(7.10)
Dependency ratio	0.09	0.12	12.00***	2.66***	1.67***	49.64***	2.13***	1.37***	49.08***
	(0.10)	(0.16)	(4.22)	(0.08)	(0.12)	(3.92)	(0.07)	(0.12)	(4.48)
Active member	1.03***	0.55***	19.36***	3.24***	1.86***	57.32***	2.80***	1.52***	57.69***
	(0.08)	(0.14)	(3.63)	(0.06)	(0.09)	(3.03)	(0.06)	(0.09)	(3.54)
Age	0.03***	-0.00	0.08	0.02***	-0.01**	-0.18	0.02***	-0.01**	-0.23
	(0.00)	(0.00)	(0.12)	(0.03)	(0.00)	(0.14)	(0.00)	(0.00)	(0.18)
Marital status	0.34**	0.18	0.50	0.27*	0.20	3.65	0.39***	0.18	3.57
	(0.14)	(0.24)	(6.04)	(0.15)	(0.24)	(7.44)	(0.15)	(0.23)	(8.86)
Literacy	-0.02	0.05	-2.44**	-0.01	-0.39**	-15.01**	0.05	0.42**	19.23***
	(0.14)	(0.23)	(5.80)	(0.13)	(0.21)	(6.43)	(0.14)	(0.21)	(8.09)
Education level	-0.03**	-0.06**	-1.11	-0.06***	-0.08***	-1.40***	-0.06***	-0.06***	-0.96
	(0.01)	(0.02)	(0.73)	(0.01)	(0.01)	(0.55)	(0.01)	(0.01)	(0.66)
Sanitary latrine	-0.28***	-0.56***	-13.00***	-0.13	-0.87***	-20.73***	-0.39***	-0.49***	-5.52
	(0.08)	(0.13)	(3.21)	(0.10)	(0.15)	(4.82)	(0.10)	(0.15)	(5.72)
Drinking water	0.58***	-1.20***	-25.30***	0.58***	-1.54***	-47.89***	0.55***	-0.93***	-33.74***
	(0.07)	(0.12)	(3.21)	(0.11)	(0.17)	(5.34)	(0.12)	(0.19)	(7.17)
Electricity access	-0.50***	-0.52***	-1.74	-0.42***	-0.06	9.69***	-0.39***	-0.01	14.07***
	(0.08)	(0.14)	(3.65)	(0.08)	(0.12)	(3.89)	(0.09)	(0.14)	(5.45)
Constant	0.68***	3.56***	155.96***	-1.20***	2.89***	85.36***	-0.53***	2.88***	57.90***
	(0.21)	(0.34)	(8.69)	(0.22)	(0.53)	(10.71)	(0.23)	(0.36)	(13.67)
No. of obs.	11759	11759	11759	12718	12718	12718	11701	11701	11701
F-value	1436.15***	226.52***	504.08***	1213.91***	205.20***	198.94***	956.47***	169.95***	164.91***
R^2	0.61	0.20	0.35	0.55	0.17	0.16	0.51	0.15	0.15
Adj. R^2	0.61	0.19	0.35	0.55	0.17	0.16	0.51	0.15	0.15.

Source: Authors' estimation based on BIHS conducted by IFPRI. Note: * p<0.10, ** p<0.05, and *** p<0.01. Values of "t" statistics are presented in parentheses.

3.5. Discussion

Bangladesh is recognized for most vulnerabilities and extreme events (cyclones, drought, and floods) emerging from global warming and climate change worldwide. Conversely, it is acknowledged that developing countries like Bangladesh that have the least impact on nature and the environment and are the least responsible for the earth's present erratic climatic condition bear the brunt of nature's ire. In terms of cyclones, salinity, coastal erosion, and their terrible effects, out of 64 administrative districts of the country, 19 districts having 41.8 million of the population—expected to increase to 57.9 million by 2050—are severely exposed to cyclone and salinity. Almost every year, cyclones and devastating tidal surges inundate the regions with saline water, negatively impacting and vandalizing the economic structure extremely, more specifically the agricultural sector. They push the regions more into dangerous and unsafe situations in terms of life and livelihood than any other region of the world (Murty and Neralla, 1992). Examples from the recent past are cyclones such as SIDR, AILA, FONI, and AMPHAN in 2007, 2009, 2019, and 2020, respectively, causing significant loss and damage to the country. Cyclone SIDR killed over 3406 people and destroyed more than millions of hectares of broadcast Aman rice just before harvesting (GOB, 2008). Similarly, cyclone AILA damaged almost 90% of the agricultural production, and AMPHAN destroyed approximately 149,000 hectares of croplands (IFRC, 2020). Households' cereal food consumption bears the consequences of these extreme events. Our findings also show that households located in the cyclonic areas suffered immensely and sacrificed cereal food consumption significantly and spent more than other regions of the country (Table 1). These results were also validated by the research and analysis conducted at home and abroad (Henry et al., 2019; Arouri et al., 2015; Thomas et al., 2010). Second, as in many other nations, drought is a prime cause of food insecurity in Bangladesh. The country's North-Western regions are exposed to drought. Almost every five years, Bangladesh suffered major country-wide droughts (Dey et al., 2011). Geographical and agricultural droughts are common and regular phenomena that affect crop production, leading to food insecurity in areas where it outbreaks. The analysis indicated that drought has both long-run and short-run destructive impacts on cereal food consumption, pushing the households toward food insecurity. Our findings are also advanced by the studies of Rahman et al. (2008), Ahmed (2006), Climate Change Cell (2009), and Nasreen and Hossain (2002). Nevertheless, we did not find any influence in households' cereal food purchase and spiraling prices of the cereal grain. This might be due to the government's "open market sale"[25] (OMS) program, from where the marginalized segments of the society bought cereal food at a subsidized price.

Third, Bangladesh is called a riverine country and one of the most flood-prone countries globally. According to the flood history of the country, 16–68% of the total surface areas are inundated every year. Particularly in the monsoon season, 20–25% of plain land is inundated by the "normal flood"[26] (Annual flood report, 2014) and considered beneficial because normal flooding boosts soil fertility by siltation and replenishes soil moisture causing no major harm to life and property. However, "extreme flood"[27] is disastrous for crops and infrastructures. It is largely accepted that the brunt of disasters triggered by extreme events, especially floods, has been disproportionately larger on agriculture (FAO, 2015). Almost every 3–4 years, extreme floods strike and cause huge economic losses to the country. The immediate loss and damage to agriculture create food insecurity for the smallholder farmers and agricultural laborers in the remote village areas. Therefore, floods are both a boon and a curse for the country by making it an extremely complex stigma. From our panel data analysis, we also confirmed that floods' periodic effect (short-term impact) is stronger over the long term and less disastrous than cyclones and drought in the country. A comparative analysis between flood and drought effect on rice production taking data from 1969–1970 to 1983–1984 reveals that drought is more deleterious than a flood (World Bank, 2000). A study conducted by Banerjee (2010) pooling data from the period of 1978–2000 focused on agricultural productivity in flood-prone areas in Bangladesh and found that only "extreme floods" are harmful to agricultural production and productivity. Another research executed by Paul and Routray (2010) also validated that habitants residing in the high and sudden flood geographic circumference suffer significantly. However, data analysis from 1953 to 2020 indicates that the frequency of "extreme flood" increased significantly in recent years along with cyclones and droughts, which is a visible notification of the consequence of climate change.

[25] The Government of the People's Republic of Bangladesh announces and launches a program country-wide, which sells rice and wheat at a subsidized price at BDT 10 (USD 0.12) per Kg. Additionally, it follows other government initiatives, including a significant reduction in import duties and an increase in imports for stabilizing the market price.
[26] Areas inundated around 20% of the country with a lasting period of three weeks or less where the depth of water was 1–2 m in the floodplain and 3 m in the low-lying areas (BNWP, 1986; BUP, 2000; and Banerjee, 2010).
[27] Areas affected by the flood account to more than 35% of the country's surface areas with a period of continuous inundation for one month or more, where water standing depth was 2 m or more in most of the floodplain areas and 3 m or more in low-lying areas (BNWP, 1986; BUP, 2000; and Banerjee, 2010).

3.6. Conclusions

First, as 80% of Bangladesh is flood-prone, it has multiple effects on agricultural farm families. Occasionally, the flood becomes a blessing than a curse. Our findings also validate this. At different time points, we found various effects, which might be due to the magnitude, frequency, and occurring time (whether early, as usual, or late). Above all, floods have dangerous effects on household cereal food consumption and purchase from other sources. Second, cyclones, salinity, tidal surges, SLR, and coastal erosions are always detrimental to agricultural production practices. At all points of our panel data analysis, we confounded negative impact with significance at various levels. Third, in drought-stricken areas, we found significant outcomes indicating that drought severely impacts the respective areas over time. However, the bottom line is that cyclone-affected areas are more vulnerable than all other areas.

Finally, considering the base year's entire sample as a control variable, our results guaranteed that climate change and extreme climatic events, as a whole, significantly affect household cereal food consumption and force them to purchase from other sources, leading to soaring cereal prices. Additionally, their combined effects limit the country's economic progress and sustainable development, distorting some development indicators.

The current challenge is to reduce the risks and hazards of climate change and extreme climatic events toward cereal production and future food production. The existing deficit situations of food require knowledge-based agricultural practice, time-bound policy, adaptation, and mitigation. Therefore, to stave off the impacts of climate change and its resultant climatic extremes and boost the country's agricultural production performance for offsetting households' food insecurity, this study recommends some policy measures and direct actions. This study suggests intensifying agricultural research through robust budget allocation and environment-friendly and climate-benign technology innovation and adoption. Further, it points to the need for launching crop insurance schemes and the development of various technologies sustaining the saline, drought, and flood-prone areas. Additionally, the study advocates the adoption of cultivars and the strengthening of the flood forecasting and early warning system (FFEWS) of the Bangladesh Water Development Board.

CHAPTER IV

Climate Change, Extreme Climatic Events and Household Expenditure

4.1. Introduction

Bangladesh is an agrarian country and more than 70% people live in rural areas and their primary occupation is agriculture. As a key economic sector, agriculture continues to be the mainstay for the rural livelihood and contributes for nearly 14.74% of the country's GDP (gross domestic product) (BBS, 2017) and engaged 65% of the labor forces (Yu et al., 2010). Owing to global warming, Bangladesh is experiencing disastrous weather extremes repeatedly nowadays. For instance, in the recent past cyclone 'Fani' in 2019, super cyclone 'Amphan' in 2020, and cyclone 'Yaas' in 2021 are the piece of evidence of extreme events. Being one of the prime hot spots for climatic extremes and catastrophes in the world, the country is suffering from severe household income loss and deficiency in the subsequent household expenditure. Cyclones, droughts and floods are recursive in nature and economic burden due to these extreme climatic events is enormous (Nino et al., 2003; Khandker, 2007; Sarker et al., 2012). Besides, climate change and variability quivers and intensify the extreme climatic events significantly for making landfall (IPCC, 2011a, b and Khan and Rahman, 2007) and that leads to amounting of income losses over time. For example, Bandyopadhyay and Skoufias (2015) pointed that climate-induced precipitation variability influences employment via household income reduction resulting in less household expenditure especially on food expenditure. In addition, climate change is acting as a buttress of food price hike substantially (Friel and Bradbear, 2013). Moreover, it escalates the momentum of the food supply chain (FSC) adversely (Godfray et al., 2010).

Intergovernmental Panel on Climate Change (IPCC, 2007) identifies Bangladesh one of the smallest countries in the world that has been suffering severe vulnerability to the issues related to climate change, extreme climatic events and related anthropogenic hazards. In addition, IPCC also predicts by 2100, average global temperature increases 1.8 to 4.0^{o}C and affects crop, livestock and fisheries production and people at hunger risk may be double by 2050. Poor people at root level are real sufferers undoing any harm to environment related to climate change (Pal, 2010). Climate variability and change increases the frequency and intensity of extreme events (Patwary, 2016) and it causes substantial damage to crop, livestock and fisheries. Nonetheless, Bangladesh has made remarkable progress in reducing poverty and hunger, as well as achieved Millennium Development Goals (MDGs) by 2015 successfully. In 2010, Bangladesh achieved national food security by increasing annual rice production from 151 kg/capita in 1995 to 217 kg/capita due to increases in area irrigated and in yield (Mainuddin and Kirby, 2015).

Geographically, Bangladesh is a low lying delta and characterized by the confluence of three mighty rivers- the Ganges, the Brahmaputra and the Meghna and it is crisscrossed by more than 200 rivers. Down-stream riparian and extensive floodplains are the salient morphological feature of the state. Besides, in its South, the Bay of Bengal is located embracing almost 19 administrative districts out of 64 districts. This hydro-meteorological complex stigma produces the country vulnerable to an array of extreme climatic event such as cyclones, droughts and floods (see fig. 2). For instance, in year 2007, Bangladesh experienced a severe flooding from July to September that caused extreme damage to agricultural production. Furthermore, giving no time to recover, in the same year on 15th November cyclone SIDR, a mighty as well as deadly storm had landfall across the Southern cost of the country and killed above 3,000 human life. The estimated economic loss was over US$ 1.00 billion and nowadays the loss disquietingly increasing (see figure 1). Extreme weather events have significant adverse effects on crop yield and subsequent food security (Chavez et al., 2015). Erratic weather condition accompanied by weather extremes such as cyclones, droughts, and floods batter and raze their life repeatedly and make them more vulnerable to household expenditure. Owing to extreme events, Bangladesh experiences soared price of basic commodities.

Climate change will increase dependency of developing countries on imports and accelerate existing food insecurity especially in South Asia (Josef et al., 2007). More than one out of seven people don't have access to sufficient protein and energy for their diet still today, and even more suffer from some form of micronutrient malnourishment (FAO, 2009). Wheeler and Braun (2013) argued that climate change could potentially interrupt progress toward a world without hunger. The stability of whole food systems may be at risk under climate change because of short-term variability in supply. Moreover, climate variability and change will exacerbate food insecurity in areas currently vulnerable to hunger and under nutrition. Households for a long time need to adapt to these dynamic conditions to maintain their livelihoods and food self-sufficiency remains a key development agenda for the country.

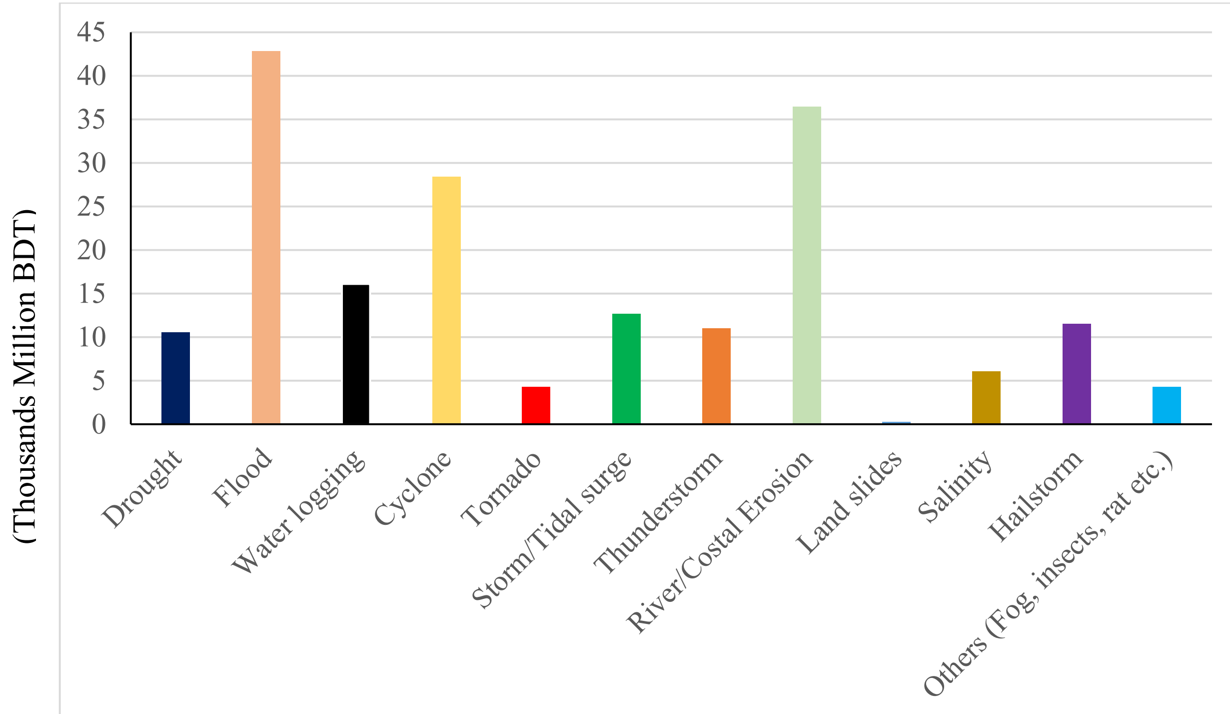

Figure 1. Financial loss by extreme events in between 2009-2014

Source: BBS, 2015 (Bangladesh Disaster-related Statistics).

Though this research dimension is important due to long-term communal and regional impacts of extreme climatic events but existing studies seldom analyze the impact of climate change and extreme climatic events on household expenditure. Our novelty in this paper to contribute to assess the effects of climatic disaster like cyclones, droughts, and floods in Bangladesh. In the paper, we want to seek answer of the query, "to what degree do climate change and climatic extremes influence the household expenditure?"

The structure of this paper is designed as follows. Firstly, the papers aimed at the impact of climate change and climatic extremes on household expenditure of Bangladesh taking evidence from Bangladesh Integrated Household Survey (BIHS). Following section reviews existing literature on climate change, extreme climatic events and their effects on household income and expenditure to understand its significance and to monitor whether present research problem (i.e., climate change and extreme climatic events) demand for sufficient research novelty or not. Subsequent section, discusses about materials and methods elaborately in which analytical procedures, variable measurements, variable definition, data source and descriptive statistics are got priority. Consequent section presents the empirical research results of the analysis. Finally, we would have concluded the discussion in the light of overall arguments and facts.

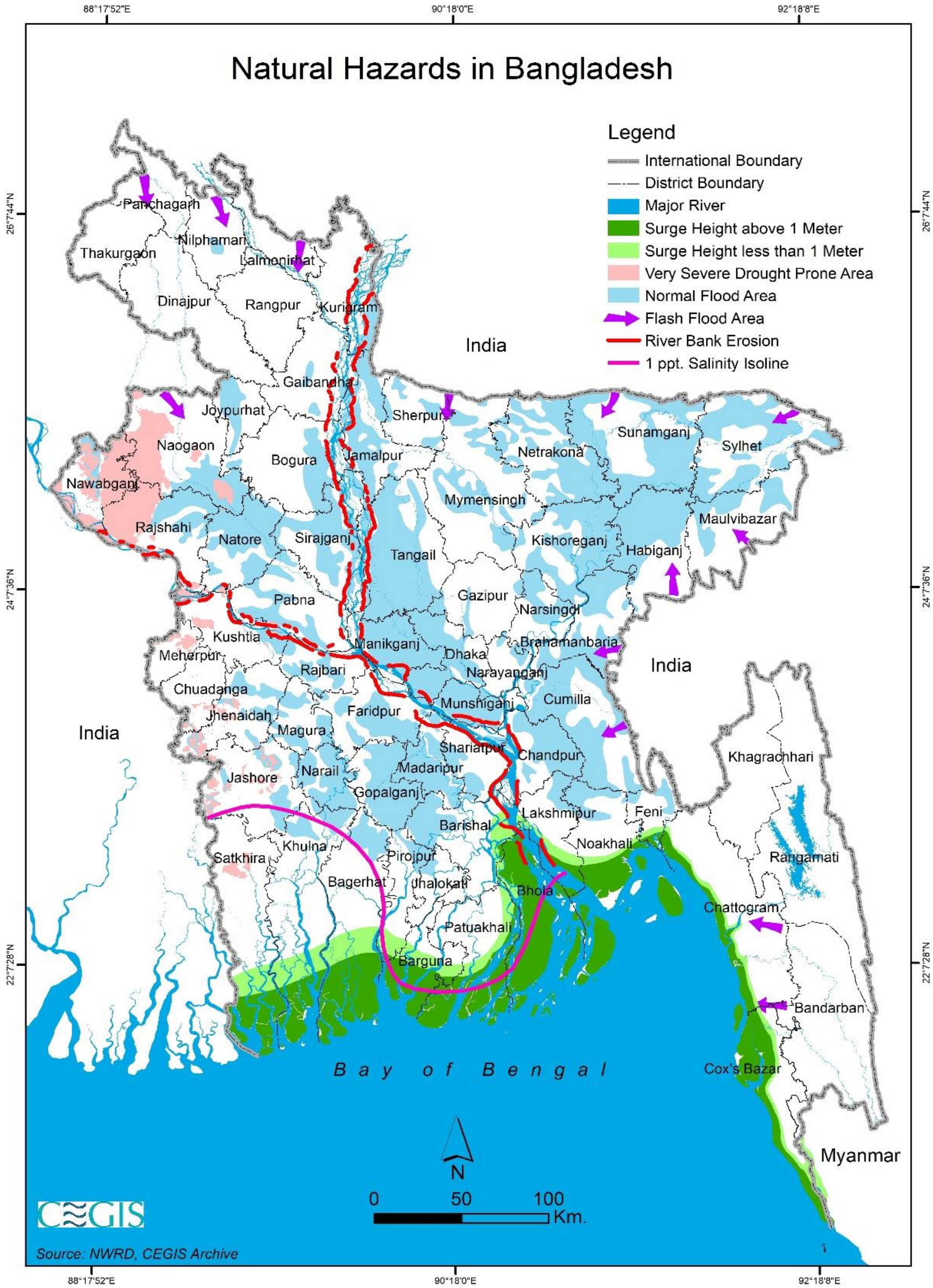

Figure 2. Climate extremes areas of Bangladesh (MoEF, 2008)

Source: Center for Environmental and Geographic Information Services (CEGIS)

4.2. Literature Review: Climate change, extreme climatic events and household expenditure

Research on climate change and extreme climatic events –cyclones, droughts and floods aligned with household expenditure on food and non-food entities are precisely summarized in this section. Arguably, climatic extremes linked with climate variability are expected to rise as the globe is becoming warmer in relation with significant economic adversity mostly in the developing and lest developed countries, the poor segment of the world (Acevedo, 2014; Felbermayr & Groschl, 2014; Karim, 2018). It is bleak reality that altering of climate is inevitable to cause and continuously lashing those who are in the vulnerable geographic location. Besides, it is a great challenge to poverty eradication and food security as well.

As the climate variability and change induced to cause repeated catastrophic events and that could lead to accumulation of income losses over time. Therefore, climatic extremes have become a serious development concern with probability of rolling back years of development gains and exacerbate inequality. For example, Bandyopadhyay and Skoufias (2015) indicated that climate induced precipitation variability influence employment resulting less consumption in flood affected areas in rural Bangladesh.

In the existing literature regarding climate change, extreme climatic events and their impact on economic development- income, expenditure, consumption, welfare have been taken priority and have been discussed in covering widespread angle. For instance, Gray et al. (2012) paid attention on natural disasters and population mobility, Keerthiratne and Tol (2018) focus on natural disaster and income inequality, Ahmed et al. (2009) research on climate volatility and poverty, Karim (2018) plotted on impact of climatic disaster (i.e., recurrent flooding) on household income, expenditure, assets and labor market outcomes. The author conducted this research pooling data from Household Income and Expenditure Survey (HIES) in Bangladesh and showed that recurrent flooding has significant negative impact on agricultural income and expenditure (Karim, 2018). Alamgir et al. (2018) argued that climate change has potential influence on farmers' net income distribution and regional vulnerability. Climate change is occurring and increasingly hitting the impoverished segment, moreover, the resource-poor rural peasant communities are frequently shocked by its' negative impact on household food security. Climatic extremes and non-linear climatic variability are occurring across multiple domains and varying on wide scales. Moreover, these new hazards and correlations are emerging in way that had not been forecast.

Changing of precipitation pattern and temperature fluctuation in different regions of Bangladesh are significantly higher in comparison with IPCC prediction. This variability has a negative impact on rice and wheat production (Hossain and Silva, 2013) and significant production reduction taken place and these all lead to significant income reduction in the household and subsequent household expenditure too. Fifth assessment report of the IPCC reported that food production in Asia will vary and show declining trend in large parts of the regions under the buckle of climate change (IFPRI, 2013). Shrestha at el. (2017) showed that in northern Thailand vulnerability of farm households exists under the negative impact of climate change.

Mottaleb et al. (2013) found that climatic extremes cyclone 'Aila' that made landfall in the coastal belts of Bangladesh in May 2009, resulted in greater falls in household schooling expenditure and children's school admission who are affected compare to unaffected households. Olutumise et al., (2021) conducted a study to evaluate the impact of climate variability on household healthcare expenditure in Southwest of Nigeria taking cross-sectional data employing multinomial logit and binary logistic models. They found that household food production is decreasing due to increasing climatic extremes- heavy rainfall, storms and floods. Likewise, households that belonged to weather extremes areas had experienced to spend more on healthcare issues. An empirical study on effects of droughts and household education expenditure in rural Iran by Khalili et al., (2020a), revealed that households severely exposure to droughts demonstrated decreased farm income and increased households' education expenditure as well as households forced to drop their female from school. In another study by the same authors published in the same year affirmed that households' expenditure is higher on healthcare which are severely affected by droughts compare to their counterparts that are not affected (Khalili et al., 2020b).

A study conducted by Arouri et al. (2014) employing panel data from the Vietnam Household Living Standard Survey (VHLSS) in 2004, 2006, 2008, and 2010. They confirmed that weather extremes such as storms, floods, and droughts have significant negative effects on household income and expenditure. In another study, Bui et al. (2014) conducted a study using data from the Vietnam Household Living Standard Survey in 2008 and revealed that due to extreme weather events household per capita income and expenditure declines by 6.9% and 7.1%, respectively. They assured that natural disasters significantly worsen the poverty and inequality as well. In Ethiopia, Dercon (2004) focused on economic growth and shocks and found that rainfall shock has a long term effects on household food consumption.

In summary, existing literature related to the impact of climate change and variability, extreme climatic event, adaptation and mitigation, forecasting and climate modeling were found a much talk at home and abroad. However, it suffers from an array of research gap climatic extreme and household expenditure, are discussed in this paper. Additionally, a lot of published articles were not prevalence with their country coverage. This article, therefore, keen to seek relation between extreme climatic events and household expenditure, by entangling up to date, comprehensive and neatly organized forms of household expenditure data.

4.3. Materials and Methods

In this part of the research analysis, we would like to give the message and information on analytical technique, variable measurement, variables definition, data source, and the descriptive statistics for the study stepwise.

4.3.1. Analytical technique: Pooled-OLS, Fixed Effects and Random Effects

To address the effects of climate change and extreme climatic events – cyclones, droughts and floods on households' expenditure, this study judiciously proceeds with panel estimation approaches of the pooled-OLS, the fixed effects (FE) and the random effects (RE) model. Simple pooled-OLS cannot adjust for the time-specific or company-specific effects. But, the fixed effects and the random effects model can able to solve this type of problem. Basically, the pooled-OLS technique is a form of statistical regression analysis that finds the line of best fit for a dataset by giving a visual construction of the relationship between data points. But, the fixed effects model, theoretically, is better to the cases of unobservable individual-effects which are correlated with the included variables. Conversely, if the individual-effects are strictly uncorrelated with the explanatory variables, then the random effects model is a better choice (Green, 2018). After estimation, we then compare the fixed effects model and the random effects model in order to seek the most suitable model for the panel datasets. In this regard, the Hausman test results will guide to select the appropriate model for the panel regression. Hence, the null hypothesis (H_0) defines as the RE model is appropriate whereas the alternative hypothesis (H_1) states the FE model is more appropriate. Therefore, the following are the econometric expressions for the measurement of the impact of climate extremes.

$$HH\_Exp \text{ (Household total expenditure)} = \alpha_{it} + \beta_1 \text{ (Affected group)} + \beta_2 \text{ (Farm size)} + \beta_3 \text{ (Family size)} + \beta_4 \text{ (Gender)} + \beta_5 \text{ (Dependency ratio)} + \beta_6 \text{ (Active member)} + \beta_8 \text{ (Age)} + \beta_9 \text{ (Marital status)} + \beta_{10} \text{ (Literacy)} + \beta_{11} \text{ (Education level)} + \beta_{12} \text{ (Sanitary latrine)} + \beta_{13} \text{ (Drinking water)} + \beta_{14} \text{ (Electricity access)} + \beta_i \text{ (Regional dummies)} + \varepsilon_{it} \text{ ----------------------------- (1)}$$

$$HH\_FExp \text{ (Household food expenditure)} = \alpha_{it} + \beta_1 \text{ (Affected group)} + \beta_2 \text{ (Farm size)} + \beta_3 \text{ (Family size)} + \beta_4 \text{ (Gender)} + \beta_5 \text{ (Dependency ratio)} + \beta_6 \text{ (Active member)} + \beta_8 \text{ (Age)} + \beta_9 \text{ (Marital status)} + \beta_{10} \text{ (Literacy)} + \beta_{11} \text{ (Education level)} + \beta_{12} \text{ (Sanitary latrine)} + \beta_{13} \text{ (Drinking water)} + \beta_{14} \text{ (Electricity access)} + \beta_i \text{ (Regional dummies)} + \varepsilon_{it} \text{ ----------------------------- (2)}$$

$$HH\_nFExp \text{ (Household non-food expenditure)} = \alpha_{it} + \beta_1 \text{ (Affected group)} + \beta_2 \text{ (Farm size)} + \beta_3 \text{ (Family size)} + \beta_4 \text{ (Gender)} + \beta_5 \text{ (Dependency ratio)} + \beta_6 \text{ (Active member)} + \beta_8 \text{ (Age)} + \beta_9 \text{ (Marital status)} + \beta_{10} \text{ (Literacy)} + \beta_{11} \text{ (Education level)} + \beta_{12} \text{ (Sanitary latrine)} + \beta_{13} \text{ (Drinking water)} + \beta_{14} \text{ (Electricity access)} + \beta_i \text{ (Regional dummies)} + \varepsilon_{it} \text{ ----------------------------- (3)}$$

where α_{it} ($i = 1,\ldots, n$) is the unknown intercept for every individual, t denotes the year analyzed, β_s are the coefficients for every independent variables included in the models and ε_{it} is the error term.

4.3.2. Variables measurement

4.3.2.1. The dependent variables

For assessing the impact of climate change and extreme climatic events on household expenditure, we logically have taken three dependent variables viz.: household total expenditure; household food expenditure; and household non-food expenditure. In more detailed way, first, household total expenditure (HH_Exp.)- the amount of money (BDT) expend for entire consumption (e. g. food expenditure and non-food expenditure) by the all family members in a family. Second, household food expenditure (HH_FExp.)- the amount household spend on food only to feed all the members in a family. Third, household non-food expenditure (HH_nFExp.)- denotes the spending on non-edible items, e.g.; house rent, education cost, treatment cost, payment for clothing, bills pay for gas, electricity and water, transportation and the related cost. In all these three cases, data were collected in the last one month during the survey administered and transformed to natural log (ln). Accordingly, our null hypothesis (H_0) is household in the climate vulnerable areas spent less compare to their base year because of climatic stress. Additionally, it is important to explain that we used deflated value in the measurement to check the inflation effect in the treatment year.

4.3.2.2. The independent variables

In this analysis, we used the following independent/ control variables that are consist of a set of “Socio-Demographic”, “Economic” and “Regional” features of the farm households. The “socio-demographic” characteristics included farm size, family size, gender, dependency ratio, active member, age, marital status, literacy, and education level, etc. The “economic” features of control variables included access to a sanitary latrine, usage of safe drinking water, and availability of electricity to the households. And, the “regional” variables are location specific dummy variable. All these variables are considered to be pertinent to explain the response of the dependent variable.

4.3.3. Variables definition

Household expenditure is defined as the total quantity of money spent by the household during a specific period of time, e.g., last 7 days, 1 months or 1 year on all sorts of purchases goods and services. It is, of course, in present value (PV) currency terms (BLS, 2011; and ICPSR, 2011). Bangladesh Integrated Household Survey (BIHS) was conducted under direct guideline and supervision of International Food Policy Research Institute (IFPRI) in Bangladesh through a well-constructed structured questionnaire, it collected and compiled households' expenditure data elaborately. Explicitly, it gathered data on broad two categories such as food expenditure and non-food expenditure. All kinds of edible expenses, e. g., spending on all foods including tobacco went under the head of Household Food expenditure (HH_FExp.). On the other hand, Household Non-food Expenditure (HH_nFExp.) entangles the following- house rent and related, treatment cost, educational expenses, clothing materials, transport/ travelling, fuel and lighting, cosmetic and related, footwear, ceremonies and recreations, furniture, taxes and related, personal articles (jewelry) and miscellaneous households' durable goods (radio, TV, VCD, VCR), etc. In our analysis, Household Total Expenditure (HH_Exp.), Household Food expenditure (HH_FExp.) and Household Non-food Expenditure (HH_nFexp.) are per capita monthly recall data and deflated to its base line value. Table 1 gives the details of all variables used in this article.

Table 1. Definition of the variables

Variables	Definition
HH_Exp.	Household expenditure (as a proxy of income) refers to the amount of money spend for final consumption by the members belong to the same family circumference to meet daily needs i. e., food, clothing, housing, energy, transport, durable goods (notably cars), treatment cost, leisure, and miscellaneous services (OECD, 2021).
HH_FExp.	The share of total household expenditure spent on food is treated as food expenditure and it is a widely accepted indicator of household food security as well. According to Engel's law, the poorer and more

	vulnerable household has larger share of household income spent on food (INDDEX, 2021).
HH_nFExp.	Household non-food expenditure indicates the expenses on non-edible items, such as payment for clothing, house rent, education cost, medical cost, bills pay for gas, electricity and water, transportation and other related cost.
Farm size	Using land under operation to agricultural production by household (own land plus rented in)
Family size	Total number of members in a family
Gender	1 = yes, if household head is female, and 0 = male
Dependency ratio	No. of dependent/ no. of working force
Active member	Household members' age in between 15 to 60 years consider as active family working force for earnings.
Age	Household head's age in years
Marital status	1 = yes, if the household head is married, and 0 = otherwise
Literacy	1 = literate, if household head can read and write, and 0 = otherwise
Education level	Year of schooling
Sanitary latrine	1 = access to sanitary latrine, and 0 = otherwise
Drinking water	1 = usage of tube-well water or related for drinking and household activities, and 0 = otherwise
Electricity access	1 = households have electricity connection, and 0 = otherwise
Khulna	1 = Khulna, 0 = otherwise
Barisal	1 = Barisal, 0 = otherwise
Rajshahi	1 = Rajshahi, 0 = otherwise
Chattogram	1 = Chattogram, 0 = otherwise
Dhaka	1 = Dhaka, 0 = otherwise
Rangpur	1 = Rangpur, 0 = otherwise
Sylhet	1 = Sylhet, 0 = otherwise

Source: authors' assumption.

4.3.4. Data

This study was conducted by taking household survey data collected in the period of 2011-12, 2015 and 2018-19 which was administered by the International Food Policy Research Institute (IFPRI) with its technical expertise and sample taken from the then seven (currently eight) administrative divisions covering whole country. A multi-stage stratified random sampling technique was followed to collect household data from the pre-defined sample household. First of all, considered 325 primary sampling unit across the country and then pick up 20 farm households from each primary sampling unit and then total volume of sample was 6500. This data sets are called the Bangladesh Integrated Household Survey (BIHS) data. The BIHS data sets are thoroughly and uniquely captured all features of households through a well-defined structured questionnaire. Further, it is worthy to explain that the attrition rate from the base line survey (in 2011-12) to 2nd follow-up survey (in 2015) is 4.41% (Ahmed, 2016). In the 3rd phase, however, it was approximately 13.78%, as the total sample is 5604. Till to date, IFPRI has conducted these three rounds of households' survey. Interestingly, we analyzed all the three data sets. Reviewing of all characteristics these data sets are nationally representative and consistently persuasive.

4.3.5. Descriptive statistics

Table 2 shows the descriptive statistics of the variables of interest. The total number of observations were 18494. The mean, stander deviation, maximum and minimum value of each variable are also presented in the table mentioned above. Besides, we tested the correlation among the variables included in the analysis and found no strong correlation among the main explanatory variables (see Appendix VI).

Table 2. Descriptive statistics

Variable	Observation No.	Mean	Std. Dev.	Min	Max
HH_Exp	18494	12644.06	8255.86	750.36	127494.50
HH_FExp	18494	7160.72	4687.32	221.42	74705.89
HH_nFExp	18494	5483.33	4601.11	313.47	59504.63
Affected	18494	0.51	0.49	0	1
Farm size	18494	57.83	109.69	0	2577.5.

Family size	18494	4.44	1.83	1	21
Gender	18494	0.80	0.39	0	1
Dependency ratio	18494	0.86	0.76	0	6
Active member	18494	2.47	1.20	0	12
Age	18494	45.47	13.87	16	108
Marital status	18494	0.89	0.30	0	1
Literacy	18494	0.32	0.46	0	1
Education level	18494	3.81	4.13	0	16
Sanitary latrine	18494	0.55	0.49	0	1
Drinking water	18494	0.36	0.48	0	1
Electricity access	18494	0.62	0.48	0	1

Source: Authors' calculation.

4.4. Empirical Results

4.4.1. Impact assessment on household expenditure as a whole

From Table 3, it is seen that the coefficient of the variable 'Affected group' is significant with negative sign in all the three estimated econometric models- Pooled-OLS, Fixed Effects and Random Effects and the significant levels are 5%, 10% and 1%, respectively. This means that people (affected group) those who are currently living in the three respective climate vulnerable areas such as cyclones, droughts and floods stricken areas spent less in their household expenditure compare to their counterpart the unaffected and resilient group. This is because the affected households lost their earning means due to weather extremes such as cyclones, droughts and floods as well as got less harvest from their agricultural operations (cultivation of cereals and others) and even sometimes no return from their investment in the agriculture sectors. Based on models Pooled-OLS, Fixed Effects and Random Effects, climate change and climatic extremes lead to a fall of household expenditure by 1%, 3% and 2%, respectively. As the intensity and frequency of extreme climatic events are increasing nowadays, the farm households are also suffering more regarding household expenditure.

Table 3 Impact of climate change and extreme climatic events on HH total expenditure

HH_Exp	Pooled-OLS	Fixed Effects	Random Effects
Affected	-0.01** (0.04)	-0.03* (0.10)	-0.02*** (0.00)
Farm size	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)
Family size	0.13*** (0.00)	0.14*** (0.00)	0.14*** (0.00)
Gender	-0.07*** (0.00)	-0.00 (0.73)	-0.04*** (0.00)
Dependency ratio	-0.08*** (0.00)	-0.08*** (0.00)	-0.08*** (0.00)
Active member	0.01*** (0.00)	-0.01*** (0.00)	0.00 (0.82)
Age	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)
Marital status	0.15*** (0.00)	0.02 (0.16)	0.11*** (0.00)
Literacy	-0.02*** (0.00)	-0.01*** (0.01)	-0.00 (0.39)
Education level	0.03*** (0.00)	0.00*** (0.00)	0.02*** (0.00)
Sanitary latrine	0.14*** (0.00)	0.05*** (0.00)	0.10*** (0.00)
Drinking water	0.11*** (0.00)	-0.01** (0.04)	0.05*** (0.00)
Electricity access	0.20*** (0.00)	0.11*** (0.00)	0.17*** (0.00)
Khulna	0.11*** (0.00)	0 (omitted)	-0.20*** (0.00)
Barishal	0.21*** (0.00)	0 (omitted)	-0.11*** (0.00)
Rajshahi	0.10*** (0.00)	0 (omitted)	-0.20*** (0.00)
Chittagong	0.39*** (0.00)	0 (omitted)	0.08*** (0.00)
Dhaka	0.25*** (0.00)	0 (omitted)	-0.06*** (0.00)
Rangpur	0 (omitted)	0 (omitted)	-0.31*** (0.00)
Sylhet	0.32*** (0.00)	0 (omitted)	0 (omitted)
Constant	7.89*** (0.00)	8.49*** (0.00)	8.30*** (0.00)
Number of obs.	18089	18089	18089
F-value	971.40*** (0.00)	311.44*** (0.00)	13460.02*** (0.00)
R^2	0.51	0.39 (overall)	0.49 (overall)
Adj. R^2	0.50	-	-
Hausman Test		1241.70 (0.00)	
F test for individual Effect		3.26*** (0.00)	

Source: Authors' estimation. Note: * p<0.10, ** p<0.05, and *** p<0.01. Values of "t" statistics are presented in the parentheses.

4.4.2. Impact assessment on household food expenditure

Table 4 shows that the coefficient of the variable 'affected group' is negative at different levels of significance with models estimated in the analysis. Pooled-OLS, and Random Effects Models both are significant at 1% level, but the Fixed Effects model is insignificant (significant at 20% level). This also indicate that the households (affected group) resided in the cyclones, drought and flood prone areas expend less to their household food expenditure. Pooled-OLS and Random Effects models show that per capita household food expenditure fall by 1% and 2% This is because of household income loss and loss of household agricultural production.

Table 4 Impact of climate change and extreme climatic events on HH food expenditure

HH_FExp	Pooled-OLS	Fixed Effects	Random Effects
Affected	-0.010*** (0.01)	-0.03 (0.20)	-0.02*** (0.00)
Farm size	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)
Family size	0.15*** (0.00)	0.15*** (0.00)	0.15*** (0.00)
Gender	-0.00 (0.58)	0.06*** (0.00)	0.01* (0.06)
Dependency ratio	-0.07*** (0.00)	-0.08*** (0.00)	-0.07*** (0.00)
Active member	0.01 (0.87)	-0.03*** (0.00)	-0.00* (0.06)
Age	0.00*** (0.00)	0.00 (0.13)	0.00*** (0.00)
Marital status	0.14*** (0.00)	0.04** (0.02)	0.12*** (0.00)
Literacy	-0.03*** (0.00)	-0.03*** (0.00)	-0.02*** (0.00)
Education level	0.02*** (0.00)	0.00*** (0.00)	0.02*** (0.00)
Sanitary latrine	0.09*** (0.00)	0.03*** (0.00)	0.07*** (0.00)
Drinking water	0.05*** (0.00)	-0.03*** (0.00)	0.02*** (0.00)
Electricity access	0.13*** (0.00)	0.04*** (0.00)	0.10*** (0.00)
Khulna	0.13*** (0.00)	0 (omitted)	-0.25*** (0.00)
Barishal	0.23*** (0.00)	0 (omitted)	-0.15*** (0.00)
Rajshahi	0.09*** (0.00)	0 (omitted)	-0.28*** (0.00)
Chittagong	0.37*** (0.00)	0 (omitted)	-0.01 (0.41)
Dhaka	0.29*** (0.00)	0 (omitted)	-0.09*** (0.00)
Rangpur	0 (omitted)	0 (omitted)	-0.39*** (0.00)

Sylhet	0.39*** (0.00)	0 (omitted)	0 (omitted)
Constant	7.39*** (0.00)	8.00*** (0.00)	7.85*** (0.00)
Number of obs.	18089	18089	18089
F-value	746.67*** (0.00)	239.59*** (0.00)	11091.04*** (0.00)
R^2	0.43	0.34 (overall)	0.43 (overall)
Adj. R^2	0.43	-	-
Hausman Test		620.18*** (0.00)	
F test for individual Effect		2.46*** (0.00)	

Source: Authors' estimation. Note: * p<0.10, ** p<0.05, and *** p<0.01. Values of "t" statistics are presented in the parentheses.

4.4.3. Impact assessment on household non-food expenditure

Table 5 represents the results that the coefficient of the variable 'affected group' are negative in all the three models. Here, the Random Effects model is significant at 10% level and the rest two (Pooled-OLS and Fixed Effects) are insignificant. These results also confirm that households located in the climate vulnerable and extreme climatic areas spent less on non-food items than the unaffected farm households. According to Random Effects model per capita household non-food expenditure (education, treatment and the related) fall by 1%.

Table 5 Impact of climate change and extreme climatic events on HH non-food expenditure

HH_nFExp	Pooled-OLS	Fixed Effects	Random Effects
Affected	-0.00 (0.31)	-0.00 (0.89)	-0.01* (0.06)
Farm size	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)
Family size	0.12*** (0.00)	0.12*** (0.00)	0.12*** (0.00)
Gender	-0.17*** (0.00)	-0.06*** (0.00)	-0.13*** (0.00)
Dependency ratio	-0.10*** (0.00)	-0.07*** (0.00)	-0.09*** (0.00)
Active member	0.03*** (0.00)	0.00 (0.25)	0.02*** (0.00)
Age	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)
Marital status	0.17*** (0.00)	0.00 (0.83)	0.12*** (0.00)
Literacy	-0.01 (0.14)	-0.00 (0.55)	0.00 (0.30)
Education level	0.04*** (0.00)	0.01*** (0.00)	0.03*** (0.00)

Sanitary latrine	0.21*** (0.00)	0.09*** (0.00)	0.16*** (0.00)
Drinking water	0.18*** (0.00)	0.01 (0.13)	0.10*** (0.00)
Electricity access	0.30*** (0.00)	0.20*** (0.00)	0.28*** (0.00)
Khulna	0.08*** (0.00)	0 (omitted)	-0.11*** (0.00)
Barishal	0.16*** (0.00)	0 (omitted)	-0.03** (0.05)
Rajshahi	0.10*** (0.00)	0 (omitted)	-0.07*** (0.00)
Chittagong	0.40*** (0.00)	0 (omitted)	0.22*** (0.00)
Dhaka	0.18*** (0.00)	0 (omitted)	-0.00 (0.99)
Rangpur	0 (omitted)	0 (omitted)	-0.18*** (0.00)
Sylhet	0.19*** (0.00)	0 (omitted)	0 (omitted)
Constant	6.89*** (0.00)	7.41*** (0.00)	7.15*** (0.00)
Number of obs.	18089	18089	18089
F-value	760.70*** (0.00)	189.28*** (0.00)	10330.50*** (0.00)
R^2	0.44	0.34 (overall)	0.44 (overall)
Adj. R^2	0.44	-	-
Hausman Test		1164.05*** (0.00)	
F test for individual Effect		2.73*** (0.00)	

Source: Authors' estimation. Note: * p<0.10, ** p<0.05, and *** p<0.01. Values of "t" statistics are presented in the parentheses.

Likewise, to examine the impact of climate change and extreme climatic events on household expenditure (per capita), we have taken household characteristics and location as explanatory variables in the area the household belongs to which are defined in the methodology part in this article and those are generally used as determinants of households' income and expenditure in the literature (Bui et al., 2014). As the literature guides education and household wealth- farm size may sway the household income and expenditure. Our regression results, almost in all cases- Pooled OLS, Fixed Effects and Random Effects, report that farm size, education level of the household heads and other economic indicators such as usage of sanitary latrine, safe drinking water sources and availability of electricity in the house have significant positive impact on household expenditure Tables 3-5.

The F-test for individual effect was found significant (Prob. > F = 0.00) in all cases which represents there is specific individual household effect. In addition, the probability value of "Hausman Test" is significant, which guides the rejection of null hypothesis (H_0) by accepting the alternative hypothesis (H_1) of "Fixed effect" model is more efficient than "Random effect" model.

4.5. Discussion

Among 'South Asian'[28] countries, Bangladesh is widely recognized as the most disastrous prone country due to its fatality to life, property and development activities. In between 2009 and 2014 (5 years), a total of 4,361,261 households were affected by the climatic extremes. Households affected by extreme events such as droughts, floods, waterlogging, cyclones, tornado, storm/tidal surge, thunderstorm, river/coastal erosion, landslides, salinity, hailstorm and others (fog, etc.) by 14.80%, 34.48%, 13.88%, 21.31%, 4.14%, 8.65%, 14.94%, 4.95%, 0.08%, 4.09%, 11.88%, and 7.90%, respectively. Additionally, average non-working days due to these extreme events approximately 12.13% (BBS, 2016). Therefore, it is easily understandable that climate change and climatic extreme have horrendous impact on household income and expenditure. Bui et al (2014) showed that due to natural disaster household per capita income dropped by 7% in the exposure areas of Vietnam. Other researchers, e. g., Krueger and Perri (2010), and Masozera et al. (2007) also found a significant negative impact of weather extremes on household income. According to Household Income and Expenditure Survey (HIES) 2016 of Bangladesh, average household size was 4.06, per household income 15,988 BDT[29], and per household expenditure 15,715 BDT (BBS, 2018). From our analysis, we can see that household resided in the climate vulnerable areas spent less on the household expenditure and it was 3% fall (Fixed Effects Model-the most efficient model on the basis of Hausman Test) on the total household expenditure that means a negative relation between extreme events and household per capita expenditure. Our findings are in line with Bui et al. (2014) and they reported that shock from natural disaster declines per capita household expenditure by 8.3%. Moreover, our analyses on food expenditure (Dercon, 2004) and non-food expenditure showed negative sign (-) in all the models underpinning the evidence that extreme

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[28] South Asia includes the following countries of **Bangladesh, Bhutan, India, Pakistan, Nepal, and Sri Lanka**. Very often **Afghanistan** and the **Maldives** are considered part of South Asia as well.
[29] One US$ is equal to 84.94 Bangladeshi Taka. As on 14th September 2021.

climatic events have negative effects on food consumption, education, health and the associated. Our findings are also supported by Olutumise et al. (2021); Khalili et al. (2020a); Khalili et al. (2020b) and Mottaleb et al. (2013) on non-food expenditure such as education expenditure as well as on healthcare expenditure. Though GOs (government organizations), NGOs (non-government organizations- national and international) and foreign development partners are working in Bangladesh and play a vital role to alleviate the misery at the time of extreme events and post events by supporting the affected group immediately with food aid and other aid too. For example, international development partners distributed about 4.82 billion dollars as aid in between July 2020 and April 2021 in the country (the financial express, 2021). Besides, Government's safety net program run to help the vulnerable group of the society. As illustration, in fiscal year (FY) 2018-19, government allocated and disbursed a hefty budget of approximately BDT 642 billion or equivalent to 2.5% of the national Gross Domestic Product (GDP) (WB, 2018). In the same way, immediately after super cyclone Amphan (20th May 2020), the international Federation of Red Cross and Red Crescent Societies (IFDC) and Bangladesh Red Crescent Society (BDRCS) jointly launched an emergency humanitarian assistance of about US$ 5.1 million for the severely affected cyclone victims (IFRC, 2020).

4.6. Conclusions

Environment benign innovative technology adoption and awareness building regarding climate change and extreme climatic events are the greatest work for mitigation and copping up strategy against the adverse effect of the catastrophes. In farming, farmers are practicing with advanced and innovative techniques for minimizing and reducing economic losses. As for illustration, usage of flood tolerant, drought tolerant and saline tolerant rice varieties in the respective regions along with other high yielding varieties (HYV) of crops. Likewise, they are proceeding with improved technologies in the livestock and fisheries sectors as well that has brought remarkable progress among the economic sectors. Besides, for reducing flood damage, Bangladesh Water Development Board (BWDB) has developed a silver bullet technique of Early Warning System (EWS) of flood to make awareness about the potential negative outcomes and Bangladesh is the only harbor country of this technology in South Asia.

Impact evaluation on household total expenditure, all the econometric models showed that the coefficients of the variable affected group were significant at different level with negative sign meaning that the habitants who resided in the repeated climate hit and vulnerable areas spent less on their household total expenditure compare to unaffected and more resilient group due to less income, reduction in income, squeezed employment opportunities, less own farm production, and damage and loss to farm production over years.

In case of household food expenditure, the coefficient of the variable affected group in all the 3 estimated econometric models are negative where pooled-OLS and Random effect model are significant at 5% and 1% level, respectively. Meaning that the affected people spent less on their basic food demanded for.

During the adverse and catastrophic period (cyclone, flood and drought), price of essential goods and services shoot up. Households those are affected, vulnerable and more resource constrained (i. e. poorer segment of the society) and already consuming the lowest cost foods unable to substitute cheaper foods and compelled to spend more on basic staples. And even, more frequently reduce the quality of their diets, or even curtail the quantity they demanded. Moreover, at more devastating situations, household members remain starvation and reduce the non-food expenditures that are required simultaneously and equally (e. g. on health and education) (Lele et al., 2016). In the light of findings, it is clear that the affected people sacrifice their non-edible expenditure for their basic cereal food demand.

Almost all the explanatory variables included in the model demonstrate logical insights on how farm household may be more resilience against climate change and extreme weather events regarding household expenditures.

CHAPTER V

Political Discussion on Climate Change in Bangladesh

5.1 Introduction

In this part, the message related to climate change and the aligned policy discussion has taken from a fundamental paper entitled "Birth of a Climate Change Policy and Related Debates: Analyzing the Case of Bangladesh" written by Hossain (2009). Climate change is a global problem and it will have harmful effects on all most all part of the universe. However, some regions align to be affected vehemently owing to particular geo-morphological and demographic features. The Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report describes four regions of the world such as Africa, small islands, the Arctic, and the mega-deltas of Asia and Africa (IPCC, 2007). Bangladesh is located in one of the Asian mega-deltas. The country is vulnerable and exposed for other reasons as well. One, since Bangladesh is situated very close to the Himalayas' foothills where glaciers are liquefying. Additionally, in the regions monsoon comes as one of the highest rainfall totals. Two, the country is a basin of catchment for 92% of runoff annually produced in the Ganges-Brahmaputra-Meghna river basin. Third, large number of population (e. g., 120 million) and population density (more than 1200 per sq.km.) (Hossain, 2009). Almost every five years, more than 50 million people victimized by climatic extremes such as escalated cyclones and tidal surges, increased temperature, sea-level rising (SLR), floods and saline water intrusion, more intense monsoon rains bring severe floods, flash floods and river erosion, and on the other side reduced rainfall in the winter season resulting in drought (Mukta & Hossain, 2008). Bangladesh predicts a decline of rice and wheat production by 8% and 32%, respectively, by the year 2050 due to the negative impact of climate change (Ericson et al., 2005). These all are a clear indication of climate change and it is not possible to limit the impact only by adapting to climate change effects in Bangladesh.

Therefore, the country realized to formulate a comprehensive nationally devised plan and actions to tackle the climate change effects. Considering this views, Bangladesh government through the Ministry of Environment and Forests (MOEF) has taken a number of policies and institutional decisions. The MoEF has taken the vital responsibility to make a substantial improvement and formulation of some policy and institutional instruments to reduce the impacts of climate change and vulnerability. These included the National Adaptation Programme of Action (NAPA) formulated in 2005, Bangladesh Climate Change Strategy and Action Plan (BCCSAP) emerged in September 2008 as a key policy document to address climate change in Bangladesh, Climate Change Unit (CCU) and Climate Trust Fund (CTF). Before BCCSAP, the National Adaptation Programme of Action (NAPA) was formulated as first ever major climate change related policy document of Bangladesh, which was formulated as a response to the decision of the Seventh Session of the Conference of the Parties (COP7) of the United Nations Framework Convention on Climate Change (UNFCCC) (MoEF, 2005).

5.2 Bangladesh climate change strategy and action plan (BCCSAP) and its six pillars

The BCCSAP was originated as a 10-year programme for implementation from 2009 to 2018. 120 actions under 37 programmes have been set in BCCSAP from the beginning under six broad themes (MoEF, 2008). The six pillars of the BCCSAP are viz.:

1. Food security, social protection and health (9 programmes, 26 actions),
2. Comprehensive Disaster Management (4 programmes, 10 actions),
3. Infrastructure (7 programmes, 28 actions),
4. Research and knowledge management (5 programmes, 19 actions),
5. Mitigation and low carbon development (7 programmes, 22 actions) and
6. Capacity building and institutional strengthening (5 programmes, 15 actions) (MoEF, 2008).

5.3 Projects implemented under the head of "Food Security, Social Protection and Health"

The government of Bangladesh are executing a number of projects for the adaptation and mitigation of adverse effects of climate change as well as to increase agricultural production for food security in the household level (MoEF, 2008). The projects being implemented based on the main thematic areas, some of them are presented here.

- Farm Productivity and Food Security Enhancement of the Vulnerable Farmers in Jamalpur and Sherpur districts
- Research on climate resilient rice variety development and its propagation

- Measure for supplying Safe Drinking Water and Social Security for Women and Children those who are severely exposed to adverse impacts of climate change
- Risk reduction through adaptive measures in the context of Climate Change impact on health sector in Bangladesh
- Improve management of Food Security by increasing agricultural production and protection of the crops from the ill-effects of climate change through Strengthening the Agricultural Weather Forecasting and Early-warning System on Adverse climate condition

5.4 Projects implemented under the head of "Comprehensive Disaster Management"

- Establishment of Cyclone Resistant Housing at the Cyclone Aila Affected Areas from Khulna District
- Establishment of Cyclone Resistant Housing at the Cyclone Aila Affected Areas from Borishal District
- Establishment of Cyclone Resistant Housing at the Cyclone Aila Affected Areas from Borishal, Khulna and Chittagong District

5.5 Projects implemented under the head of "Research and knowledge management"

- Sustainable Cropping System for Drought and Coastal/Saline prone areas in Bangladesh
- Pilot Project on temperature and Saline Tolerant Crops to adapt with Climate change
- Research Capacity building for Knowledge Management on Climate Change

5.6 Projects implemented under the head of "Mitigation and low carbon development"

- Pilot Initiative on Reduction, Reuse and Recycle (3R) of Wastes
- Coastal Afforestation along the Embankment
- Nursery projects for countrywide mass Afforestation to adapt with Adverse Impacts of Climate Change

5.7 Conclusions

In FY 2008-2009, government allocated around 43 million US dollar to redress climate change impacts in Bangladesh. In the subsequent years (from 2009 to 2012), approximately 300 million US dollar disbursed to execute adaptation and mitigation actions recommended by BCCSAP. To escalate the activities against climate change, the government has brought modification in the name of concern ministry with the “Ministry of Environment, Forestry and Climate Change”. Moreover, more than 500 projects are now ongoing countrywide to bring sustainability and resilience against climate change allocating a handsome budget in the name of “Climate Change Trust Fund” (MoEF, 2021). Besides, Campaign for Sustainable Rural Livelihoods (CSRL), an alliance of more than 150 national and international non-government organizations (NGOs) working in Bangladesh, has been leading the advocacy works around climate change in Bangladesh since 2007.

CHAPTER VI

Policy Implications towards Food Security in Bangladesh

6.1. Policy Implications

Climate change, climatic extremes as well as their correlations have long-term ramifications on Bangladesh's economy through huge loss and damage to agricultural production (Karim, 2018; Mottaleb et al., 2013; IPCC, 2007). At the same time, the country is trying to achieve the SDGs especially the first two goals of the United Nations by increasing agricultural production to offset its unfavorable effects. The stand-alone goal-1, "end poverty in all its forms everywhere" and goal-2 "end hunger, achieve food security and improved nutrition through sustainable agriculture" are entwined closely and demonstrating a massive caution due to huge agricultural crop damage for attaining them by the country. According to Global Food Security Index in 2019, Bangladesh was ranked 83rd position out of 113 countries globally and among South Asia held the lowest in terms of food security. Based on our findings, the food loss has a reciprocal relation with food supply and it is emerging as a prominent factor nowadays. These results brace recent research by Wang, (2010) and Miyan, (2015) that climate change will have a significant adverse effect on food security in the current times. Though in the existing national agricultural policy of Bangladesh, it is overtly elucidated that increase agricultural production by means of modern technology and improved farming practices. In addition, it reiterates for research for developing varieties and technologies suitable for droughts, flood and salinity areas. Besides, it gives emphasis on price stabilization when crop damage occurs as well as to preserve agricultural land. But, the ultimate reality is that cultivable land are reducing (Hasan et al. 2013) over time in the name of rapid urbanization and industrialization aspiring for so-called development. Nonetheless, our observation and findings reinforced in the issues for the strengthening agricultural research as well as for its sustainable development which will help for augmenting food security to a large extent. We are reporting policies and recommendations as follows:

6.1.1 National policy

Bangladesh's economy still now primarily dependent on agriculture. In addition, large number of labor forces are engaged in agriculture sectors especially the crop sector. Owing to cyclones, agricultural drought and floods food grain production hampered vehemently. For supporting the food security of the country, we are proposing some policy recommendation based on findings.

6.1.1.1 Policy for cyclone and saline prone areas

Findings- from our analysis, we argued that cyclone and saline prone areas (the coastal areas) of the country are more vulnerable to climate change and climatic extremes- cyclones, salinity, sea level rise (SLR) and coastal erosion. For this reason, households resided on that location suffered a lot in terms of food production, food consumption and income generation.

Existing policy- though there are some policies for the safeguard and to make the areas more resilient from cyclone, salinity, coastal erosion, tidal surge and sea level rise (SLR) such as coastal embankment, tree plantation along the sea shore, etc.

Recommendations- in the light of our research findings and existing policy, we would like to produce the following policy guidelines with emphasis to make the households more resilience in terms of food production, consumption and income generations.

- Intensifying research for developing varieties and technologies suitable for salinity regions.
- Crop insurance will be the sustainable strategy that are widely recognized across the world.
- More budget allocation for the cyclone and saline prone areas compare to other vulnerable areas.

6.1.1.2 Policy for drought prone areas

Findings- drought-prone areas of the country are the second-highest vulnerable of the country. Due to drought, households loss their agricultural production significantly and suffered a lot in terms of agricultural production practices, food consumption and income earnings.

Existing policy- in the national agricultural policy of the country repeatedly emphasis for the retain of ground water so that agricultural production practices do not pampered. For these, government has taken various program such as tree plantation, usage of rain water, discourage the usage of ground water, digging ditch or pond for the preservation of rain water, etc.

Recommendations-along with the existing policy of the country, we would also recommend some policy so that the affected households can get benefit as well as it can reduce the ill effects of the droughts. The followings are our suggestions:

- ❖ Aggravating research for developing varieties and technologies sustainable for droughts prone climate hit areas.
- ❖ As the drought prone areas are the second highest vulnerable area, government should allocate budget accordingly so that it can maintain a harmony across the country.
- ❖ Introduce crop insurance scheme.

6.1.1.3 Policy for flood prone areas

Findings-as 80 percent of the country are flood plain and floods happen almost every year and causes huge damage to agriculture sector along with other sectors. Conversely, floods are not always detrimental for the country. Sometimes floods are blessings than curse. Few research also validates it. From our findings, we also argued that flood prone areas are the least vulnerable areas of the country.

Existing policy- every 4/5 years' intervals, Bangladesh experienced extreme flood and incurred huge amount of agricultural production loss along with livelihood. Nowadays, flash flood has added to the damage history of the country. For this, government of the country has taken wide ranges of plan to minimize the flood damage. Some of the policies like- flood forecasting and early warning systems, flood tolerant rice variety innovation, etc.

Recommendations- though floods have simultaneously positive and negative impacts on farm families, after that extreme floods are very detrimental to life and livelihoods. To reduce the harmful effects from floods we propose some policy along with the existing policy of the country. These are the followings:

- Intensifying research for developing flood tolerant rice verities for the flood and flash flood prone regions.
- The study advocates for strengthening of the flood forecasting and early warning system (FFEWS) of the Bangladesh Water Development Board (BWDB).
- Due to flash flood, huge damage occurred nowadays. This flash flood is somewhat a political issue. Government should negotiate with the neighboring country India to check flash floods.
- Crop insurance will be one of the sustainable strategies for flood affected farmers.

6.2 International policy

Correspond to our findings, we are proposing some policy issues which are aligned to international affairs. The government of the country also consider these with keen interest. These are as follows:

- Bangladesh has a long history of receiving international aid and grants. Therefore, enhancing global institutional cooperation and collaboration is crucial for the survival and sustaining of climate hit vulnerable countries like Bangladesh.

- Bangladesh imports food from the world market, it has far-fetched implications for policy formulation. A restrictive monetary policy is required to bring success in stabilizing rising food prices.
- Due to flash flood, huge damage occurred nowadays. This flash flood is somewhat a political issue. Government should negotiate with the neighboring country India to check flash floods.

6.3 Long and short term policy

Long term policy- some policy should be taken for long term because in some issues needs continuous efforts. These are the followings:

- ❖ Development of adaptation and mitigation strategies for long-term resilience.
- ❖ A subsidy policy for agricultural inputs where monetary policy must be used in consistence with fiscal policy to stabilize food prices in the national market which aggravate the country's aggregate food production.
- ❖ Budget allocation for agricultural research and development is still scanty. Government should take necessary steps for the allocation of a handsome budget corresponds to present climate variability that will expedite research vehemently.
- ❖ Ensure green agriculture and green economy through investment in agricultural sector.
- ❖ Environmentally friendly and climate benign sustainable technology innovation is a precondition for smooth agricultural production.

Short term policy- there are a few policies which are required for short term basis. When the emergency occurs, that policy will be a good tool to recover and to bring them to mainstream. These are:

- ❖ Government should collect data on climate change and its effects on agricultural Households very neatly and with utmost attention for further policy formulation.
- ❖ Development of strategies for curbing price shoot up for essential commodities and vulnerability to small and marginal farmers because of crop failure.
- ❖ Scope of alternative employment for income generation at the time of weather extremes for lower income group, especially for rural women is very limited. Government should take care this issue very carefully and create alternative income generating activities (IGA).
- ❖ Innovation and adoption of climate-smart technology to buffer household level as well as national level food supply to potential food security situation from erratic climatic shock.

6.4 Lesson learned for the organizations

From our research results, we can understand some interlinked issues which may be useful for a few of the country's ministry- ministry of agriculture, ministry of food, and ministry of education.

6.4.1 lesson for ministry of food

From our analysis, we have found that due to climate change and climatic extremes the affected households are suffering a lot in terms of agricultural production loss and damages. And these effects also have subsequent effects of less household food consumption, as well as reduce income. Climatic extremes also push to increase the price of the essential food commodities at the time of extreme events in the outbreak areas. In these case ministry of food can take several initiatives to reduce the miseries of the households. They come forward with humanitarian assistance immediately such as food aid, cash incentives, as well as rehabilitation.

6.4.2 Lesson for ministry of agriculture

In the changing climatic situations and extreme events, people are haplessly helpless and they are in need of humanitarian assistance at once. On that case, ministry of agriculture should come with their technologies and production packages. Post extreme events farmers are in need of seed, fertilizers, irrigation and harvesting equipment. These can be a great help instantly for the victim farm households.

6.4.3 Lesson for ministry of education

Education is the backbone of a nation. Education helps to take decision properly at right time. From our findings, we can argue that educated farm households are less vulnerable compare to illiterate household head. In addition, to understand the climate change and climatic extremes basic education is essentials. The ministry of education should come forward in the name of "education for sustainable development" for the farmers whose who are affected by climatic extremes.

6.5 Conclusions

Global climatic scenarios are evolving gradually. IPCC, in its 3rd Assessment Report mentioned Bangladesh along with other South Asian countries are the most vulnerable to this anthropogenic hazard (McCarthy et al., 2001). In the meantime, Bangladesh is experiencing and suffering from global warming miserably by hoisting very fluctuating temperature, precipitation and humidity affecting to its many fronts (e. g., agriculture, forestry, environment). Bangladesh is a low-lying delta are now severely affected by human-induced climate change and its resultant climatic extremes such as cyclones, droughts and floods. Owing to erratic weather condition country's agriculture sector huts enormously in terms of production failure, damage and loss to harvestable crops, limiting the agricultural production practices and operations. As a results, food shortage, and less farm income exhibit to the farm households. On the negative side, food supply shortage in the market induces food demand and it provoke to swell food price significantly that means gears up inflation. This household food loss substantially interrupts food availability and supply chain for consumption as well as income reduction has potential negative impact on subsequent household expenditure on food expenditure and non-food expenditure (e. g., expenditure on education, treatment and others) To address these multiple issues, we judiciously employed the vector auto-regressive (VAR) model, the difference-in-differences (DiD/DD) model and Pooled-OLS, Fixed Effects and Random Effects model. The findings emerged from our time series and panel data analyses are presented in this episode very precisely and stepwise.

First, due to cyclones, droughts and floods a plenty of food grain loss and damage occurred. These loss and damage to crops lead to food shortage in the household level as well as in the national level then food grain import take place and make Bangladesh vulnerable in terms of food security and other economic factors. In this part, we are passionate to appraise the effects of climate change and its correlations on the agriculture sector especially food grain production, the staple food - rice and wheat of Bangladesh. Rice, wheat and maize production are critically hampered by extreme climatic stress that leads to food grain loss and forced food import. This vicious circle of food crisis makes Bangladesh's economy in jeopardy and lean-to food refuge. Our all-out attempts to embody, the adverse effects of climate variability and change on food grain production, by taking data based on yearly time series spanning from 1984 to 2017. VAR model results have conveyed that loss of food grain and food production failure make the country long-term food import dependency to the world food market. Here, we have found that food grain loss is a key player to boost food import by a 1% significant level of confidence. Besides, it has a negative association with food grain availability for consumption. In addition, the rate of inflation gears up significantly under a 10% level of confidence. From our Granger causality analysis, we have found a bidirectional relationship between food grain loss and food grain import. Food grain loss Granger causes food grain import at a 1% significant level. Likewise, food grain import Granger causes food grain loss at a level of 5% significant which is unrealistic and contradictory to the real-world phenomena that mean it is difficult to explain the food grain loss only with food grain import. The series food grain loss and food grain availability for consumption have one-way causality. Food grain availability has been Granger caused by food grain loss at 5% level of significance. On the other hand, the movement of the GDP growth rate and the rate of inflation in context of food grain loss and food grain import, we found the variable GDP growth rate and food grain import have exhibited unidirectional Granger causality. Food grain import Granger cause GDP growth rate under 10% level of significance. In addition, the association among the variable inflation rate, food grain loss and food grain import, revealed that under 10% and 5% level of confidence interval the variable inflation rate Granger caused by the variable food grain loss and food grain import, respectively. The impulse-response functions (IRFs) indicate that the food grain availability for consumption and the food grain loss have always a negative relation. And, food grain import has a positive association with the supply of food for consumption over the years. The impact of impulse response of food grain availability to food grain loss is steadily negative. On the dark side, food grain loss induces import of food continuously.

Second, though 80% of Bangladesh is flood-prone, it has multiple effects on agricultural farm families. Occasionally, the flood becomes a blessing than a curse. Our findings from DD approach also validate this. At different time points, we found various effects, which might be due to the magnitude, frequency, and occurring time (whether early, as usual, or late). Above all, floods have dangerous effects on household cereal food consumption and purchase from other sources. Analysis by considering coastal belt of the country pointed that cyclones, salinity, tidal surges, SLR, and coastal erosions are always detrimental to agricultural production practices. At all points, we confounded negative impact with significance at various levels. In drought-stricken areas, we found drought severely impacts the respective areas over time. Analysis, considering the base year's entire sample as a control variable, our results guaranteed that climate change and extreme climatic events, as a whole, significantly affect household cereal food consumption and force them to purchase from other sources, leading to soaring cereal prices. Additionally, their combined effects limit the country's economic progress and sustainable development, distorting some development indicators. However, the bottom line is that cyclone-affected areas are more vulnerable than all other areas.

Third, Impact evaluation on household total expenditure, all the econometric models showed that the coefficients of the variable affected group were significant at different level with negative sign meaning that the habitants who resided in the repeated climate hit and vulnerable areas spent less on their household total expenditure compare to unaffected and more resilient group due to less income, reduction in income, squeezed employment opportunities, less own farm production, and damage and loss to farm production over years. In case of household food expenditure, the coefficient of the variable affected group in all the three estimated econometric models are negative where pooled-OLS and Random effect model are significant at 5% and 1% level, respectively. Meaning that the affected people spent less on their basic food demanded for as well. For household non-food expenditure, we also found that the affected people sacrifice their non-edible expenditure.

Finally, from the above evidences (by using data sets which was collected and developed by IFPRI in the name of BIHS) we can say and assure that climate change and climatic extremes have profound negative impacts on agricultural farm households in Bangladesh in the process of food grain damage and loss, instigating food price spiraling, and reduction in farm income and then subsequent household expenditure. Ultimately, climate change and climatic extremes emerging in the country as a potential threat to national food security as well as to country's aggregate economy.

Along with above discussion, we also give emphasis on the following- environment benign innovative technology adoption and awareness building regarding climate change and extreme climatic events will be the greatest work for mitigation and copping up strategy against the adverse effect of the catastrophes. In farming, farmers are practicing with advanced and innovative techniques for minimizing and reducing economic losses. For illustration, usage of flood tolerant, drought tolerant and saline tolerant rice varieties in the respective regions along with other high yielding varieties (HYV) of crops. Likewise, they are proceeding with improved technologies in the livestock and fisheries sectors as well that has brought remarkable progress among the economic sectors. Besides, for reducing flood damage, Bangladesh Water Development Board

(BWDB) has developed a silver bullet technique of Early Warning System (EWS) of flood to make awareness about the potential negative outcomes and Bangladesh is the only harbor country of this technology in South Asia.

Appendices:

Appendix I: Variance of decomposition

Variance Decomposition of CONSUMPTION:						
Period	S.E.	Consumption	Import	GDP	Inflation	Loss
1	0.054710	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.072493	99.12698	0.419997	0.010254	0.349175	0.093598
3	0.083383	97.86090	1.007008	0.057930	0.820349	0.253813
4	0.090446	96.68600	1.542004	0.107104	1.237004	0.427892
5	0.095064	95.74782	1.960562	0.139379	1.558987	0.593253
6	0.098064	95.04785	2.262564	0.154299	1.792807	0.742484
7	0.099993	94.54303	2.468673	0.157608	1.956393	0.874296
8	0.101220	94.18413	2.602878	0.155626	2.067713	0.989654
9	0.101990	93.92855	2.686255	0.153305	2.141640	1.090248
10	0.102469	93.74337	2.735329	0.153854	2.189554	1.177897

Variance Decomposition of IMPORT:						
Period	S.E.	Consumption	Import	GDP	Inflation	Loss
1	0.058520	0.014898	99.98510	0.000000	0.000000	0.000000
2	0.071206	0.012915	89.79279	8.365152	1.635488	0.193651
3	0.077053	0.045259	82.97057	13.76540	2.243738	0.975034
4	0.080469	0.095382	78.14666	17.20057	2.344006	2.213377
5	0.082935	0.112094	74.37356	19.56182	2.287406	3.665113
6	0.084972	0.106886	71.23571	21.31303	2.200006	5.144365
7	0.086784	0.122493	68.52475	22.69511	2.115179	6.542468
8	0.088464	0.197874	66.12177	23.83458	2.038484	7.807290
9	0.090058	0.354088	63.95561	24.79943	1.969655	8.921224
10	0.091588	0.594256	61.98344	25.62834	1.908048	9.885910

Variance Decomposition of GDP:

Period	S.E.	Consumption	Import	GDP	Inflation	Loss
1	0.154558	0.001251	0.895007	99.10374	0.000000	0.000000
2	0.162997	3.160576	1.187695	91.28798	1.914959	2.448792
3	0.168092	4.715828	1.422320	86.45646	2.703314	4.702076
4	0.171379	5.173476	1.474720	83.91405	2.946793	6.490965
5	0.173865	5.184884	1.450310	82.43647	2.994836	7.933497
6	0.176026	5.069010	1.415084	81.43000	2.969701	9.116208
7	0.178063	4.966627	1.396340	80.62526	2.917011	10.09476
8	0.180057	4.931627	1.401215	79.90290	2.855710	10.90855
9	0.182030	4.976061	1.428147	79.21376	2.794176	11.58786
10	0.183980	5.093002	1.472573	78.54128	2.736091	12.15705

Variance Decomposition of INFLATION:

Period	S.E.	Consumption	Import	GDP	Inflation	Loss
1	0.181371	0.184029	0.166316	1.214090	98.43556	0.000000
2	0.213796	0.272043	2.223461	6.596452	90.39696	0.511080
3	0.222686	0.259308	3.446005	8.432801	87.23640	0.625482
4	0.225282	0.388933	3.933602	9.021936	86.02860	0.626933
5	0.226236	0.599616	4.084211	9.237826	85.45516	0.623187
6	0.226724	0.805633	4.116246	9.330645	85.10930	0.638180
7	0.227046	0.966042	4.115481	9.379326	84.86925	0.669899
8	0.227282	1.074050	4.108775	9.412070	84.69367	0.711435
9	0.227460	1.138474	4.102557	9.439734	84.56224	0.756996
10	0.227599	1.172172	4.097601	9.466474	84.46090	0.802855

Variance Decomposition of LOSS:

Period	S.E.	Consumption	Import	GDP	Inflation	Loss
1	0.048228	22.86580	0.892448	17.32710	4.553772	54.36088
2	0.069914	13.16999	1.953079	35.68565	2.849337	46.34194
3	0.084987	9.206819	2.273774	41.67838	1.975778	44.86525
4	0.096829	7.093738	2.417340	44.32262	1.523335	44.64297
5	0.106894	6.012003	2.531685	45.71752	1.250098	44.48870
6	0.115847	5.636315	2.656780	46.49587	1.065624	44.14542
7	0.124018	5.752371	2.799725	46.90859	0.935122	43.60419
8	0.131580	6.195003	2.956835	47.08530	0.842376	42.92048
9	0.138623	6.837838	3.121528	47.10663	0.777635	42.15637
10	0.145197	7.588468	3.287442	47.02739	0.733889	41.36281

Cholesky Ordering: CONSUMPTION IMPORT GDP INFLATION LOSS

Appendix II: Eigenvalue stability condition

Eigenvalue	Modulus
.9665459	.966546
.8042166	.804217
.6166719	.616672
.3455291	.345529
.1279073	.127907

All the eigenvalues lie inside the unit circle.

VAR satisfies stability condition.

Appendix III: Correlation matrix of 2011–19

	Cons	PQ	PV	Treat	Year	FS	HH	FH	DR	HM	Age	MS	L	SY	SL	WS	EC	I
Cons	1.00																	
PQ	0.31	1.00																
PV	0.26	0.66	1.00															
Treat	-0.14	-0.04	-0.52	1.00														
Year	-0.14	-0.04	-0.52	1.00	1.00													
FS	0.29	-0.24	-0.15	-0.03	-0.03	1.00												
HH	0.73	0.29	0.18	-0.00	-0.00	0.20	1.00											
FH	0.26	0.02	0.03	-0.03	-0.03	0.19	0.27	1.00										
DR	0.04	0.08	0.04	0.00	0.00	-0.08	0.23	-0.22	1.00									
HM	0.59	0.18	0.10	0.03	0.03	0.24	0.65	0.33	-0.48	1.00								
Age	0.18	-0.00	-0.03	0.07	0.07	0.14	0.11	0.15	-0.09	0.19	1.00							
MS	0.16	0.03	0.03	-0.02	-0.02	0.08	0.19	0.44	0.06	0.12	-0.03	1.00						
L	-0.05	-0.05	-0.07	0.06	0.06	0.01	-0.00	-0.03	0.02	-0.00	-0.19	0.07	1.00					
SY	-0.05	-0.07	-0.08	0.05	0.05	0.04	-0.01	-0.01	0.02	-0.00	-0.15	0.07	0.84	1.00				
SL	-0.00	-0.07	-0.14	0.19	0.19	0.06	0.03	-0.02	-0.03	0.08	0.05	0.01	0.18	0.22	1.00			
WS	0.06	-0.10	-0.15	0.16	0.16	0.06	0.04	0.05	-0.04	0.09	0.11	0.06	0.08	0.11	0.15	1.00		
EC	-0.04	-0.05	-0.22	0.04	0.40	0.00	0.03	-0.01	-0.04	0.10	0.05	0.02	0.18	0.20	0.22	0.23	1.00	
I	-0.14	-0.04	-0.52	1.00	1.00	-0.03	-0.00	-0.03	0.00	0.03	0.07	-0.02	0.06	0.05	0.19	0.16	0.40	1.00

Source: Authors' calculation.

Appendix IV: Correlation matrix of 2011–15

	Cons	PQ	PV	Treat	Year	FS	HH	FH	DR	HM	Age	MS	L	SY	SL	WS	EC	I
Cons	1.00																	
PQ	0.30	1.00																
PV	0.30	0.97	1.00															
Treat	-0.09	0.01	-0.02	1.00														
Year	-0.09	0.01	-0.02	1.00	1.00													
FS	0.28	-0.22	-0.22	0.00	0.00	1.00												
HH	0.59	0.24	0.23	0.20	0.20	0.17	1.00											
FH	0.26	0.02	0.01	-0.01	-0.01	0.17	0.21	1.00										
DR	0.03	0.08	0.08	-0.04	-0.04	-0.09	0.18	-0.24	1.00									
HM	0.59	0.18	0.18	0.06	0.06	0.24	0.58	0.33	-0.47	1.00								
Age	0.18	-0.00	-0.00	0.06	0.06	0.12	0.09	0.14	-0.15	0.22	1.00							
MS	0.16	0.04	0.03	-0.01	-0.01	0.06	0.15	0.45	0.07	0.10	-0.02	1.00						
L	0.02	-0.05	-0.02	-0.55	-0.55	0.02	-0.12	-0.00	0.02	-0.03	-0.13	0.05	1.00					
SY	-0.05	-0.07	-0.05	0.12	0.12	0.03	0.03	-0.01	0.01	0.01	-0.14	0.06	0.40	1.00				
SL	-0.03	-0.04	-0.05	0.59	0.59	0.05	0.14	-0.03	-0.04	0.08	0.06	-0.00	-0.23	0.21	1.00			
WS	0.11	-0.07	-0.04	-0.56	-0.56	0.04	-0.08	0.04	-0.00	0.02	0.03	0.05	0.38	-0.00	-0.27	1.00		
EC	-0.00	-0.01	0.00	0.11	0.11	0.01	0.06	-0.02	-0.06	0.09	0.03	0.03	0.06	0.21	0.18	0.04	1.00	
I	-0.09	0.01	-0.02	1.00	1.00	0.00	0.20	-0.01	-0.04	0.06	0.06	-0.01	-0.55	0.12	0.59	-0.56	0.11	1.00

Source: Authors' calculation.

Appendix V: Correlation matrix of 2015–19

	Cons	PQ	PV	Treat	Year	FS	HH	FH	DR	HM	Age	MS	L	SY	SL	WS	EC	I
Cons	1.00																	
PQ	0.33	1.00																
PV	0.32	0.96	1.00															
Treat	-0.05	-0.05	0.00	1.00														
Year	-0.05	-0.05	0.00	1.00	1.00													
FS	0.28	-0.21	-0.21	-0.03	-0.03	1.00												
HH	0.60	0.25	0.24	-0.20	-0.20	0.18	1.00											
FH	0.26	0.01	-0.00	-0.01	-0.01	0.18	0.22	1.00										
DR	0.04	0.08	0.07	0.05	0.05	-0.08	0.16	-0.21	1.00									
HM	0.58	0.17	0.18	-0.03	-0.03	0.23	0.57	0.32	-0.48	1.00								
Age	0.15	-0.02	-0.01	0.01	0.01	0.11	0.05	0.15	-0.12	0.18	1.00							
MS	0.17	0.03	0.03	-0.00	-0.00	0.07	0.16	0.44	0.07	0.12	-0.04	1.00						
L	-0.06	-0.03	0.01	0.62	0.62	-0.03	-0.12	-0.03	0.06	-0.04	-0.12	0.04	1.00					
SY	-0.04	-0.02	0.00	-0.07	-0.07	0.01	0.02	-0.01	0.04	-0.01	-0.18	0.06	0.37	1.00				
SL	0.03	0.00	0.00	-0.42	-0.42	0.04	0.12	0.00	-0.05	0.08	0.03	0.03	-0.16	0.18	1.00			
WS	-0.00	-0.07	-0.02	0.70	0.70	-0.00	-0.13	0.01	0.01	0.00	0.05	0.03	0.47	-0.01	-0.23	1.00		
EC	-0.02	-0.01	0.03	0.30	0.30	-0.02	-0.02	-0.01	-0.03	0.05	0.01	0.02	0.23	0.12	0.00	0.27	1.00	
I	-0.05	-0.05	0.00	1.00	1.00	-0.03	-0.20	-0.01	0.05	-0.03	0.01	-0.00	0.62	-0.07	-0.42	0.70	0.30	1.00

Source: Authors' calculation.

Note: Cons-consumption; PQ-Purchase volume (physical term); PV-Purchase volume (monetary terms); Treat- Treatment group; Year; FS-Farm size; HH-Household size; FH-Female headed household; DR-Dependency ratio; HM- Households members' age between 15–60 years; Age-Age of Household head; MS- Marital status of household head; L- Literate; SY-Schooling year; SL-Sanitary latrine; WS- Drinking water source; EC- Electricity connection to the household; I-Interaction term (Typical DD).

Appendix VI: Correlation matrix.

	Aff.	Far.	Fam.	Gen.	Dep.	Act.	Age	MS	Lit.	Ed.	SL.	DW	EA
Aff.	1.00												
Far	0.05	1.00											
Fam.	0.02	0.18	1.00										
Gen.	0.00	0.18	0.23	1.00									
Dep.	0.02	-0.08	0.18	-0.23	1.00								
Act.	0.00	0.23	0.60	0.32	-0.48	1.00							
Age	0.01	0.12	0.08	0.15	-0.12	0.20	1.00						
MS	0.01	0.07	0.17	0.44	0.07	0.11	-0.03	1.00					
Lit.	-0.01	0.00	-0.10	-0.02	0.04	-0.03	-0.15	0.05	1.00				
Ed.	-0.01	0.02	0.02	-0.01	0.02	-0.00	-0.16	0.06	0.51	1.00			
SL.	-0.03	0.05	0.12	-0.02	-0.04	0.09	0.05	0.01	-0.12	0.21	1.00		
DW	-0.08	0.02	-0.08	0.03	-0.00	0.03	0.06	0.04	0.34	0.02	-0.16	1.00	
EA	-0.09	-0.00	0.02	-0.02	-0.04	0.08	0.04	0.02	0.15	0.18	0.14	0.18	1.00

Source: Authors' calculation.

Note: Aff. = Affected group, Far. = Farm size, Fam. = Family size, Gen. = Gender, Dep. = Dependency ratio, Act. = number of active family members, Age, MS = Marital status, Lit. = Literacy, Ed. = Education level, SL. = Usage of sanitary latrine, DW = Safe drinking water sources, and EA = Households have electricity connection.

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ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the Most Merciful

Alhamdulillah, first and foremost, I would like to show my gratitude, gratefulness and gratification to the Almighty "Allah", for blessing me with a healthy and well-functioning body and mind in order to live a prosperous and decent life, learn and search the unseen treasures lying in every corner of this enigmatic and beautiful world, particularly to my noble research and composition of Doctoral (the PhD) Dissertation in time.

This tiny research work was carried out in the period between 2019 and 2022 at the Department of Human Environmental Science under the Graduate School of Human Development and Environment, Kobe University, Japan. In this ever-evolving world, there is always a race of competition for existence in which those are having the will to come forward succeeded and sustained. Research is an avenue to unravel and discover new knowledge and helps to win and gives evidence of existence. Ever since the universe has taken place, the human kingdom emerges and regime on it; and even struggling with an unending quest to unearth the hidden truth- research is pursued. It has broadened human vision and mission, opened the newer and newer avenues and enlightened the dark-obscure-mysterious facts of the globe.

Acquisition of the doctor of philosophy (the PhD) degree and writing a factual and original dissertation is absolutely a long and arduous process, and it is certainly not done singlehandedly and individual knowledge and experience. Today, at the acme of my dissertation, with love and respect, I humbly remember my parents, family members in Japan as well as in my home country, Bangladesh (especially my lovely wife, Dr. Ayasha Akter, Post-Doctoral Research Scholar, Kobe University and Assistant Professor, Bangladesh Agricultural University and my cute daughter-my heart, Afra Islam and Ahnaf Islam-my son), teachers, friends, relatives and well-wishers: as a single flower makes no garland, this piece of research work would not have taken form without their wholehearted encouragement, inspiration and live involvement. An utterance of appreciation will certainly be not less than the best to reciprocate my sincere thanks to all that has assisted me to sail my boat through such a tough and cumbersome of voyage and this eventual destination.

I am really fortunate enough and would like to grasp the opportunity to express my profound thanks and gratitude towards my esteemed and revered academic advisor Professor Dr. Masayuki Sato. With a great sense of gratefulness, I want to thank him for his erudite and sagacious guidance, generous and friendly behavior, constant encouragement, careful monitoring, critical evaluation, financial assistance and smart counseling during the whole course of this research journey. I couldn't have imagined having a better advisor and mentor for my doctoral study. His diligence, assiduous, patience and concrete understanding of the subject matter was really a wonderful source of motivation and inspiration for me. Of course, I would confess gently that I have been benefited enormously by doing research under such a nice personality and a beacon of a think tank like him. It is worthy and will give an appropriate notion regarding an academic advisor by the underneath lines.

"*One can wish to do the right things and even one can wish to do it for the right reasons.*
But if don't have right guidance, can never grab the right target."

To underpin the above statement, I would like to quote from Jasimuddin, a famous poet in Bangladesh, popularly known as 'Palli Kabi' 'pastoral poet', and he is the contemporary of Poet Kazi Nazrul Islam and Poet Rabindranath Thakur. The Poet said,

"*Parent builds body and teacher builds mind, none can say who the superior is*"

Next to my principal supervisor, I am highly obliged in taking the scope to sincerely thank two of my sub-supervisors Professor Dr. Kazuhiro Ota and Professor Dr. Atushi Ushimaru, the Graduate School of Human Development and Environment, Kobe University for their scholastic advice, generous attitude, lovely care and a huge amount of their invaluable time and effort. I really owe to them.

I would also like to thank Professor Dr. Keiichi Ogawa, the Graduate School of International Cooperation Studies, Kobe University for his benevolent and unconditional support and valuable suggestions during my research studentship (from September 2018 to March 2019) under his supervision.

I am feeling proud to show my respect and thanks to a number of very respected and distinguished mentors- Professor Dr. Ohmido Nobuko, Professor Dr. Naoko Shirasugi, Professor Dr. Mutsuoka Koji, Professor Dr. Sawa Munenori, Professor Dr. Inahara Minae, Professor Dr. Kiyono Mieko, Professor Dr. Kazuko Okuyama and Professor Dr. Tabata Tomohiro, the Graduate School of Human Development and Environment, Kobe University and Professor Dr. Ryo Fujimoto, the Graduate School of Agricultural Sciences, Kobe University, for their good advice, generosity and affection. Along with them, I wish to remember the contributions of some other Professors and Research Scholar from other Universities- Professor Dr. Kazunobu Okubo, the

Graduate School of Economics, Ryutsu Keizai University; Professor Dr. Sovannroeun Samreth, the Graduate School of Liberal Arts, Saitama University; Professor Dr. AHM Saiful Islam, the Department of Agricultural Economics, Bangladesh Agricultural University, Bangladesh and Dr. Subir Bairagi, Research fellow, University of Arkansas, the USA.

My sincere thanks and gratefulness also goes to the officers and staff of the Academic Affair Section, Library Section and Accounts Section, especially Hitomi Mitsutake san, Namiko Nishimura san, Kusunoki Saki san and Saeko Nakagawa san for their cordial cooperation and assistance.

I also take the privilege to express my deepest love and gratefulness to my tutor Kumiko Hayase, who obtained Master's degree from Kobe University, for her very friendly and naive behavior and kind assistance in preparing and producing necessary documents for my 1st year academic courses and performing other related official formalities at the time of enrollment into PhD program. I am really indebted to her and never forget her.

I am feeling thoughtful towards my fellow laboratory members for their stimulating discussions, suggestions and for all the fun we have had over the last three years. Here, I want to mention name few of my lab mates and friends with utmost fondness- Ippei Aoshima, Kou Yanagibayashi, Hideka Shigemitsu, Araki, Yuma, Miku, Yusuf Sanoh, John Kaweta, Xiaohui Ye, Shelly Shaw, Kino Saito, Khang and many more.

It is an honor for me to express a deep sense of gratitude albeit I have no valuable words to the families who helped me a lot throughout my stay in Kobe City are also commemorating in the same manner. In particular, I am very much weak to Tadayasu Tsuchitani and his wife Yoshiko (Afra, my daughter called them grandfather and grandmother and end of every month her grandfather used to give her very nice toys and playthings), Kenichi Kuwahara and his wife Keiko Kuwahara (they are our first Japanese friend who used to translate Japanese documents into English and helped us with their utmost); Hiroko Fukutome and her husband Masahiro Fukutome (this family almost do everything for our livelihood-entertainment to their house, document translation, official formalities to word office, keep us up to date by passing daycare's information, sometimes pick up my daughter, take care health care issues and even used to do our glossary shopping. How can we forget their cordial help and contribution!); Robiul Awal and his wife Eti Awal; Rie Kinbara; Maito Takagi and his wife. Actually, they are immortal in our memory.

I am also pleased and obliged to my daughter's daycares' teachers. Without their cordial support and cooperation, it was not possible to continue our research with attention and devotion. I am really thankful to them and acknowledge their contribution whole heartedly. I want to mention some of their names-Makina Sensei, Yaumau Sensei, Nishigami Sensei (She helped a lot for preparing daycare documents) and Nishino Sensei.

I feel blessed by getting a lot of little angels those who are the very good friend of my daughter, AFRA ISLAM. I remembering them with my decent love and care. They are Marina Chan, Hinako Chan, Aki Chan, Maito Chan, Kaho Chan, Kiko Chan, Miku Chan, Chiho Chan, Harune Chan, Himara Chan, Aona Chan, Kotoha Chan, Hina, Sena, Nonoka, Mayra and many more. Along with these princesses, I also remember the name of some princes- Auba Kun, Aowto Kun, Ashahi Kun, Masimim Kun, Kera Kun and so on. Here, I want to take the privilege that I am very much nostalgic and aligned to disclose one of my very decent and lovely feelings that "I love very much Japanese children, they are very cute, adorable, pompous and holy, especially the little girl, just like a fairy". They always exist in my lovely heart.

These acknowledgments would not be completed without mentioning the name of my bursary in the Kobe University-the Hyogo International Association's scholarship and Hata Toshiharu Fund Scholarship (Kobe University Fund) that helped me immensely to bear my study expenses as well as my daily household spending for survival.

Last but not the least, my eternal love and respect will remain affluent towards Japan and the Japanese always from my flabby heart. We (my family) rely on and live on scholarship and the scholarship comes from basically tax paid by the Japanese people. So, as a foreign national, we are burden to their economy. Nonetheless, our stay in Japan were very enjoyable, pleasant and secured. I have never encountered any hassle and have never felt any insecurity during my entire stay. Wherever and whenever I sought any help I got their service freely and in a benign manner. The Japanese, what a gentle nation you are! How great you are! I have never learned, heard and experienced such a very noble, sober, peace-loving and kind nation like you ever before. One who wants to learn manner and etiquette, come Japan. One who wants to learn how to serve customers, come Japan. One who wants to learn science and technology, come Japan. One who wants to enjoy the beauty of nature, come Japan, especially the Kobe City, it is a conjugation of mountain and sea that gives the city a panoramic view. To the best of my knowledge and thinking, you (the Japanese) belong to the apex of humanity and Japan is the best place for acquiring knowledge of all branches.

You (Japan) has given me a lot. I respect you with my bowed head and owe to you forever. My dream to come Japan repeatedly and sip its essence of beauty to satisfy my knowledge trustiness as well as to do research with esteemed Professors if I get opportunity. Japan, I salute you, I love you, and I will miss you a lot as well.

Kobe University
Islam Mohammad Saiful
January 17th, 2022